DICTIONARY OF ENVIRONMENTAL HEALTH

FRANK R. SPELLMAN

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Preface

Every branch of science and every profession has its own language for communication. Environmental health is no different. To work even at the edge of the major environmental aspects of this challenging field, you must acquire a fundamental but wide-ranging vocabulary and understanding of the components that make it up. As Voltaire said: “If you wish to converse with me, define your terms.” In this text, I define (and in many instances explain—fully explain) the terms or “tools” (concepts and ideas) used by environmental health professionals, environmental science professionals, safety/industrial hygiene practitioners/engineers, and non-science professionals—assisting each in the application of their skills by increasing their understanding.

With over 15,000 terms, this desk reference is about our world: the sun, the air, the water, the soil, the dust, the plants and animals, the chemicals, and the metals that we depend on to maintain life as we know it. When unspoiled they all support a healthy life; they make it beautiful and fun. They allow us to live and maintain the so-called Good Life. This important reference book also identifies, describes, and defines environmental elements, the essentials of life on earth that as wonderful and important as the air, water, soil, and biota are they may also make people sick or worse, or damage plants and animals and destroy that “Good Life” we all covet..

This is an indispensable resource and reference that provides a comprehensive treatment of a very broad field. The entries are timely and factual, well balanced, referenced, and written in plain English for general readers, college students, environmental health practitioners, lawyers, public administrators, utility directors (water and wastewater treatment), public service managers, non-environmental managers, regulators and non-environmental health professionals in any field who desire to obtain understanding of everyday environmental health issues.

It is important to point out that environmental health is not a single topic, but rather a complex, colorful, and diversified range of interrelated subjects including all of the basic sciences: computer science, government, engineering, energy, renewable energy, hydraulic fracking, water and wastewater treatment, security, disease, industrial hygiene, injury identification prevention and control, and much more. The practicing environmental health specialist, technician, or student of environmental health should know these topics—without them it is difficult (if not impossible) to practice professionally in any of the environmental fields.

Although it is impossible to include all environmental health terms in this work, my intention is to present the terms and definitions/explanations drawn from varied, specialized, and technical environmental fields and includes a variety of appropriate background areas that are related enough to be accessible to interested professionals in many different technical areas, students, and other specialties, as well as general readers.

The purpose of *The Environmental Health Dictionary* is to greatly enhance the quantity of high-quality definitions and explanations to fill the need created by the rapidly expanding fields of environmental health, technology, science for professionals in environmental health, environmental control, environmental engineering, occupational safety and health, medicine, law, planning, loss prevention, security management, terrorism, homeland security, news organizations, energy, renewable energy, industry, teachers, and students.

Frank R. Spellman
Norfolk, Virginia

A

A: Abbreviation for ampere, amp (coulombs/second); electron flow in electrical circuit; the unit of measurement of current.

Abandoned Well: A well whose use has been permanently discontinued or which is in a state of such disrepair that it cannot be used for its intended purpose.

Abasia: The inability to walk because of a lack of motor coordination.

Abate: To do away with; to put an end to; demolish; to nullify or make void; a reduction in severity or degree.

Abatement: Reducing the degree or intensity of, or eliminating, pollution.

Abatement Cost: The cost of reducing emissions from some established reference level.

Abatement Debris: Waste from remediation activities.

Abatement Dose: In exposure assessment, the amount of a substance that penetrates an exposed organism's absorption barriers (e.g., skin, lung tissue, gastrointestinal tract) through physical or biological processes. The term is synonymous with internal dose.

Abatement Period: The amount of time given an employer to correct a hazardous condition that has been cited.

Abient: Tendency to move away from stimuli.

Abiogenic: Not resulting from the activities of living organisms.

Abiotic: The nonliving part of the physical environment (for example, light, temperature, and soil structure).

Abiotic Factors: The physical and non-living chemical factors, such as light, water, temperature, minerals, and climate, that influence living organisms.

Abottoir: A slaughterhouse for animals intended for human consumption such as cattle, sheep, and pigs.

Absolute Entropy: The entropy of a substance existing at a temperature of absolute zero (0 Kelvin); any pure substance can be assumed to have entropy of zero at this point.

Absolute Expansion: The true expansion of liquid with a change in temperature, allowing for the expansion of the container holding the liquid in calculating this measurement.

Absolute Humidity: A statement of humidity, usually expressed in grams per cubic meter, that describes the mass of water vapor present in relation to the unit volume of space that it occupies.

Absolute Permeability: In regards to fluids, a measurement of the ability of the fluid, such as oil, gas, or water, to flow through a rock formation when the formation is at complete saturation.

Absolute Pressure: Total pressure in a system, including both the pressure of a substance and the pressure of the atmosphere (about 14.7 psi, at sea level).

Absolute Risk: In epidemiology, absolute risk is the decrease in risk of a given activity or treatment in relation to a control activity or treatment. An estimate of health risk by determining the rate of occurrence of a disease in the study population.

Absolute Temperature Scale: A temperature scale whose zero point corresponds to absolute zero, such as the Kelvin or Rankine scale.

Absolute Zero: The zero point on a temperature scale of ideal gases where all molecular motion is assumed to stop, denoted by K on the Kelvin scale (or 0ºR on the Rankine scale), -273ºC on the Celsius scale, or -459ºF on the Fahrenheit scale.

Absorb: To take up or receive matter through the process of absorption.

Absorbance: The ability of a medium to absorb radiation, which depends on temperature and wavelength; expressed as the ratio of transmitted energy to incident energy.

Absorbed Dose: The energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy).

Absorbent: The ability of attracting and absorbing substances.

Absorber: In a photovoltaic device, the material that readily absorbs photons to generate charge carriers (free electrons or holes).

Absorptance: The ratio between the solar radiation absorbed by a surface and the total amount of solar radiation that strikes it.

Absorption: 1. The taking up of one substance by another, such as a liquid by a solid or a gas by a liquid. 2. The physical integration of a liquid into the pore spaces of a solid, such as water being absorbed into a sponge.

Absorption Barrier: The body's skin, lung tissue, or gastrointestinal tract where differential diffusion of substances across a boundary occurs.

Absorption Cycle: In refrigeration, a process during which the primary fluid (refrigerant) and the secondary fluid (absorbent) mix after the refrigerant leaves the evaporator.

Absorption Field: An area through which septic tank effluent discharges through leaching or seepage into the surround ground by means of a series of perforated pipes laid in shallow trenches backfilled with gravel.

Absorption Units: Devices or units designed to transfer the contaminant from a gas phase to a liquid phase.

Acariasis: A disease caused by mites.

Acaricide (aka miticide): Pesticide used to destroy mites on domestic animals, crops, and humans.

Acarid: A mite member of the order Acarina that may be parasitic and cause disease.

Acaroids: A pesticide used to destroy mites; also known as matricide.

Acceleration: When an object's velocity increases, we say it accelerates. Acceleration shows the change in velocity in a unit time, or

$$\text{Acceleration} = \Delta v/\Delta t$$

Because velocity is measured in meters per second (m/s) and time is measured in seconds (s), acceleration is measured in (m/s)/s, m/s^2, which can be both positive and negative and always varying; it is rarely constant.

Accelerations determine the final velocity of an object. To determine an object's final velocity (v), given that it started at some initial velocity (v_o) and experienced acceleration (a) over a period of time (t), use the equation derived from the definition of acceleration

$$v = v_o + at$$

Example

Problem:

A truck starts at rest (with an initial velocity $v_o = 0$) and it accelerates for 5 s at an acceleration rate of 12 m/s^2, then what will be the final velocity?

Solution:

$$v = v_o + at$$
$$v = 0 \text{ m/s} + (12 \text{ m/s}^2) \times (5 \text{ s})$$

or

$$v = 60 \text{ m/s}$$

It is important to note that a change in direction also constitutes acceleration. Remember, our definition of velocity is a speed in a given direction. Thus, a change in direction is a change in velocity, and any change in velocity is acceleration. Moreover, whenever we step on the brakes to slow our cars we are experiencing another kind of acceleration called *deceleration*—a negative acceleration, or slowing down.

The Acceleration of Gravity

Downward on Earth a free-falling object has an acceleration of 9.8 m/s/s. The acceleration of gravity at the surface of Earth is often referred to as 1*g*. Any object that is falling to the surface of Earth owing to the acceleration of gravity is in *free fall*. When the velocity and time for a free-falling object being dropped from a position of rest is tabulated, it displays the following pattern.

Time (s)	Velocity (m/s)
0	0
1	–9.8
2	–19.6
3	–29.4
4	–39.2
5	–49.0

The general acceleration equation is:

$$x = x_o + v_o t + \tfrac{1}{2} at^2$$

where

x = position of object
v_o = initial velocity (original speed)
t = time elapsed
a = constant acceleration

Example

Problem:

A water balloon is dropped from a five-story building. How long will it take to hit the street below? Ignoring air friction, the only acceleration involved is the acceleration of gravity (g), and the height of the building is 20 m.

Solution:

In the acceleration equation, we use x = 20 m (when the galloon hits the street), x_o = 0 m (we take the balloon's starting point at the top of the five-story building to be zero), v_o = O m/s (the balloon starts from rest), and g = 9.8 m/s^2 (only gravity is acting on the balloon). Inserting these values into the equation and solving for t, we determine that

$$\mathrm{x = x_o + v_o t + \tfrac{1}{2} at^2}$$

or

$$20 \text{ m} = 0 \text{ m} + 0 \text{ m/s(t)} + 1/2\ (9.8 \text{ m/s})\mathrm{t}^2$$

or

$$40/9.8 \text{ s}^2 = \mathrm{t}^2$$
$$\mathrm{t} = 2.0 \text{ s}$$

Accelerator: A device that employs electrostatic or electromagnetic fields to impart kinetic energy to molecular, atomic, or sub-atomic particles.

Accelerograph (aka accelerometer): An instrument that records the acceleration of the ground during an earthquake.

Acceptable Air Quality: Air containing no known contaminants at harmful concentrations as determined by specialists with which a substantial majority of the people exposed do not express dissatisfaction.

Acceptable Quality Level (AQL): Maximum percentage of regulated product that, for sampling inspection, can be considered as a process average.

Acceptor: 1. A molecule, or part of a molecule's structure that accepts an electron pair from a donor. 2. In photovoltaic materials, a dopant material, such as boron, having fewer outer shell electrons than required in an otherwise balanced crystal structure, providing a hole that can accept a free electron.

Access: The process of interacting with a system (verb or a noun). Users access a system (v). A user gains computer access (n).

Access Control: 1. Ensures that resources are only granted to those users who are entitled to them. 2. Log-on systems protect data on networked workstations and stand alone machines, as well as laptops. Larger networks and companies should determine what needs protection, and the level of data protection needed.

Access Management Access: Maintenance of access information that consists of four tasks: account administration, maintenance, monitoring, and revocation.

Accident: This term is often misunderstood and is often mistakenly used interchangeably with **injury**. The meanings of the two terms are different, of course. Let's look at the confusion caused by the different definitions supplied to the term **accident**. The dictionary defines an accident as "a happening or event that is not expected, foreseen or intended." Defined another way: "an accident is an event or condition occurring by chance or arising from an unknown or remote cause." The legal definition is: "an unexpected happening causing loss or injury which is not due to any fault or misconduct on the part of the person injured, yet entitles some kind of legal relief."

Are you confused? Stand by. This definition will help clear your heads. "With rare exception, an accident is defined, explicitly or implicitly, by the unexpected occurrence of physical or chemical change to an animate or inanimate structure. It is important to note that the term covers only damage of certain types. Thus, if a person is injured by inadvertently ingesting poison, an accident is said to have taken place; but if the same individual is injured by inadvertently ingesting poliovirus, the result is but rarely considered accidental. This illustrates a curious inconsistency in the approach to accidents as opposed to other sources of morbidity, one, which continues to delay

> progress in the field. In addition, although accidents are defined by the unexpected occurrence of damage, it is the unexpectedness, rather than the production and prevention of that damage per se, that has been emphasized by much of accident research. The approach is not justified by present knowledge and is in sharp contrast to the approach to the causation and prevention of other forms of damage, such as those produced by infectious organisms, where little, if any, attention is paid to the unexpectedness of the insults involved, and only their physical and biological nature is emphasized—with notable success."
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> Haddon et al. (1964), p.28.

Now you should have a better feel for what an accident really is; however, another definition, perhaps one more applicable to our needs is provided by safety experts—the authors of the ASSE *Dictionary of Safety Terms*, 1989. Let's see how they define *accident.*

"An accident is an unplanned and sometimes injurious or damaging event which interrupts the normal progress of an activity and is invariably preceded by an unsafe act or unsafe condition thereof. An accident may be seen as resulting from a failure to identify a hazard or from some inadequacy in an existing system of hazard controls. Based on applications in casualty insurance, an event that is definite in point of time and place but unexpected as to either its occurrence or its results" (p. 1).

In this text we use ASSE's definition of *accident.* And again, because it is so important, an accident (based on the ASSE definition) is:

> "An unplanned and sometimes injurious or damaging event which interrupts the normal progress of an activity and is invariably preceded by an unsafe act or unsafe condition thereof. An accident may be seen as resulting from a failure to identify a hazard or from some inadequacy in an existing system of hazard controls. Based on applications in casualty insurance, an event that is definite in point of time and place but unexpected as to either its occurrence or its results."

Accident Analysis: A comprehensive, detailed review of the data and information compiled from an accident investigation. An accident analysis should be used to determine causal factors only, and not to point the finger of blame at any one. Once the causal factors have been determined, corrective measures should be prescribed to prevent recurrence.

Accident Investigation: Simply put, accident investigation is a vital part of any effective safety and health program. The key word we emphasize is "effective." Anyone can devise a safety program that he or she might assume fits the bill as an effective "safety program"—but that does not necessarily mean that the program is really effective. One thing is certain: If company safety policy does not insist upon investigation of all accidents (and even so-called near misses), then the company's safety policy is definitely not effective.

Why is it so important to investigate accidents? The simple answer is we must investigate accidents to reduce the likelihood of their being repeated. Note that we are talking about all types of accidents, near misses and other minor occurrences included. If not corrected, those "minor mishaps" and "near misses" may result in much more serious accidents the next time around. We have all heard "If we do not learn from the past (our mistakes), we are doomed to repeat it (them)." Why would any logical person want to take a chance on repeating a near miss or minor accident that could generate quite a different result next time around?

To reduce the likelihood of accidents being repeated, their causes must be identified, so that remedial actions can be taken to ensure they do not happen again. The accident investigation process also helps investigators and safety engineers compile facts to be used as legal or liability evidence in the event of claims or lawsuits for losses or injuries. The new safety professional soon discovers that if one of his company's workers is seriously injured (or worse) while on the job, the likelihood of litigation emanating from the worker or the family is quite good. For this reason (and others), many insurance companies require complete compilation of such facts.

Most texts make the point that whenever an accident investigation is conducted, the purpose of the investigation is not to place blame or find fault. We disagree with this view. When an accident occurs, someone is certainly at fault. To determine the proper corrective action to be taken requires that blame for an accident be fixed. This is not to say that the safety engineer who investigates an accident must be a Gestapo agent. Heavy-handed tactics are not required and definitely not recommended. Instead, the safety engineer should remember the words of Sergeant Joe Friday (of television's *Dragnet* fame) who said: "Just the facts, ma'am." A good safety investigation is impersonal, and completely fact-oriented.

The safety engineer is not a disciplinarian. As Willie Hammer (1989) points out: "Whether disciplinary action should be taken if blame is fixed on an individual is beyond the duties of safety engineers (professionals). They are obligated to find out who was or may have been responsible for the accident; whether it was a worker, supervisor, manager, or other party" (p. 273). We share Mr. Hammer's view on this topic; if the facts collected point the finger of blame at some individual, this should be reported. Higher authority should handle the disposition of the incident. Just the facts . . . recommendations for punishment or disciplinary action, and/or personal opinions are beyond the purview of safety engineering—and the safety professional.

Accident Investigation Process: We recommend a proactive approach to accident prevention. We are certain that preventing accidents is much better than having to react to them—and their consequences. We also understand that accidents happen. Even the best-managed safety program will not erase the potential for some accidents to occur. They will happen.

The accident investigation process begins, of course, with an accidental occurrence. The accident may be nothing more than a slight injury to a worker, or minor damage to company or non-company property. On the other hand, the accident may be major—even catastrophic. The accident investigation process should begin as soon after the occurrence as possible, because the investigator must gather facts from fresh evidence. Looking for evidence at the scene of an accident that has been tampered with or cleaned up makes the investigator's job much more difficult. Another problem with waiting too long to look at the accident is that witnesses who have just witnessed an accident (with the incident still fresh in their minds) are much more likely to relate what they saw more accurately to the investigator.

You must be aware of another problem—the reluctance or refusal of workers, witnesses, and/or supervisors to report accidents. Frequently workers have reasons they may not want to go on record about an accident. Company policy must insist that all accidents be reported.

All accidents? It depends. For example, many companies require that any personal injury resulting in the need for more than minor first aid at the work site, or that results in lost work time must be reported immediately (or as soon as possible) to the work center supervisor. This is important for two reasons: (1) to ensure that an injured worker receives proper medical attention and (2) to ensure that the incident is properly recorded in the OSHA 300 log.

Does this mean that when a worker receives a minor bruise or scratch while working at the job site, he or she should not report the accident? Again, it depends—on company policy, and the type of work being done. For example, in a wastewater treatment plant, a minor scratch received while repairing a treatment process machine where the worker is exposed to raw wastewater may be more than just a minor occurrence. A worker who is scratched, then exposed to the wastestream may not recognize the injury as a major event then (and thus will not report it), but three days later, when any pathogens contained in the wastewater have entered the body and had a chance to "do their work," a simple scratch may turn into a serious event—possibly life-threatening, if not properly treated.

After an accident is reported, the work center supervisor normally accomplishes the first investigation. In fact, many companies use an accident investigation form called a "Supervisor's" or "Employer's First Report of Accident." This is a good practice, because the supervisor not only possesses the most knowledge about his or her employees, but also knows the equipment and work practices in his or her area. In companies employing a full-time safety engineer, company policy may or may not require that the supervisor wait until the safety engineer arrives to conduct the investigation as a team. Experience shows us that allowing the supervisor to investigate first is better. The supervisor is usually right on the scene or nearby when the incident occurs, and waiting for the safety engineer to show up on scene may require too long a delay. Remember that the idea is to investigate as soon as possible. The exception might be, of course, incidents involving a fatality or multiple fatalities. In such cases, the safety engineer should be called immediately (along with OSHA) to investigate. But for minor occurrences, the supervisor should have the first look, the safety engineer should read his or her report, and if deemed pertinent, should perform a follow-up investigation. This follow-up investigation is not intended to check out the supervisor's ability to conduct investigations but rather to determine causal factors and mitigation procedures. The safety engineer is the company's safety expert, and his or her job is to recommend steps (remedial actions) to ensure that like incidents do not occur again. Experience has also demonstrated that an immediate first look (conducted by the supervisor) works well to gather the majority of facts—then the follow-up investigation (conducted by the safety engineer) works well to "fine-tune" the investigation to the point where items overlooked by one set of eyes might be picked up by another set.

Whatever type of form and/or protocol the supervisor uses to make his or her first report of accident, the supervisor's main mission must be to determine the what, where, when, how, and possibly the why. To answer these questions, the supervisor must gather facts. Normal practice involves using five methods to gather accident information:

- interviewing the victim,
- interviewing accident witnesses,
- investigation of the accident scene, including taking photographs when possible,
- re-enactment of the accident, and
- reconstruction of accident.

Findings must be recorded on the Supervisor's or Employer's First Report of Accident or similar form.

Accident Prevention: The act of averting a circumstance that could cause loss or injury to a person.

Accident Site: The location of an unexpected occurrence, failure, or loss, either at a plant or along a transportation route, resulting in a release of hazardous materials.

Accidental Myiasis: Presence of a non-parasitic fly within a host.

Accidental Spills: The unintended release of chemicals and hazardous compounds or materials into the environment.

Acclimation Temperature: The ambient temperature that an organism has become accustomed to by a period of constant exposure to this condition over time.

Acclimatization (aka Acclimation): The physiological and behavioral adaptations or adjustments of an organism to changes in its environment.

Accommodation: In optics, the ability of the eye to quickly and easily readjust to other focal points after viewing a VDT so as to be able to focus on other objects, particularly objects at a distance.

Accretion: The addition of air particles to hydrate drops, such as snow, rain, or sleet, by coagulation as the drops fall through the sky.

Accumulated Dose: A total dose resulting from repeated exposure to a toxic substance or radiation.

Accumulated Dose Equivalent: An estimated lifetime maximum permissible dose of radiation (5 rems/yr) for persons working with radioactive materials or x-rays.

Accuracy: The closeness of an individual measurement or of the average of a number of measurements to the true value. Deviation from the true value is a measure of bias in the individual measurement or averaged value.

Acetaldehyde: CH_3CHO, a colorless liquid or gas with a pungent, fruity odor. It is used in the production of intermediates during the synthesis of acetic acid, acetic anhydride, and aldol compounds. It is an eye, nose, and throat irritant and is hazardous to the respiratory system, skin, and kidneys and is toxic by inhalation and ingestion.

Acetate: A salt or ester of acetic acid.

Acetic: A substance having the sour properties of vinegar or acetic acid.

Acetic Acid (CH_3COOH): A colorless liquid organic acid with a vinegar-like odor.

Acetylene: C_2H_2, an odorless, colorless gas obtained from limestone and coal; its combustion in pure oxygen produces the highest achievable flame temperature, over 3300ºC.

ACFM: Actual cubic feet per minute of gas flowing at existing temperature and pressure.

ACH, AC/H (air changes per hour): The number of times air is replaced in an hour.

Acid: Any substance that releases hydrogen ions (H^+) when it is mixed into water.

Acid Aerosol: Acidic liquid or solid particles small enough to become airborne. High concentrations can irritate the lungs and have been associated with respiratory diseases like asthma.

Acid-Based: Describes batteries that use an acid such as sulfuric acid as the major component of the electrolyte.

Acid Deposition: The environmental deposit of acidic or acidifying compounds (with a pH of less than 5.6) from the atmosphere by rain or other precipitation that has an excessive concentration of sulfuric or nitric acids, as a result of chemical pollution of the atmosphere from such sources as automobile exhausts and the industrial burning of coal or oil.

Acid Gas: A term for any of the acidic constituents of natural gas, such as hydrogen sulfide or carbon dioxide.

Acid Hydrolysis: A chemical process in which acid is used to convert cellulose or starch to sugar.

Acid Mine Drainage: The dissolving and transporting of sulfuric acid and toxic metal compounds from abandoned underground coal mines to nearby streams and rivers when surface water flows through the mines.

Acid Neutralizing Capacity: Measure of ability of a base (e.g., water or soil) to resist changes in pH.

Acid Precipitation: Rain, snow, or fog that contains higher than normal levels of sulfuric or nitric acid, which may damage forests, aquatic ecosystems, and cultural landmarks.

Acid Rain: Any form of precipitation made more acidic from falling though air pollutants (primarily sulfur dioxide) and dissolving them.

Acid Surge: A period of short, intense acid deposition in lakes and streams as a result of the release (by rainfall or spring snowmelt) of acids stored in soil or snow.

Acidic: The condition of water or soil that contains a sufficient amount of acid substances to lower the pH below 7.0.

Acidic Solution: A solution that contains significant numbers of (H^+) ions.

Acidosis: An abnormal increase in the acidity of the body's fluids, caused either by accumulation of acids or by depletion of bicarbonates.

Acoustic Trauma: A single incident which produces an abrupt hearing loss. Welding sparks (to the eardrum), blows to the head, and blast noise are examples of events capable of providing acoustic trauma.

Acoustics: In general, the experimental and theoretical science of sound and its transmission; in particular, that branch of the science that has to do with the phenomena of sound in a particular space such as a room or theater. Safety engineering is concerned with the technical control of sound, and involves architecture and construction, studying control of vibration, soundproofing, and the elimination of noise—to engineer out the noise hazard.

Acrid: Unpleasantly sharp, pungent, or bitter to the taste or smell.

Actinide: A classification for any of the heavy radioactive metallic elements having atomic numbers in the range from 90 (thorium) to 103 (lawrencium).

Actinides in the Environment: Refers to the sources, environmental behavior, and effects of radioactive actinides in the environment.

Action Level: Term used by OSHA and NIOSH (National Institute for Occupational Safety and Health—a federal agency that conducts research on safety and health concerns) and defined in the Code of Federal Regulations (CFR), Title 40, Protection of Environment. Under OSHA, "action level" is the level of toxicant that requires medical surveillance, usually 50 percent of the PEL (Personal Exposure Level). Note that OSHA also uses the action level in other ways besides setting the level of "toxicant." For example, in its hearing conservation standard, 29 CFR 1910.95, OSHA defines the action level as an eight-hour time-weighted average (TWA) of 85 decibels measured on the A-scale, slow response, or equivalently, a dose of 50 percent (see Chapter 27 for more information on hearing conservation). Under CFR 40 §763.121, action level means an airborne concentration of asbestos of 0.1 fiber per cubic centimeter (f/cc) of air calculated as an eight-hour time-weighted average.

Action Potential: Describes the sequence of electrical changes occurring when a nerve cell membrane is exposed to a stimulus that exceeds its threshold.

Activated Carbon: A highly porous form of carbon, typically from wood, lignite, coal, or coconut shell; widely used as a filtration medium (e.g., to remove taste and odor from water).

Activated Sludge: In wastewater treatment, the activated sludge unit process follows primary settling. The basic components of an activated sludge sewage treatment system include an aeration tank and a secondary basin, settling basin, or clarifier. Primary effluent is mixed with settled solids recycled from the secondary clarifier and is then introduced into the aeration tank. Compressed air is injected continuously into the mixture through porous diffusers located at the bottom of the tank, usually along one side.

Wastewater is fed continuously into an aerated tank, where the microorganisms metabolize and biologically flocculate the organics. Microorganisms (activated sludge) are settled from the aerated mixed liquor under quiescent conditions in the final clarifier and are returned to the aeration tank. Left uncontrolled, the number of organisms would eventually become too great; therefore, some must periodically be removed (wasted). A portion of the concentrated solids from the bottom of the settling tank must be removed from the process (waste activated sludge or WAS). Clear supernatant from the final settling tank is the plant effluent.

Activated Sludge Terminology

To better understand the activated sludge process, you must understand the terms associated with the process.

- *Activated*—to speed up reaction. When applied to sludge, it means that many aerobic bacteria and other microorganisms are in the sludge particles.
- *Activated sludge*—a floc or solid formed by the microorganisms. It includes organisms, accumulated food materials, and waste products from the aerobic decomposition process.
- *Activated sludge process*—a biological wastewater treatment process in which a mixture or influent and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated mixed liquor by sedimentation and is returned to the process as needed. The treated wastewater overflows the weir of the settling tank in which separation from the sludge takes place.
- *Adsorption*—the adherence of dissolved, colloidal, or finely divided solids to the surface of solid bodies when they are brought into contact.

- *Aeration*—mixing air and a liquid by one of the following methods: spraying the liquid in the air; diffusing air into the liquid; or agitating the liquid to promote surface adsorption of air.
- *Aerobic*—a condition in which "free" or dissolved oxygen is present in the aquatic environment. Aerobic organisms must be in the presence of dissolved oxygen to be active.
- *Bacteria*—single-cell plants that play a vital role in stabilization of organic waste.
- *Biochemical oxygen demand (BOD)*—a measure of the amount of food available to the microorganisms in a particular waste. It is measured by the amount of dissolved oxygen used up during a specific time period (usually five days, expressed as BOD_5).
- *Biodegradable*—from "degrade" (to wear away or break down chemically) and "bio" (by living organisms). Put it all together, and you have a "substance, usually organic, which can be decomposed by biological action."
- *Bulking*—a problem in activated sludge plants that results in poor settleability of sludge particles.
- *Coning*—a condition that may be established in a sludge hopper during sludge withdrawal, when part of the sludge moves toward the outlet while the remainder tends to stay in place. Development of a cone or channel of moving liquids surrounded by relatively stationary sludge.
- *Decomposition*—generally, in waste treatment, decomposition refers to the changing of waste matter into simpler, more stable forms that will not harm the receiving stream.
- *Diffuser*—a porous plate or tube through which air is forced and divided into tiny bubbles for distribution in liquids. Commonly made of carborundum, aluminum, or silica sand.
- *Diffused air aeration*—a diffused air activated sludge plant takes air, compresses it, then discharges the air below the water surface to the aerator through some type of air diffusion device.
- *Dissolved oxygen*—atmospheric oxygen dissolved in water or wastewater, usually abbreviated as DO.

Note: The typical required DO for a well-operated activated sludge plant is between 2.0 and 2.5 mg/l.

- *Facultative*—facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials. In other words, facultative bacteria can live under aerobic or anaerobic conditions.
- *Filamentous bacteria*—organisms that grow in thread or filamentous form.
- *Food-to-microorganisms ratio*—a process control calculation used to evaluate the amount of food (BOD or COD) available per pound of mixed liquor volatile suspended solids. This may be written as F/M ration.

$$\frac{\text{Food}}{\text{Microorganism}} = \frac{\text{BOD, lb/day}}{\text{MLVSS, lb}} = \frac{\text{Flow, MGD x BOD, mg/l} \times 8.34\ \text{lb/gal}}{\text{Vol., MG x MLVSS, mg/l} \times 8.34\ \text{lb/gal}}$$

- *Fungi*—multicellular aerobic organisms.
- *Gould sludge age*—a process control calculation used to evaluate the amount of influent suspended solids available per pound of mixed liquor suspended solids.
- *Mean cell residence time* (MCRT)—the average length of time mixed liquor suspended solids particle remains in the activated sludge process. This is usually written as MCRT and may also be referred to as *sludge retention rate* (STR).

$$\text{MCRT, days} = \frac{\text{Solids in Activated Sludge Process, lbs}}{\text{Solids Removed from Process, lb/day}}$$

- *Mixed liquor*—the contribution of return activated sludge and wastewater (either influent or primary effluent) that flows into the aeration tank.
- *Mixed liquor suspended solids (MLSS)*—the suspended solids concentration of the mixed liquor. Many references use this concentration to represent the amount of organisms in the liquor. Many references use this concentration to represent the amount of organisms in the activated sludge process. This is usually written MLSS.
- *Mixed liquor volatile suspended solids (*MLVSS)—the organic matter in the mixed liquor suspended solids. This can also be used to represent the amount of organisms in the process. This is normally written as MLVSS.
- *Nematodes*—microscopic worms that may appear in biological waste treatment systems.
- *Nutrients*—substances required to support plant organisms. Major nutrients are carbon, hydrogen, oxygen, sulfur, nitrogen, and phosphorus.
- *Protozoa*—single-cell animals that are easily observed under the microscope at a magnification of 100x. Bacteria and algae are prime sources of food for advanced forms of protozoa.
- *Return activated sludge*—the solids returned from the settling tank to the head of the aeration tank. This is normally written as RAS.
- *Rising sludge*—rising sludge occurs in the secondary clarifiers or activated sludge plant when the sludge settles to the bottom of the clarifier, is compacted, and then rises to the surface in relatively short time.
- *Rotifiers*—multicellular animals with flexible bodies and cilia near their mouths used to attract food. Bacteria and algae are their major source of food.

- *Secondary treatment*—a wastewater treatment process used to convert dissolved or suspended materials into a form that can be removed.
- *Settleability*—a process control test used to evaluate the settling characteristics of the activated sludge. Readings taken at 30 to 60 minutes are used to calculate the settled sludge volume (SSV) and the sludge volume index (SVI).
- *Settled sludge volume*—the volume of ml/l (or percent) occupied by an activated sludge sample after 30 or 60 minutes of settling. Normally written as SSV with a subscript to indicate the time of the reading used for calculation (SSV_{30} or SSV_{60}).
- *Shock load*—the arrival at a plant of a waste toxic to organisms, in sufficient quantity or strength to cause operating problems, such as odor or sloughing off of the growth of slime on the trickling filter media. Organic overloads also can cause a shock load.
- *Sludge volume index*—a process control calculation used to evaluate the settling quality of the activated sludge. Requires the SSV_{30} and mixed liquor suspended solids test results to calculate.

$$\text{Sludge Vol. Index (SVI), ml/g} = \frac{\text{(30 min settled vol., ml/l)(1,000 mg/g)}}{\text{Mixed Liquor Suspended Solids, mg/l}}$$

- *Solids*—material in the solid state.
  Dissolved—solids present in solution. Solids that will pass through a glass fiber filter.
  Fixed—also known as the inorganic solids. The solids that are left after a sample is ignited at 550° Celsius (centigrade) for 15 minutes.
  Floatable solids—solids that will float to the surface of still water, sewage, or other liquid. Usually composed of grease particles, oils, light plastic material, etc. Also called *scum.*
  Non-settleable—finely divided suspended solids that will not sink to the bottom in still water, sewage, or other liquid in a reasonable period, usually two hours. Non-settleable solids are also known as colloidal solids.
  Suspended—the solids that will not pass through a glass fiber filter.
  Total—the solids in water, sewage, or other liquids; it includes the suspended solids and dissolved solids.
  Volatile—the organic solids. Measured as the solids that are lost on ignition of the dry solids at 550°C.
- *Waste activated sludge*—the solids being removed from the activated sludge process. This is normally written as WAS.

Activation: The creation of a radioactive element from a stable one by the absorption of neutrons or protons, occurring when a particle interacts with an atomic nucleus, making the nucleus into an unstable state and causing it to become radioactive.

Activation Energy: The energy needed to initiate a chemical reaction.

Activation Entropy: The entropic contribution to the free energy barrier that an atom in a metastable position must surmount in order to participate in a thermally activated process.

Activator: A chemical added to a pesticide to increase its activity.

Active Capacity: A reservoir's capacity normally usable for storage and regulation of inflows to meet operating requirements for power and other uses.

Active Ingredient: In any pesticide product, the component that kills, or otherwise controls, target pests. Pesticides are regulated primarily on the basis of active ingredients.

Active Material: A material that reacts chemically to produce electric energy when a battery discharges, and which is restored to its original state during the charge.

Active Transport: An energy-expending mechanism by which a cell moves a chemical across the cell membrane from a point of lower concentration to a point of higher concentration, against the diffusion gradient.

Activity: The rate of disintegration (transformation) or decay of radioactive material. The units of activity are the curie (Ci) and the Becquerel (Bq).

Activity Monitors: System monitor designed to prevent virus infection by monitoring for malicious activity on a system, and blocking that activity when possible.

Acuity: Acuteness of vision or perception.

Acute: Health effects that show up a short length of time after exposure. An acute exposure runs a comparatively short course and its effects are easier to reverse than those of a chronic exposure.

Acute Effect: An adverse effect on any living organism which result sin severe symptoms that develop rapidly; symptoms often subside after the exposure stops.

Acute Exposure: A short interval of usually heavy exposure to radiation or a toxic substance.

Acute Exposure Guideline Level (AEGL): Guideline intended to describe the risk to humans resulting from once-in-a-lifetime, or rare, exposure to airborne chemicals. Acute exposures are defined as single, non-repetitive exposures for not more than eight hours.

There are three AEGL values:

- AEGL-1: discomfort, non-disabling.
- AEGL-2: Irreversible or other serious, long-lasting effects or impaired ability to escape.
- AEGL-3: Life-threatening effects or death.

Acute Toxicity: The discernible adverse effects induced in an organism with a short period of time (days) of exposure to an agent.

Adaptation: Changes in an organism's physiological structure or function or habits that allow it to survive in new surroundings.

Add-on-Control Device: An air pollution control device such as carbon absorber or incinerator that reduces the pollution in an exhaust gas. The control device usually does not affect the process being controlled and thus is "add-on" technology, as opposed to a scheme to control pollution through altering the basic process itself.

Additive Effect: A biologic response to exposure to multiple substances that equals the sum of response of all the individual substances added together

Adequately Wet: Asbestos containing material that is sufficiently mixed or penetrated with liquid to prevent the release of particulates.

Adhesion: Static attractive force at the contacting surface between two bodies of different substances in contact with each other.

Adiabatic: 1. Means without loss or gain of heat. 2. When air rises, air pressure decreases and expands adiabatically in the atmosphere; since the air can neither gain nor lose heat, its temperature falls as it expands to fill a larger volume.

Adiabatic Lapse Rate: The temperature profile or lapse rate, used as a basis for comparison for actual temperature profiles (from ground level) and hence for predictions of stack gas dispersion characteristics.

Administered Dose: In exposure assessment, the amount of a substance given to a test subject (human or animal) to determine dose-response relationships. Since exposure to chemicals is usually inadvertent, this quantity is often called potential dose.

Administrative Controls: Administrative controls attempt to limit the worker's exposure to the hazard. Normally accomplished by arranging work schedules and related duration of exposures so that employees are minimally exposed to health hazards, another procedure transfers workers who have reached their upper permissible limits of exposure to an environment where no additional exposure will be experienced. Both control procedures are often used to limit worker exposure to air contaminants or noise. For example, a worker who is required to work in an extremely high noise area where engineering controls are not possible would be rotated from the high noise area to a quiet area when the daily permissible noise exposure is reached.

Reducing exposures by limiting the duration of exposure (basically by modifying the work schedule) must be carefully managed (most managers soon find that attempting to properly manage this procedure takes a considerable amount of time, effort, and "imagination"). When practiced, reducing worker exposure is based on limiting the amount of time a worker is exposed, ensuring that OSHA Permissible Exposure Limits (PELs) are not exceeded.

Let's pause right here and talk about Permissible Exposure Limits (PELs) and Threshold Limit Values (TLVs). You should know what they are and what significance they play in the safety engineer's daily activities. Let's begin with TLVs.

Threshold Limit Values (TLVs) are published by the American Conference of Governmental Industrial Hygienists (ACGIH) (an organization made up of physicians, toxicologists, chemists, epidemiologists, and industrial hygienists) in its *Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment.* These values are useful in assessing the risk of a worker exposed to a hazardous chemical vapor; concentrations in the workplace can often be maintained below these levels with proper controls. The substances listed by ACGIH are evaluated annually, limits are revised as needed, and new substances are added to the list as information becomes available. The values are established from the experience of many groups in industry, academia and medicine, and from laboratory research.

The chemical substance exposure limits listed under both ACGIH and OSHA are based strictly on airborne concentrations of chemical substances in terms of milligrams per cubic meter (mg/m^3), parts per million (ppm), and fibers per cubic centimeters (fibers/cm^3). Allowable limits are based on three different time periods of average exposure: (1) 8-hour work shifts known as TWA (time weighted average), (2) short terms of 15 minutes or STEL (short-term exposure limit), and (3) instantaneous exposure of "C" (ceiling). Unlike OSHA's PELs, TLVs are recommended levels only, and do not have the force of regulation to back them up.

OSHA has promulgated limits for personnel exposure in workplace air for approximately 400 chemicals listed in Tables Z1, Z2, and Z3 in Part 1910.1000 of the *Federal Occupational Safety and Health Standard*. These limits are defined as permissible exposure limits (PEL), and like TLVs are based on 8-hour time weighted averages (or ceiling limits when preceded by a "C"). Keeping within the limits in the Z Tables is the only requirement specified by OSHA for these chemicals. The significance of OSHA's PELs is that they have the force of regulatory law behind them to back them up—compliance with OSHA's PELs is the law.

Evaluation of personnel exposure to physical and chemical stresses in the industrial workplace requires the use of the guidelines provided by TLVs and the regulatory guidelines of PELs. For the safety engineer to carry out the goals of recognizing, measuring and effecting controls (of any type) of workplace stresses, such limits are a necessity, and have become the ultimate guidelines in the science of safety engineering. A word of caution is advised, however. These values are set only as guides for best practice, and are not to be considered absolute values. What are we saying here? These values provide reasonable assurance that occupational disease will not occur, if exposures are kept below these levels. On the other hand, occupational disease is likely to develop in some people—if the recommended levels are exceeded on a consistent basis.

Let's get back to administrative controls.

We stated that one option available to the safety engineer in controlling workplace hazards is the use of an administrative control that involves modifying workers' work schedules to limit the time of their exposure so that the PEL/TLV is not exceeded. We also said (or at least implied) that this procedure is a manager's nightmare to implement and manage. Practicing safety engineers don't particularly like it, either; they feel that such a strategy merely spreads the exposure out, and does nothing to control the source. Experience has shown that in many instances this statement is correct. Nevertheless work schedule modification is commonly used for exposures to such stressors as noise and lead.

Another method of reducing worker exposure to hazards is by ensuring good housekeeping practices. Housekeeping practices? Absolutely. Think about it. If dust and spilled chemicals are allowed to accumulate in the work area, workers will be exposed to these substances. This is of particular importance for flammable and toxic materials. Ensuring that housekeeping practices do not allow toxic or hazardous materials to disperse into the air is also an important concern.

Administrative controls can also reach beyond the workplace. For example, if workers abate asbestos eight hours a day, they should always wear approved Tyvek protective suits and other required personal protective equipment (PPE) on the job. After the work assignment is completed, these workers must decontaminate following standard protocol. The last thing these workers should be allowed to do is to wear their personal clothing for such work to avoid decontamination procedures, then take their contaminated clothing with them when they leave for home. The idea is to leave any contaminated clothing at work (safely stored or properly disposed of).

Implementation of standardized materials handling or transferring procedures are other administrative controls often used to protect workers. In handling chemicals, any transfer operations taken should be closed-system, or should have adequate exhaust systems to prevent worker exposure or contamination of the workplace air. This practice should also include the use of spill trays to collect overfill spills or leaking materials between transfer points.

Programs that involve visual inspection and automatic sensor devices (leak detection programs) allow not only for quick detection, but also for quick repair and minimal exposure. When automatic system sensors and alarms are deployed as administrative controls, tying the alarm system into an automatic shutdown system (close a valve, open a circuit, etc.), allows the sensor to detect a leak, sound the alarm, and initiate corrective action (for example, immediate shutdown of the system).

Finally, two other administrative control practices that go hand-in-hand are training and personal hygiene. For workers to best protect themselves from workplace hazards (to reduce the risk of injury or illness), they must be made aware of the hazards. OSHA puts great emphasis on the worker-training requirement. This emphasis is well placed. No worker can be expected to know the entire workplace, process, or equipment hazards, unless he or she has been properly trained on the hazards. Chapter 40 covers training and OSHA's requirements in this vital area.

An important part of the training process is worker awareness. Legally (and morally) workers have the right to know what they are working with, what they are exposed to while on the job. They must be made aware of the hazards. They must also be trained on what actions to take when they are exposed to specific hazards. Personal hygiene practices are an important part of worker protection. The safety engineer must ensure that appropriate cleaning agents and facilities such as emergency eyewashes, showers, and changing rooms are available and conveniently located for worker use.

Administrative Order: A legal document signed by EPA directing an individual, business, or other entity to take corrective action or refrain from an activity. It describes the violations and actions to be taken, and can be enforced in court. Such orders may be issued, for example, as a result of an administrative complaint whereby the respondent is ordered to pay a penalty for violations of a statute.

Administrative Order on Consent: A legal agreement signed by EPA and an individual, business, or other entity through which the violator agrees to pay for correction of violations, take the required corrective or cleanup actions, or refrain from an activity. It describes the actions o be taken, may be subject to a comment period, applies to civil actions, and can be enforced in court.

Administrative Procedures Act: A law that spells out procedures and requirements related to the promulgation of regulations.

Administrative Record: All documents which EPA considered or relied on in electing the response action at Superfund site, culminating in the record of decision for remedial action, or an action memorandum for removal actions.

Admittance: The reciprocal of impedance, it is the measure of how readily an alternating current flows through a circuit.

Adsorption: 1. The taking up of a gas or liquid at the surface of another substance, usually a solid (e.g., activated charcoal adsorbs gases). 2. Electrochemical attraction of positively or negatively charged molecules onto solids with an opposite charge.

Adsorption Site Density: The concentration of sorptive surface available from the mineral and organic contents of soils. An increase in adsorption sites indicates an increase in the ability of the soils to immobilize hydrocarbon compounds in the soil matrix.

Adulterants: Chemical impurities or substance that by law do not belong in a food, or pesticide.

Adulterated: 1. Any pesticide whose strength or purity falls below the quality stated on its label. 2. A food, feed, or product that contains illegal pesticide residues.

Advance Reproduction: In forest science, young seedlings and saplings that have naturally established under an overstory canopy.

Advanced Wastewater Treatment: (1) Any treatment that follows primary and secondary wastewater treatment is considered advanced treatment. (2) Advanced wastewater treatment is defined as the method(s) and/or process (es) that remove more contaminants (suspended and dissolved substances) from wastewater than are taken out by conventional biological treatment. Put another way, advanced wastewater treatment is the application of a process or system that follows secondary treatment or that includes phosphorus removal or nitrification in conventional secondary treatment.

Advanced wastewater treatment is used to augment conventional secondary treatment because secondary treatment typically removes only between 85 and 95 percent of the biochemical oxygen demand (BOD) and total suspended solids (TSS) in raw sanitary sewage. Generally, this leaves 30 mg/l or less of BOD and TSS in the secondary effluent. To meet stringent water-quality standards, this level of BOD and TSS in secondary effluent may not prevent violation of water-quality standards—the plant may not make permit. Thus, advanced wastewater treatment is often used to remove additional pollutants from treated wastewater.

In addition to meeting or exceeding the requirements of water-quality standards, treatment facilities use advanced wastewater treatment for other reasons as well. For example, sometimes, conventional secondary wastewater treatment is not sufficient to protect the aquatic environment. In a stream, for example, when periodic flow events occur, the stream may not provide the amount of dilution of effluent needed to maintain the necessary dissolved oxygen (DO) levels for aquatic organism survival.

Secondary treatment has other limitations. It does not significantly reduce the effluent concentration of nitrogen and phosphorus (important plant nutrients) in sewage. An over-abundance of these nutrients can over-stimulate plant and algae growth such that they create water quality problems. For example, if discharged into lakes, these nutrients contribute to algal blooms and accelerated eutrophication (lake aging). Also, the nitrogen in the sewage effluent may be present mostly in the form of ammonia compounds. If in high enough concentration, ammonia compounds are toxic to aquatic organisms. Yet another problem with these compounds is that they exert a *nitrogenous* oxygen demand in the receiving water, as they convert to nitrates. This process is called nitrification.

Note: The term *tertiary treatment* is commonly used as a synonym for advanced wastewater treatment. However, these two terms do not have precisely the same meaning. Tertiary suggests a third step that is applied after primary and secondary treatment.

Advanced wastewater treatment can remove more than 99 percent of the pollutants from raw sewage and can produce an effluent of almost potable (drinking) water quality. However, obviously, advanced treatment is not cost-free. The cost of advanced treatment, for operation and maintenance as well as for retrofit of present conventional processes, is very high (sometimes doubling the cost of secondary treatment). Therefore, a plan to install advanced treatment technology calls for careful study—the benefit-to-cost ratio is not always big enough to justify the additional expense.

Even considering the expense, application of some form of advanced treatment is not uncommon. These treatment processes can be physical, chemical, or biological. The specific process used is based upon the purpose of the treatment and the quality of the effluent desired.

Chemical Treatment

The purpose of chemical treatment is to remove

- BOD
- Total suspended solids (TSS)
- Phosphorus
- Heavy metals
- Other substances that can be chemically converted to a settleable solid

Chemical treatment is often accomplished as an "add-on" to existing treatment systems or by means of separate facilities specifically designed for chemical addition. In each case, the basic process necessary to achieve the desired results remains the same:

- Chemicals are thoroughly mixed with the wastewater.
- The chemical reactions that occur from solids (coagulation).
- The solids are mixed to increase particle size (flocculation).
- Settling and/or filtration (separation) then remove the solids.

The specific chemical used depends on the pollutant to be removed and the characteristics of the wastewater. Chemicals may include the following:

- lime
- alum (aluminum sulfate)
- aluminum salts
- ferric or ferrous salts
- polymers
- bioadditives

Microscreening

Microscreening (also called *microstraining*) is an advanced treatment process used to reduce suspended solids. The microscreens are composed of specially woven steel wire fabric mounted around the perimeter of a large revolving drum. The steel wire cloth acts as a fine screen, with openings as small as 20 micrometers (or millionths of a meter)—small enough to remove microscopic organisms and debris.

The rotating drum is partially submerged in the secondary effluent, which must flow into the drum then outward through the microscreen. As the drum rotates, captured solids are carried to the top where a high-velocity water spray flushes them into a hopper or backwash tray mounted on the hollow axle of the drum. Backwash solids are recycled to plant influent for treatment. These units have found greatest application in treatment of industrial waters and final polishing filtration of wastewater effluents. Expected performance for suspended solids removal is 95 to 99 percent, but the typical suspended-solids removal achieved with these units is about 55 percent. The normal range is from 10 to 80 percent.

According to Metcalf & Eddy (2003), the functional design of the microscreen unit involves the following considerations: (1) The characterization of the suspended solids with respect to the concentration and degree of flocculation; (2) the selection of unit design parameter values that will not only ensure capacity to meet maximum hydraulic loadings with critical solids characteristics, but also provide desired design performance over the expected range of hydraulic and solids loadings; (3) the provision of backwash and cleaning facilities to maintain the capacity of the screen.

Filtration

The purpose of *filtration* processes used in advanced treatment is to remove suspended solids. The specific operations associated with a filtration system are dependent on the equipment used. A general description of the process follows.

Wastewater flows to a filter (gravity or pressurized). The filter contains single, dual, or multimedia. Wastewater flows through the media, which removes solids. The solids remain in the filter. Backwashing the filter as needed removes trapped solids. Backwash solids are returned to the plant for treatment. Processes typically remove 95 to 99 percent of the suspended matter.

Biological Nitrification

Biological *nitrification* is the first basic step of *biological nitrification-denitrification.*

In nitrification, the secondary effluent is introduced into another aeration tank, trickling filter, or biodisc. Because most of the carbonaceous BOD has already been removed, the microorganisms that drive in this advanced step are the nitrifying bacteria *Nitrosomonas* and *Nitrobacter.* In nitrification, the ammonia nitrogen is converted to nitrate nitrogen, producing a *nitrified effluent.* At this point, the nitrogen has not actually been removed, only converted to a form that is not toxic to aquatic life and that does not cause an additional oxygen demand.

The nitrification process can be limited (performance affected) by alkalinity (requires 7.3 parts alkalinity to 1.0 part ammonia nitrogen); pH; dissolved oxygen availability; toxicity (ammonia or other toxic materials); and process mean cell residence time (sludge retention time). As a general rule, biological nitrification is more effective and achieves higher levels of removal during the warmer times of the year.

Biological Denitrification

Biological denitrification removes nitrogen from the wastewater. When bacteria come in contact with a nitrified element in the absence of oxygen, they reduce the nitrates to nitrogen gas, which escapes the wastewater. The denitrification process can be done in either an anoxic activated sludge system (suspended growth) or in a column system (fixed growth). The denitrification process can remove up to 85 percent or more of nitrogen.

After effective biological treatment, little oxygen demanding material is left in the wastewater when it reaches the denitrification process.

The denitrification reaction will only occur if an oxygen demand source exists when no dissolved oxygen is present in the wastewater. An oxygen demand source is usually added to reduce the nitrates quickly. The most common demand source added is soluble BOD or methanol. Approximately 3 mg/l of methanol is added for ever 1 mg/l of nitrate-nitrogen.

Suspended growth denitrification reactors are mixed mechanically, but only enough to keep the biomass from settling without adding unwanted oxygen.

Submerged filters of different types of media may also be used to provide denitrification. A fine media downflow filter is sometimes used to provide both denitrification and effluent filtration. A fluidized sand bed where wastewater flows upward through a media of sand or activated carbon at a rate to fluidize the bed may also be used. denitrification bacteria grow on the media.

Carbon Adsorption

The main purpose of *carbon adsorption* used in advanced treatment processes is the removal of refractory organic compounds (non-BOD_5) and soluble organic material that are difficult to eliminate by biological or physical/chemical treatment.

In the carbon adsorption process, wastewater passes through a container filled either with carbon powder or carbon slurry. Organics adsorb onto the carbon (i.e., organic molecules are attracted to the activated carbon surface and are held there) with sufficient contact time.

A carbon system usually has several columns or basins used as contactors. Most contact chambers are either open concrete gravity-type systems or steel pressure containers applicable to either upflow or downflow operation.

With use, carbon loses its adsorptive capacity. The carbon must then be regenerated or replaced with fresh carbon. As head loss develops in carbon contactors, they are backwashed with clean effluent in much the same way the effluent filters are backwashed. Carbon used for adsorption may be in a granular form or in a powdered form.

Note: Powdered carbon is too fine for use in columns and is usually added to the wastewater, then later removed by coagulation and settling.

Land Application

The application of secondary effluent onto a land surface can provide an effective alternative to the expensive and complicated advanced treatment methods discussed previously and the biological nutrient removal (BNR) system discussed later. A high-quality polished effluent (i.e., effluent with high levels of TSS, BOD, phosphorus, and nitrogen compounds as well as refractory organics are reduced) can be obtained by the natural processes that occur as the effluent flows over the vegetated ground surface and percolates through the soil.

Limitations are involved with land application of wastewater effluent. For example, the process needs large land areas. Soil type and climate are also critical factors in controlling the design and feasibility of a land treatment process.

Three basic types or modes of land application or treatment are commonly used: Irrigation (slow rate), overland flow, and infiltration-percolation (rapid rate). The basic objectives of these types of land applications and the conditions under which they can function vary.

In *irrigation* (also called slow rate), wastewater is sprayed or applied (usually by ridge-and-furrow surface spreading or by sprinkler systems) to the surface of the land. Wastewater enters the soil. Crops growing on the irrigation area utilize available nutrients. Soil organisms stabilize organic content of the flow. Water returns to hydrologic (water) cycle through evaporation or by entering the surface water or groundwater.

The irrigation land application method provides the best results (compared with the other two types of land application systems) with respect to advanced treatment levels of pollutant removal. Not only are suspended solids and BOD significantly reduced by filtration of the wastewater, but also biological oxidation of the organics in the top few inches of soil occurs. Nitrogen is removed primarily by crop uptake, and phosphorus is removed by adsorption within the soil.

Irrigation expected performance levels are

- BOD_5—98 percent
- Suspended solids—98 percent
- Nitrogen—85 percent
- Phosphorus—95 percent
- Metals—95 percent

The *overland flow* mode of land application used for water purification is accomplished by physical, chemical, and biological processes as the wastewater flows in a thin film down the relatively impermeable surface. In the process, wastewater sprayed over sloped terraces flows slowly over the surface. Soil and vegetation remove suspended solids, nutrients, and organics. A small portion of the wastewater evaporates. The remainder flows to collection channels. Collected effluent is discharged to surface waters.

Overflow flow expected performance levels are

- BOD_5—92 percent
- Suspended solids—92 percent
- Nitrogen—70-90 percent
- Phosphorus—40-80 percent
- Metals—50 percent

In the *infiltration-percolation* (rapid rate) land application process, wastewater is sprayed/pumped to spreading basins (a.k.a. recharge basins or large ponds). Some wastewater evaporates. The remainder percolates/infiltrates into soil. Solids are removed by filtration. Water recharges the groundwater system. Most of the effluent percolates to the groundwater; very little of it is absorbed by vegetation. The filtering and adsorption action of the soil removes most of the BOD, TSS, and phosphorous from the effluent; however, nitrogen removal is relatively poor.

Infiltration-percolation expected performance levels are

- BOD_5—85-99 percent
- Suspended solids—98 percent
- Nitrogen—0-50 percent
- Phosphorus—60-95 percent
- Metals—50-95 percent

Biological Nutrient Removal (BNR)

Recent experience has shown that biological nutrient removal (BNR) systems are reliable and effective in removing nitrogen and phosphorus. The process is based upon the principle that, under specific conditions, microorganisms will remove more phosphorus and nitrogen than is required for biological activity; thus, treatment can be accomplished without the use of chemicals. Not having to use and therefore having to purchase chemicals to remove nitrogen and phosphorus potentially has numerous cost-benefit implications. In addition, because chemicals are not required to be used, chemical waste products are not produced, reducing the need to handle and dispose of waste. Several patented processes are available for this purpose. Performance depends on the biological activity and the process employed.

Enhanced Biological Nutrient Removal (EBNR)

Recently, the trend in removing phosphorus from wastewater in secondary treatment processes has evolved into innovative enhanced biological nutrient removal (EBNR) technologies. EPA (2007) points out that an ENBR treatment process promotes the production of phosphorus accumulating organisms which utilize more phosphorus in their metabolic processes than a conventional secondary biological treatment process. The average total phosphorus concentrations in raw domestic wastewater is usually between 6 to 8 mg/L and the total phosphorus concentration in municipal wastewater after conventional secondary treatment is routinely reduced to 3 or 4 mg/L. Whereas, EBNR incorporated into the secondary treatment system can often reduce total phosphorus concentrations to 0.3 mg/L and less. Facilities using EBNR significantly reduced the amount of phosphorus to be removed through the subsequent chemical addition and tertiary filtration process. This improved the efficiency of the tertiary process and significantly reduced the costs of chemicals used to remove phosphorus. Facilities using EBNR reported that their chemical dosing was cut in half after EBNR was installed to remove phosphorus (EPA 2007).

EPA (2007) also reports that the treatment provided by these WWTPs also removes other pollutants which commonly affect water quality to very low levels. Biochemical oxygen demand (BOD) and total suspended solids are routinely less than 2 mg/L and fecal coliform bacterial less than 10 fcu/100 mL. Turbidity of the final effluent is very low which allows for effective disinfection using ultraviolet light, rather than chlorination. Recent studies report finding that WWTPs using EBNR also significantly reduce the amount of pharmaceuticals and health care produces from municipal wastewater, as compared to the removal accomplished by conventional secondary treatment. EBNR Treatment Technologies include:

- 5 mgd capacity plant
  Advanced Phosphorus Treatment Technology: BNR, filtration
  Treatment process description (liquid side only): involves screening and grinding; primary clarification; biological nutrient removal (BNR) in the contact basins; secondary clarification; filtration through single pass Dynasand filters (four cells with 4 filters per each cell); UV disinfection.
- 1.5 mgd capacity plant
  Advanced Phosphorus Treatment Technology: BNR, chemical addition, tertiary settlers and filtration
  Treatment process description (liquid side only): accomplished by screening and grit removal in the headworks; activated sludge biological treatment; biological aerated filter (IDI "BioFor" for nitrification); chemical coagulation using alum; flocculation and clarification using tube settler (IDI "Densadeg"); filtration (Single Stage Parkson "Dynasand" filters); disinfection and dechlorination. The Dynasand filter

reject rate is reported to be about 15 to 20 percent. The Dynasand filters are configured in four, two-cell units for a total of 8 filters beds which are each 8 feet deep. Influent concentrations of total phosphorus are typically measured at about 6 mg/L (very typical value for untreated domestic wastewater. The aeration basins are operated with an anoxic zone to provide for biological removal of phosphorus. About sixty percent of the influent phosphorus is removed through the biological treatment process. About sixty percent of the influent phosphorus was reported to be removed through the biological treatment process.

Sodium sulfate is added to maintain alkalinity through the treatment process for phosphorus removal. Approximately 100 to 120 mg/L sodium sulfate is applied to the wastewater just upstream of where alum is added. Alum is used to precipitate phosphorus. Alum is used to precipitate phosphorus. The alum dose is typically 135 mg/L and is used with 0.5 to 1.0 mg/L cationic polymer.

Note: A Dynasand filter is a continuous backwash, upflow, deep bed, granular media filter.

- 3 mgd capacity plant
  Advanced Phosphorus Treatment Technology: BNR, Chemical Addition, tertiary settlers and filtration
  Treatment process description (liquid side only): treatment consists of screening and grit removal; biological nutrient removal; chemical coagulation and flocculation using polymer and alum; clarification via tube settlers; filtration though mixed media bed filters; disinfection with chlorine and dechlorination (using sodium bisulfate).
- 2.6 mgd capacity plant
  Advanced Phosphorus Treatment Technology: BNR, chemical addition, tertiary settlers and filtration
  Treatment process description (liquid side only): treatment includes screening and grit removal; aeration basins; secondary clarification; chemical coagulation and flocculation using with alum and polymer; tertiary clarification (rectangular convention with including plate settlers); mixed media bed filters (5 feet deep); and disinfection (the filtration process removes enough fecal coliform so that conventional disinfection is not normally required. The average alum dose is 70 mg/L in the wastewater and varies from 50 to 180 m/L. A greater dose of alum is applied during the winter period. The polymer dose concentration to be about 0.1 mg/L.
- 2 mgd capacity plant
  Advanced Phosphorus Treatment Technology: BNR, chemical addition, two-stage filtration
  Treatment process description (liquid side only): treatment consists of screening and grit removal; BNR Activated sludge (BardenPho 5 State [Anaerobic Basin, Anoxic basin, Oxidation Ditch Aeration Basin, Anoxic Basin, Reaeration Basin]); Clarifiers (2 parallel rectangular); Chemical addition using alum and polymer; Effluent polishing and filtration [using 4 US Filter Memcor filter modules]; and UV disinfection. The US Filter units utilize two-stage filtration in which the first stage is upflow through a plastic media with air scour. The second stage filtration is through a downflow, mixed media with backwash cleaning. The concentration of alum used for coagulation was reported to be 95 mg/L.
- 39 mgd capacity plant
  Advanced Phosphorus Treatment Technology: Chemical addition, filtration
  Treatment process description (liquid only): Treatment consists of screening and grit removal; alum addition; primary clarification; extended aeration; secondary clarification; flocculation using alum and polymer; tertiary clarification; filtration; disinfection (with chlorine) and dechlorination. Wastewater is treated in two separate trains. Four 60-foot diameter ClairiCone tertiary clarifiers are used on one treatment train to provide contact with six monomedia anthracite gravity flow bed filters. The other treatment train uses conventional clarifiers for tertiary settling followed by filtration through four dual media gravity flow bed filters.
  Phosphorus is removed in four locations within this system: alum enhanced removal in the primary clarifiers; biological removal in the aeration basins; chemical flocculation and removal in the tertiary clarifiers; and removal through filtration.
- 24 mgd capacity plant
  Advanced Phosphorus Treatment Technology: BNR, chemical addition, filtration
  Treatment process description (liquid only): treatment consists of screening and grit removal; primary clarification; biological treatment with enhanced biological nutrient removal; secondary clarification; chemical addition of alum and polymer for phosphorus removal; tertiary clarification; filtration through dual media gravity bed filters and disinfection. Lime is added to the biological process to maintain pH and alkalinity. A two-stage fermenter is operated to produce volatile fatty acids which are added to the biological contact basin. The enhanced biological nutrient removal process at times reduces total phosphorus to levels that are less than the 0.11 mg/L permit limitation. However this performance is not achieved during the entire period when the seasonal phosphorus limitations are in effect. The tertiary treatment with chemical addition and filtration provides

assurance that the final effluent is of consistently good quality. Some to the treated effluent is reclaimed for irrigation.

- 0.5 mgd capacity plant
  Advanced Phosphorus Treatment Technology: Chemical addition, two-stage filtration
  Treatment process description (liquid only): treatment consists of grit removal and screening; extended aeration and secondary clarification (in combined aeration basin/clarifier); chemical addition for flocculation using PASS and filtration through two-stage Dynasand filters.
- 1.55 mgd capacity plant
  Advanced Phosphorus Treatment Technology: Chemical addition, two-stage filtration
  Treatment process description (liquid only): treatment consists of grit removal and screening; extended aeration and secondary clarification; chemical addition for flocculation using aluminum chloride (added to the wastewater at both the secondary clarifiers and the distribution header for the Dynasand filters); and filtration through two-stage Dynasand filters; disinfection with chlorine and dechlorination with sulfur dioxide. Chlorine is added to the filter influent to control biological growth in the filters.
- 4.8 mgd capacity plant
  Advanced Phosphorus Treatment Technology: multipoint chemical addition, tertiary settling and filtration
  Treatment process description (liquid only): treatment consists of screening and grit removal; primary clarification; trickling filers; intermediate clarification (with polymer addition to aid settling); rotating biological contactors; secondary clarification; chemical addition using poly-aluminum chloride; filtration through mixed media traveling bed filters; ultraviolet disinfection. The final effluent is discharged down a cascading outfall to achieve reaeration prior to missing in the receiving water. Approximately 1 mgd per day of final effluent is utilized by the local power company for cooling water.
- 54 mgd capacity plant
  Advanced Phosphorus Treatment Technology: BNR, Multi-point chemical addition, tertiary settling and filtration
  Treatment process description (liquid only): treatment consists of screening; grit removal; primary settling with possible addition of ferric chloride and polymer; methanol or volatile fatty acid added to biological reactor basins to aid BNR; ferric chloride and polymer addition prior to secondary settling; alum addition and mixing; tertiary clarification with inclined plate settlers; dual media gravity bed filtration; UV disinfection an post aeration.
- 42 mgd capacity plant
  Advanced Phosphorus Treatment Technology: Chemical (high lime) and tertiary filtration
  Treatment process description (liquid only): treatment consists of conventional that removes 90% of most incoming pollutants; screening; grit removal; primary clarification; aerobic biological selectors; activated sludge aeration basins with nitrification/denitrification processes; secondary clarification. A chemical advanced treatment—high lime process—to reduce phosphorus to below 0.10 mg/L, to capture organics from secondary treatment, to precipitate heavy metals and to serve as a barrier to viruses: lime slurry added to rapid mix basins (to achieve pH of 11); anionic polymer added in flocculation basins; chemical clarification; first stage recarbonation to lower pH to 10; recarbonation clarifiers to collect precipitated calcium carbonate; second stage recarbonation to lower pH to 7; storage in ballast ponds. Physical advanced treatment to meet stringent limits for TSS (1 mg/L) and COD (10 mg/L) including alum and /or polymer addition; multimedia filters; activated carbon contactors. Disinfection by chlorination/dechlorination process.
- 67 mgd capacity plant
  Advanced Phosphorus Treatment Technology: BNR, chemical addition, tertiary clarification and filtration
  Treatment process description (liquid only): treatment consists of screening; primary clarification; biological treatment with enhanced biological nutrient removal (BNR); polymer addition as needed; secondary clarification; equalization and storage in retention ponds; tertiary clarification with ferric chloride addition to remove phosphorus; disinfection with sodium hypochlorite; filtration through dual/mono media gravity bed filters.

Advection: The process by which solutes are transported by the bulk motion of the flowing groundwater.

Advective Wind: The horizontal air movements resulting from temperature gradients that give rise to density gradients and subsequently pressure gradients.

Adverse Effects Data: FIFRA requires a pesticide registrant to submit data to EPA on any studies or other information regarding unreasonable adverse effects of a pesticide at any time after its registration.

Adverse Health Effect: A change in body functions or cell structure that might lead to disease or health problems.

Advisory: A non-regulatory document that communicates risks information to those who have to make risk management decisions.

AED: Aerodynamic equivalent particle diameter.

Aedes: A genus of mosquito, one species of which transmits the virus that causes yellow fever in humans.

Aeolian: Having to do with the wind.

AER: Allowable emission rate

Aerate: To expose a substance to air or another gas.

Aerated Lagoon: A holding and/or treatment pond that speeds up that natural process of biological decomposition of organic waste by stimulating the growth and activity of bacteria that degrade organic waste.

Aeration: Creating contact between air and a liquid by spraying the liquid in the air, bubbling air through the liquid, or agitating the liquid to promote surface absorption.

Aeration Tank: A chamber used to inject air into water.

Aerator: A device, such as a mixer, used to aerate a substance or medium.

Aerobe: An organism that requires atmospheric oxygen to live.

Aerobic: Achieving solids reduction in manure mixtures using microorganisms that require oxygen. Thus, the breakdown of organic material tends to be odor free.

Aerobic Bacteria: Bacteria that require free elemental oxygen for their growth. Oxygen in chemical combination will not support aerobic organisms.

Aerobic Processes: Many bio-technology production and effluent treatment processes are dependent on microorganisms that require oxygen for their metabolism. For example, water in an aerobic stream contains dissolved oxygen. Therefore, organisms using this can oxidize organic wastes to simple compounds.

Aerobic Respiration: Respiration in which molecular oxygen is consumed through its use as a terminal electron acceptor, and which produces carbon dioxide and water.

Aerobic Treatment: Process by which microbes decompose complex organic compounds in the presence of oxygen and use the liberated energy for reproduction and growth. (Such processes include extended aeration, trickling filtration, and rotating biological contactors.)

Aerobic Treatment Unit (ATU): A mechanical onsite treatment unit that provides secondary wastewater treatment by mixing air (oxygen) and aerobic and facultative microbes with the wastewater. ATUs typically use a suspended growth treatment process (similar to activated sludge extended aeration) or a fixed film treatment process (similar to trickling filter).

Aerodynamic Drag: The opposing force encountered by a body moving relative to a fluid; e.g., a baseball in flight displacing the air in front of it.

Aerodynamics: 1. The scientific study of gases in motion and the forces that affect this motion. 2. The study of the effects of air in motion on an object; either objects moving through air, such as automobiles, or trucks, or stationary objects affected by moving air, such as tall buildings.

Aerometer: An instrument used to measure the weight or density of air and other gases.

Aerosol: 1. Liquid or solid particles so small they can remain suspended in air long enough to be transported over a distance. 2. A suspension of solid particles or liquid droplets in a gaseous medium.

Aerosol Propellant: A liquefied gas that is used as the driving force to expel a liquid from a container, such as an aerosol spray from a can; e.g., self-tanning spray, hair spray, spray paints, deodorants, or various household cleaning products.

Aesthetic Impact: The effect that a change in land use has or would have on the visual appeal or other aesthetic qualities of the given setting.

Affected Landfill: Under the Clean Air Act, landfills that meet criteria for capacity, age, and emissions rates set by the EPA. They are required to collect and combust their gas emissions.

Affected Public: 1. The people who live and/or work near a hazardous waste site. 2. The human population adversely impacted following exposure to a toxic pollutant in food, water, air, or soil.

Afferent Neurons: In the nervous system, they carry nerve impulses from receptors or sense organs toward the central nervous system.

AFO (Animal Feeding Operation): As defined by the USEPA (40 CFR 122.23), a "lot or facility" where animals "have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility."

Afterburner: A device that includes an auxiliary fuel burner and combustion chamber to incinerate combustible gas contaminants.

Age Tank: A tank used to store a chemical solution of known concentration for feed to a chemical feeder. Also called a day tank.

Agent: Any physical, chemical, or biological entity that can be harmful to an organism.

Agent Orange: A toxic herbicide and defoliant used in the Vietnam conflict.

Agglomerate: A mass or cluster (grouped together) of fine particles, gathered together in a body of larger size than the original particles, but not in a coherent pattern.

Aggregate: Clusters of soil particles.

Agitation: The remixing of liquid and settled solids.

Agonist: A chemical substance (such as a drug) that is capable of combining with a receptor on a cell and initiating the same reaction or activity typically produced by the binding of a substance that normally occurs in the body (i.e., is endogenous).

Agribusiness: Those aspects of larger corporate agricultural entities involved in issues of finance, sales, marketing, and the like.

Agriculture: The process of producing food, feed, fiber, and other desired products by the cultivation of certain plants and the raising of domesticated animals (livestock).

Agriculture, Animal: Means the use of land for Animal Feedlots or Animal Waste Areas.

Agriculture, Crop: Means the use of land for the production of row crops, field crops, tree crops, timber, bees, apiary products, and fur-bearing animals.

Agricultural Pollution: Farming wastes, including runoff and leaching of pesticides and fertilizers; erosion and dust from plowing; improper disposal of animal manure and carcasses; crop residues, and debris.

Agricultural Sources: Both organic and inorganic contaminants usually produced by pesticide, fertilizers, and animal wastes, all of which enter water bodies via runoff and groundwater absorption in areas of agricultural activity.

Agricultural Storage: Means facilities for the warehousing of agricultural products. Typical uses include grain elevators.

Agricultural Waste Management System: A combination of conservation practices formulated to appropriately manage a waste product that, when implemented, will recycle waste constituents to the fullest extent possible and protect the resource base in a nonpolluting manner.

Agricultural Wastes: Wastes normally associated with the production and processing of food and fiber on farms, feedlots, ranches, ranges, and forests which may include animal manure, crop and food processing residues, agricultural chemicals, and animal carcasses.

Agroecosystem: The biotic and abiotic components of an agricultural system, including not only the livestock and cultivated crops but also, for example, the water supply, other plant and animal species, and characteristics, climate, and human inputs.

Agronomy: The scientific study of agricultural crops and soils.

AHERA: The Asbestos Hazard Emergency Response Act (AHEARA) requires local education agencies to conduct inspections, develop management plans, and design or conduct response actions with respect to the presence of asbestos-containing materials in school buildings. AHERA also require states to develop model accreditation plans for persons who perform asbestos inspections, develop management control plans, and design or conduct response actions.

AHERA Designated Person: A person designated by a Local Education Agency to ensure that the AHERA requirements for asbestos management and abatement are properly implemented.

AHERA School Rules: Requires all public school districts and private schools know as local education agencies or LEAs, to inspect all school buildings for both friable and non-friable asbestos; to develop plans to manage asbestos in schools; and to carry out plans in a timely fashion. This rule also provides an opportunity for parents, teachers, and other school employees to become familiar with and involved in their school's asbestos management program. School officials are required to notify parent, teacher, and employee groups about asbestos-related activities.

Air Binding: Situation where ire enters the filter media and harms both the filtration and backwash processes.

Airborne Contaminants: Any contaminant capable of dispersion in air, and/or capable of being carried by air to other locations.

Airborne Exposure Limits: Allowable concentrations in the air for occupational and general population exposures.

Airborne Particulate Matter: Fine solids or liquid droplets suspended and carried in the air.

Airborne Particulates: Total suspended particulate matter found in the atmosphere as solid particles or liquid droplets. The chemical composition of particulates varies widely, depending on location and time of year. Airborne particulates include windblown dust, emissions from industrial processes, smoke from the burning of wood and coal, and the exhaust of motor vehicles.

Airborne Release: Release of any chemical into the air.

Airborne Toxics: Toxic inorganic and organic chemicals released into the air that may cause short- or long-term health effects in humans.

Airborne Toxins: Hazardous chemical pollutants that have been released into the atmosphere and are carried by air currents.

Air Carrier Requirements—Hazardous Materials (49 CFR): This section discusses requirements for carrying hazardous materials by air—including both carrying hazardous materials as a passenger, and accepting and/or transporting hazardous materials in commerce as an air carrier, in any aircraft in the United States and in all aircraft registered in the U.S., anywhere in the world.

Subpart A contains the air carrier requirements for inspecting and accepting hazardous materials shipments for air transportation, documentation, training, and reporting of hazardous materials incidents or discrepancies.

Subpart B addresses air carrier requirements regarding loading, unloading, and handling of hazardous materials, including quantity limitations, stowage compatibility, cargo location, and orientation of packages.

Subpart C contains special requirements for certain hazard classes and commodities such as flammable liquids, poisons, radioactive materials, and infectious substances.

All US air carriers and foreign air carriers operating flights to or from U.S. airports must comply with the 49 CFR requirements governing the acceptance, storage, loading, and transportation of hazardous materials by air. These requirements are in Subchapter C of 49 CFR, Parts 171-180.

Instead of preparing shipments in accordance with 49 CFR, Parts 172 and 173, you may prepare them in accordance with the International Civil Aviation Organizations Technical Instructions for the Safe Transport of Dangerous Goods by Air, also known as ICAO Technical Instructions. This facilitates the domestic and international transportation by air; however, Section 171.11 exempts these shipments only from certain regulations for packaging, marking, labeling, classifying, and describing materials on shipping papers. All other requirements of Parts 171 through 180 must be met.

Air Carrier Definitions

It is important that all parties involved in the handling of hazardous materials use a common set of terms and definitions. The term passenger aircraft and cargo aircraft will be used throughout the remainder of this chapter. A passenger aircraft or passenger carrying aircraft is an aircraft that carries any person other than a crewmember, company employee, an authorized representative of the United States, or a person accompanying a shipment. A cargo aircraft or cargo carrying aircraft is an aircraft that is used to transport cargo and is not engaged in carrying passengers. The terms cargo aircraft, cargo-only aircraft, and cargo aircraft only, have the same meaning in this chapter. Forbidden means the hazardous material may not be offered for transportation or transported; some materials are forbidden on passenger aircraft only; some are forbidden on all aircraft. Forbidden does not mean the material is not regulated. Magnetic Field, as it applies to carriage by aircraft, means a package with a magnetic field of more than 0.00525 gauss measured 4.5 meters or 15 feet away from any surface of the package. Such packages are forbidden to be carried on an aircraft.

Air Carrier General Requirements

An air carrier to whom the HMR applies may not transport a hazardous material by aircraft unless each of its hazmat employees involved in that transportation has been trained and tested as required in 175.20 and 172.700-704. Initial training is required within 90 days for new employees or employees who assume new hazmat related responsibilities. Until they are trained, these employees may perform a hazardous materials employee function only under supervision. DOT requires that hazmat employees be retrained and tested at least once every three years; however, the FAA, under 14 CFR, requires annual training for air carrier employees. Both DOT and FAA require the employer to maintain training records.

A person may not perform a hazmat function unless they have been trained in that function or, for a new employee or one who changes job functions; they work under the direct supervision of someone who is trained. If any regulatory requirement pertaining to a function the employee performs changes, the employee must receive training concerning that function immediately.

“Will-Carry” or “Will-Not-Carry”

Training for air carriers must also incorporate training requirements in 14 CFR, parts 121 and 135. Under these regulations, air carriers may be defined as "will-carry" or "will-not-carry." "Will-carry operators have chosen to accept and carry hazardous materials, under the HMR. "Will-not-carry" operators have chosen not to accept hazardous materials, but still require training to reject hazardous materials packages. Both "will-carry" and "will-not-carry" operators are required to include certain information in their manuals. Additional information must be provided in "will-carry" manuals. The manuals must spell out points regarding compliance with the HMR, as well as:

- Will-Carry or Will-Not-Carry status;
- Procedures or communicating incidents and discrepancies within the company, to contractors, and to the Federal government;
- Procedures for rejecting packages; and function-specific procedures that must be in the manual an employee who performs a given job function, or the employee's supervisor.

Manuals must also:

- Communicate that the operator may carry hazmat in accordance with the passenger and crew exceptions in 49 CFR 175.10;
- Indicate whether the operator is a Will-Carry or Will-Not-Carry operator;
- Indicate procedures for communicating incidents and discrepancies to employees and contractors;
- Indicate procedures for complying with the incident reporting requirements and discrepancy reporting requirements of the HMR;
- Indicate procedures for rejecting packages that do not conform to the HMR or that appear to contain undeclared hazardous materials; and
- Include function-specific procedures for: Acceptance; Rejection; and Handling.

Manuals of Will-Carry Operators must contain additional procedures and information regarding the transport of hazardous materials. Will-Carry Operators must also provide procedures and information to ensure that employees comply with the HMR in regard to the offering, acceptance, handling, storage, packing, and loading of hazardous materials; requirements for notice to the Pilot-in-Command; and the shipping of aircraft replacement parts shipped as COMAT, consumable materials, and any other regulated item. In summary, the Manual of the Will-Carry Operator must provide additional information to further re-communicate to its employee and contractors, how to properly carry hazardous materials in commerce.

Manuals of Will-Not-Carry Operators need not meet any additional requirements. However, in meeting the manual requirements that are common to both Will-Carry and Will-Not-Carry operators, the will-not-carry operator must include procedures and information necessary to assist the employee in identifying and rejecting packages that are marked or labeled as containing hazardous materials, or that show signs of containing hazardous materials. In summary, the manual of a will-not-carry operator must tell its employees how to recognize and refuse to carry hazardous materials in commerce.

Air Carrier Package Markings & Shipping Papers

The air carrier relies on the shipper for compliance with the HMR based on the package markings and description on the shipping papers. Air carriers do not open packages or test contents of packages. The air carrier must verify that the shipper has prepared the packages and shipping document properly. Section 175.30 lists specific items that you must check before you may accept hazardous material packages.

In preparing a hazardous material for transportation by air, the shipper must:

- Classify hazardous material
- Determine if regulated for air transportation, and the quantities authorized
- Describe material on shipping documents
- Determine packaging requirements
- Package material properly
- Mark and label package
- Determine placarding requirements

If the shipper used an overpack:

- The proper shipping name, ID number, and any special handling markings on the inside packages must be clearly visible or be reproduced on the outside of the overpack.
- All labels appearing on inside packages must be clearly visible or reproduced on the outside of the overpack.
- The overpack must display a statement that the inside packages comply with the prescribed specifications, when specific packaging is required.
- The overpack must not contain a package bearing the CARGO-AIRCRAFT-ONLY label unless the overpack affords clear visibility of and easy access to the package; or the material in the package may be carried in an inaccessible location; or only one package is overpacked.

The air carrier must verify that the material, as described on the shipping papers, is authorized and is within the quantity limitations for passenger or cargo aircraft, respectively, as specified in the HMT. Additionally, the air carrier must verify the content and accuracy of the shipping papers by asking questions such as these:

- Is the declaration and shipping description correct?
- When required, does the shipping paper contain emergency response information?
- Has the shipper certified that the shipment is in proper condition for transport by air?
- Finally, are two copies of the shipping papers accompanying the shipment?

The air carrier must also determine whether the hazardous materials are marked, labeled and, when require, placarded. Package markings must correspond with the proper shipping name and ID number, as required, on the shipping documents. Hazardous materials permitted on cargo aircraft, but not on passenger aircraft, must be labeled with a Cargo Aircraft Only label. Packages must be in good condition for air transportation and the package integrity must not have been compromised, and is not leaking. Finally, check that the seals on radioactive material packages have not been broken.

✔ **Important Point:** If an air carrier employee finds that the shipper has not prepared the package properly, the air carrier must refuse the package.

Air Carrier Passenger Requirements

Air carriers that transport passengers must display signs warning passengers that the carriage of some hazardous materials aboard aircraft, in their luggage, or on their person is prohibited by Federal law. The signs must inform passengers of special exceptions that are permitted and penalties for failure to comply with the law. These signs are available from the Pipeline and Hazardous Materials Safety Administration and from the Federal Aviation Administration.

Air Carrier Packaging Requirements

Unless otherwise noted, each packaging used for the shipment of hazardous materials must be designed, constructed, and maintained to prevent the release of the hazardous materials. Proper packaging is critical to the safe transportation of hazardous materials, especially in air transportation where the hazardous materials are subjected to changes in temperature, altitude, and pressure.

- Packages containing Class 4, 5, and 8 materials must meet the performance tests at the Packing Group II level, even if Column 5 of the HMT shows that the material are in Packing Group III.
- Packagings must be designed and constructed to prevent leakage that may be caused by internal pressure changes in altitude and temperature during air transportation
- Packagings for which retention of liquid is a basic function must be capable of withstanding without leakage the greater of either an internal pressure which produces a gauge pressure of not less than 75kPa or 11 psig for liquids in Packing Group III of Class 3 or Division 6.1 or 95 kPa or 14 psig for other liquids; or the pressure related to the vapor pressure of the liquid to be conveyed, when determined by calculations provided.
- Hazardous materials, packed in combination packaging, may be enclosed in an inner packaging which does not meet the pressure requirements provide it is packed inside a supplementary packaging that meets the pressure requirements, and other applicable requirements of the HMR.
- Unless otherwise noted, venting packages to reduce internal pressure is not permitted when packages are being transported by air.
- Packages must be securely closed. Friction type closures, such as topper and corks, must be held securely in place by positive means. Screw type closures must be secured to prevent loosing from vibration or substantial changes in temperature or pressure.
- Combination packages of liquids in Packing Group I and II of class 3, 4, 5, 6.1, and 8 require absorbent materials when the inner container is made of glass, earthenware, plastic, or metals. The absorbent material must be such that it does not react dangerously with the liquid.
- Absorbent material is not required for inner packagings which are so protected that they will not likely break and leak under normal conditions of transportation, and leakage from the outer packaging is not likely to occur.
- When absorbent material is required and the outer packaging is not liquid tight, some additional means of containing the liquid in the vent of leakage must be used. This may be in the form of a leak-proof liner, plastic bag, or other equally efficient means of containment.
- When a liquid hazardous material in Packing Group I is being transported on a passenger aircraft and the regulations require absorbent material, there must be sufficient material to absorb the contents of all inner packagings containing such liquids.
- For Packing Group I liquids being offered for transportation on a Cargo Aircraft Only and Packing Group II liquids offered for passenger aircraft, there must be enough absorbent material in the package to absorb the content of any one of the inner packagings. If the inner packagings are different sizes, there must be enough material to absorb the content of the packaging with the greatest quantity of liquid.
- When combination packagings are being offered for air transport, the inner packaging must conform to the

quantity limits set forth in 173.27(f), Tables 1 and 2. Table 1 indicates quantities permitted in inner packagings for passenger aircraft, and Table 2 indicates quantities permitted in inner packagings for cargo aircraft.

- Cylinder valves must be protected against damage and accidental opening when shipped by air. Valve caps must be securely attached or cylinders must be placed in a box or crate.

✔ **Important Point**: You must not transport tank cars and cargo tanks containing hazardous materials aboard aircraft.

- Hazardous materials shipped by air and authorized for cargo aircraft only must have the CARGO AIRCRAFT ONLY label affixed to the package, in addition to the hazard class label. The label warns those who handle the shipment that it may not be offered or transported on a passenger aircraft.
- A net weight of not more than 25 kg or 55 pounds of hazardous material may be carried in an inaccessible cargo compartment, or in a freight container within an accessible cargo compartment. Additionally, a net weight or not more than 75 kg or 165 pounds of a Division 2.2 (non-flammable compressed gas) may be carried on a passenger-carrying aircraft, for a grand total not to exceed 100 kg. On a cargo aircraft, the quantity limits apply to inaccessible cargo compartments and to accessible cargo compartments when the materials are not loaded in a freight container, but are loaded in a manner that makes them inaccessible.
- Radioactive materials are limited to 3.0 Transport Index (TI) per package or a total of 50.0 TI per passenger aircraft. The limits are 10.0 TI per package, with a maximum of 200 TI per cargo aircraft.
- There are no limits for the number of packages of Class 9 (Miscellaneous) material or ORM-D, on either passenger or cargo aircraft.
- Hazmat packages with text or arrows to indicate the proper orientation of the package must be stored and loaded in accordance with the markings.
- Packages must be secured in an aircraft so that movement or damage of the package in flight is prevented.

Air Carrier Loading Requirements

- Incompatible hazardous materials may not be placed next to each other or in a position that might lead to a dangerous interaction in the event of leakage. Look at the Stowage Compatibility Table located in 175.78, Table 1. The numbers across the top of the table and the numbers along the left hand side of the table represent hazard classes. An “X” at the intersection of arrow and a column means that these materials may react dangerously with each other and may not be placed next to or in contact with each other in storage or on board the aircraft or in a position which would allow interaction in the event of leakage of the contests. Refer to 175.78 for specific requirements regarding the stowage compatibility of cargo.
- Do not load magnetized materials in the vicinity of a magnetic compass or compass master unit that is a part of the instrument equipment of the aircraft in a manner that affects its operation. The magnetized materials might cause an erroneous magnetic compass reading on the aircraft. If this requirement cannot be met, a special aircraft swing and compass calibration may be made.
- On a passenger aircraft, hazardous material may be carried in a main deck cargo compartment provided that the compartment is inaccessible to passengers and that it meets all certification requirements for a Class B or Class C aircraft cargo compartment.
- You must load hazardous material acceptable only for cargo aircraft in such a manner that a crew member or other authorized person can see, handle, and—when size and weight permit—separate such packages from other cargo during flight.
- When packages in the hazard classes or divisions shown here are carried on cargo aircraft, they may be carried in a location which is inaccessible to a crewmember during flight and are not subject to the weight limitation specified in 175.75(a)(2).
- When packages of hazardous materials acceptable for cargo or passenger aircraft are carried on cargo aircraft, only where other means of transportation are impracticable or not available, packages may be carried in accordance with procedures approved in writing by the FAA Air Transportation Security Field Office responsible for the operator’s overall aviation security program or the FAA Air Transportation Security Division, in the region where the operator is located.
- When packages of hazardous materials acceptable for cargo or passenger aircraft are carried on small, single pilot, cargo aircraft only because other means of transportation are impracticable or not available, they may be carried without regard to quantity limitations as specified in 175.75 in a location that is not accessible to the pilot if the condition shown here are met.

Air Carrier Paperwork

Before an aircraft departs, the pilot-in-command must be given written notification describing all hazardous materials that have been loaded. This does not apply to the exceptions listed in 175.10. There is no standard format required for use by air carriers for pilot notification. The notification to pilot-in-command must be readily available to the pilot during flight as it contains information that would be critical in the case of a spill or other emergency.

In addition to acceptance requirements, 49 CFR, Part 175, Subpart A, contains requirements for reporting hazardous materials discrepancies. Discrepancies are situations where hazardous materials are improperly described, certified, labeled, marked, or packaged in a manner which is not known at the time the carrier accepts the shipment. If a discrepancy is discovered after the shipment as been accepted, the air carrier must notify the nearest FAA Civil Aviation Security Office.

Discrepancies List:

- Hazardous material improperly described, certified, packaged, marked, or labeled
- Packages that exceed the authorized quantity limitations for air transportation
- Hazardous materials not described or certified as such on shipping papers
- Unauthorized inside containers or improper closures
- Inside containers not oriented as shown on package
- Insufficient/improper absorbent material (when required)
- Undeclared/hidden shipments of hazardous material

Air Carrier Hazmat Incidents

Despite all safety efforts, incidents do occur. When hazardous materials are involved in a transportation incident, a report may be required. For certain incidents, you must notify either the National Response center (NRC) or, for infectious substances, the Centers for Disease Control (CDC), as soon as practical but not later than 12 hours after the incident occurs. For any such incident, you must also follow up with a written Hazardous Materials Incident Report.

You must also file a written Hazardous Materials Incident Report within 30 days of discovering any unintentional release of hazardous materials or unintentional discharge of hazardous waste, as well as under certain other conditions (see 171.16). But unless a requirement listed in 171.15 applies, you do not need to notify the NRC or CDC by phone.

You must notify the NRC as soon as practical in the event of fire, breakage, spillage, or suspected radioactive contamination from a radioactive material. You must also notify the offeror in such a case as soon as practical.

✔ **Important Point:** You must notify the CDC as soon as practical in the event of fire, breakage, spillage, or suspected contamination involving an infectious substance other than a diagnostic specimen or regulated medical waste.

As soon as practical but no later than 12 hours after the occurrence of the release of a marine pollutant the person in physical possession of the hazardous material must provide notice of the incident to the National Response Center (1-800-424-8802). Notice must include: name of the reporter; contract number; date, time, and location of the incident; extent of injuries; and specifies regarding the hazardous material involved.

Hazmat incidents that result in any of the following require notification as soon as possible to the National Response Center or the Center for Disease Control:

- Death or injury requiring hospitalization;
- Change in the operational flight pattern or routine of an aircraft;
- The shutdown of a major facility or transportation artery for more than one hour;
- An evacuation of the general public that lasts more than one hour;
- Release of a marine pollutant in the quantity identified; or
- A situation that, in your judgment, requires notification, even if none of the above conditions are met—for example, a continuing danger to life, although no death has yet occurred.

Air Carrier Miscellaneous Requirements

- Cargo facilities, a similar sign must be displayed informing shippers of the requirements applying to air shipments of hazardous materials, and the penalties for failure to comply with those requirements.
- Materials may not be carried in the cabin of a passenger aircraft of on the flight deck of any aircraft, except as authorized in 175.10.
- Materials required for the safe operation of the aircraft include aviation fuel and oil in tanks required to operate the aircraft, and hazardous materials required on board an aircraft to make the aircraft airworthy include fire extinguishers, oxygen generators, escape chutes, and life rafts.
- Replacements for such hazardous materials must be in compliance with the HMR. To ship aircraft spares and supplies, the shipper may use packaging specifically designed for these items, if the packaging provides at least an equivalent level of protection to those required by 49 CFR. Aircraft batteries are not subject to the quantity limitations in 172.101 and 175.75(a). A serviceable tire in a tire assembly may not be inflated to a gauge pressure that exceeds the maximum rate pressure for that tire.
- Flight crew and passengers may carry hazardous materials intended for personal use. Nonradioactive medicinal and toilet articles (including aerosols) may be carried by flight crew and passengers in checked or carry-on baggage. Other aerosols for personal use in Division 2.2 with no subsidiary risk, may only be car-

ried in checked baggage. Each container carried may contain no more than 470 ml (16 fluid ounces) or 1.1 lbs of material. The total capacity of all the containers carried by one person may not be more than 70 net weight ounces of 68 fluid ounces. Personal smoking materials are allowed, but not lighters with flammable liquid reservoirs and containers with light fluid for filling lighters. Strike anywhere matches are forbidden. Butane curling irons may not include refills, and are limited to one per person.

- A crewmember or passenger may carry small arms ammunition, for personal use only, in their checked baggage. The ammunition must be securely packed in fiber, wood or metal boxes or containers specifically designed for that purpose. They may also carry duty free perfumes, colognes, and alcohol not exceeding 140 proof, in their carry-on baggage. Dry ice used to cool perishables, may be carried as cargo in both checked and carry-on baggage. Quantities are limited to 2.3 kg or 5.07 pounds in cargo and checked baggage, and 2 kg or 4.4 pounds in carry-on baggage. The packaging must permit the release of carbon dioxide gas. For dry ice in cargo or checked baggage, the package must be marked with: The name of the contents being cooled; the net quantity of dry ice; and the words Carbon Dioxide, Solid, or Dry Ice.
- Hazardous materials intended for use in specialized air operations include: hazardous materials loaded and carried for purposes of aerial seeding, dusting, spraying, fertilizing, crop improvement or pest control; smoke grenades and flares used in sport parachuting; pyrotechnics used in air shows; and hazardous materials expended during flight for weather control, environmental restoration and protection.
- Hazardous materials that must be carried to meet the medical needs of passengers or crewmembers include: oxygen, or any hazardous material used to generate oxygen, for the medical use by a passenger, which is furnished by the air carrier; implanted medical devices, such as a heat pacemaker; wheelchairs and other mobility devices may be accepted as checked baggage when the battery is disconnected and the terminals are insulated, or the battery is securely attached to the wheelchair, or the battery is removed, properly marked and packed in a strong rigid packaging.
- Nonspillable batteries used in mobility aids such as wheelchairs are excepted from the Hazardous Materials Regulations, but the battery must be protected against short circuits and securely packaged. For batteries manufactured after September 30, 1995, the battery and the outer packaging must be marked NONSPILLABEE or NONSPILLABLE BATTERY; and the battery must be capable of passing the vibration and pressure differential test.
- Spillable batters must be packed in leak tight packaging with enough absorbent material to absorb all of the battery contents. Additionally, the package must be labeled corrosive and marked “Battery, wet, with wheelchair”, and the Pilot in Command must be notified.
- The last group, miscellaneous hazardous materials exceptions, includes: carbon dioxide (solid), or dry ice, used for food and beverage service aboard the aircraft; alcohol, perfumes, and colognes carried for sale on the aircraft; small medical thermometers; and weather agency barometers.

✔ **Important Point**: Column 9 of the Hazardous Materials Table entitled, “Quantity Limitations,” forbids or limits the quantity of hazardous materials in one package that may be offered or transported by aircraft. Unless otherwise specified, the quantity limits are net quantity limits. That is, the total weight of the hazardous material, not including the tare weight of the package.

Air Change: The amount of air required to completely replace the air in a room or building.

Air Change Per Hour (ACH): The movement of a volume of air in a given period of time; if a house has one air change per hour, it means that the air in the house will be replaced in a one-hour period.

Air Change Ratio: The replacement of a quantity of air in a given space within a certain period of time, typically expressed in units per hour.

Air Cleaner and Fan Condition: Measurements can be made with a pitot tube and manometer.

Air Cleaning: Indoor-air quality-control strategy to remove various airborne particulates and/or gases from the air. Most common methods are particulate filtration, electrostatic precipitation, and gas sorption.

Air Contaminant: Any particulate matter, gas, or combination thereof, other than water vapor.

Air Contamination: The result of introducing foreign substances into the air so as to make the air contaminated.

Air Currents: Created by air moving upward and downward.

Air Curtain: A continuous broad steam of high-velocity, temperature-controlled air that is circulated across an opening, in order to reduce airflow in or out of the space, minimize heat loss or gain, contain a fluid, and so on.

Air Density: The weight of air in lbs per cubic foot. Dry standard air at T = 68° F (20° C) and BP = 2992 in HG (760 mm HG) has a density of 0.075 lb/cu ft.

Air Distribution: The delivery of outdoor or conditioned air to various spaces in a building, usually by mechanical means.

Air Emission: Release or discharge of a pollutant into the ambient air.

Air Exchange Rate: The rate at which outside air replaces indoor air in a given space.

Air Gap: Open vertical gap or empty space that separates drinking water supply to be protected from another waste system in a treatment plant or other location. The open gap protects the drinking water from contamination by backflow or back siphonage.

Air Handling Unit: Equipment that includes a fan or blower, heating and/or cooling coils, regulator controls, condensate drain pans, and air filters.

Air Infiltration: Uncontrolled inward leakage of outdoor air through cracks, interstices, and other unintentional openings of a building caused by the pressure effects of wind and/or the stack effect.

Air Mass: A large body of air with particular characteristics of temperature and humidity. An air mass forms when air rests over an area long enough to pick up the conditions of that area.

Air Monitoring: Air monitoring is the process of continuous or periodic ambient air sampling to measure the concentration and type of pollutants present. It is widely used to measure human exposure and to characterize emission sources. It is often employed within the context of the general survey, investigating a specific complaint, or simply for regulatory compliance. It is also used for more fundamental purposes, such as in confined space entry operations. While it is true that just about any confined space entry team member can be trained to properly calibrate and operate air monitors for safe confined space entry, it is also true that a higher level of knowledge and training is often required in the actual evaluation of confined spaces for possible oxygen deficiency and/or air contaminant problems.

Air Sample Volume

OSHA's *Analytical Method* and NIOSH's *Manual of Analytical Methods* list a range of air sample volumes, minimum volume (VOL-MIN) to maximum volume (VOL-MAX) that should be collected for an exposure assessment. The volume is based on the sampler's sorptive capacity and assumes that the measured exposure is the OSHA PEL.

The range of volumes listed may not collect a sufficient mass for accurate laboratory analysis if the actual contaminant concentration is less than the PEL or the Time Weighted Average-Threshold Limit Value (TWA-TLV).

If a collection method recommends sampling 10 liters of air, the industrial hygienist may not be sure if an 8.5-liter air sample will collect sufficient mass for the lab to quantify. This makes an important point. That is, finding that an insufficient air volume (i.e., too little mass) was sampled after the lab results are returned can turn out to be an enormous waste of resources. To avoid this situation, it is essential to understand the restrictions faced by analytical labs: Limit of Detection (LOD) and Limit of Quantification (LOQ).

To compute a minimum air sample volume to provide useful information for evaluation of airborne contaminant concentration in the workplace, the industrial hygienist must understand how to correctly manipulate the LOD and the LOQ. Knowledge of these limits will provide increased flexibility in sampling.

Limit of Detection (LOD)

The *limit of detection* (LOD) has many definitions in the literature. For example, the American Chemical Society (ACS) Committee on Environmental Analytical Chemistry (2002) defines the LOD as the lowest concentration level than can be determined to be statistically different from a blank sample (a blank sample is a sample of a carrying agent—a gas, liquid, or solids—that is normally used to selectively capture a material of interest, and that is subjected to the usual analytical or measurement process to establish a zero baseline or background value, which is used to adjust or correct routine analytical results).

The analytical instrument output signal produced by the sample must be three to five times the instrument's background noise level to be at the limit of detection; that is, the signal-to-noise ratio (S/N) is three-to-one (3/1). S/N ratio is the analytical method's lower limit of detection.

Limit of Quantification (LOQ)

The *limit of quantification* (LOQ) is the concentration level above which quantitative results may be obtained with a certain degree of confidence. That is, LOQ is the minimum mass of the analyte above which the precision of the reported result is better than a specified level. The recommended value of the LOQ is the amount of analyte that will give rise to a signal that is 10 times the standard deviation of the signal from a series of media blanks.

Precision, Accuracy, and Bias

Sample results are only as good as the sampling technique and equipment used. Thus, in any type of air monitoring operation (air, water, or soil), it is important that the industrial hygienist factor in the precision, accuracy and any possible bias involved in the monitoring process.

Precision is the reproducibility of replicate analyses of the same sample (mass or concentration). For example, how close to each other is a target shooter able to place a set of shots anywhere on the target?

Accuracy is the degree of agreement between measured values and the accepted reference value. The investigator must carefully design his sampling program and use certain statistical tools to evaluate his data before making any inferences from the data. In our target shooting analogy, accuracy can be equated to how close a target shooter comes to the bull's-eye.

Bias is the error introduced into sampling that causes estimates of parameters to be inaccurate. More specifically, bias is the difference between the average measured mass or concentration and a reference mass or concentration, expressed as a fraction of the reference mass or concentration. For example, how far from the bull's-eye is the target shooter able to place a cluster of shots?

Calibration Requirements

The American National Standards Institute (1994) defines calibration as the set of operations which establishes, under specified conditions (i.e., instrument manufacturer's guidelines or regulator's protocols), the relationship between values indicated by a measuring instrument or measuring system, and the corresponding standard or known values derived from the standard. Note: Before any air-monitoring device can be relied on as accurate, it must be calibrated. Calibration procedures can be found in OSHA's Personal Sampling for Air Contaminants [www.osha.gov].

Types of Air Sampling

Although the information provided in the following discussion is area specific (**area sampling**), it is important to point out that one of the most important air sampling operations is personal sampling. **Personal sampling** puts the sample detection device on the worker. This is done to obtain samples that represent the worker's exposure while working. As the preferred method of evaluating worker exposure to airborne contaminants, personal sampling, as mentioned, requires the worker to wear the detection device on their person in the breathing zone area. A small air pump and associated tubing connected to the detector is also worn by the worker. Personal sampling allows the industrial hygienist to define a potential hazard, check compliance with specific regulations, and determine the worker's daily time-weighted-average (TWA) exposure.

Analytical Methods for Gases and Vapors

In routine practice the sampler will collect air samples to determine the concentration of a known contaminant or group of contaminants and will request or conduct analysis for these compounds. The first step in this procedure is to develop a sampling plan. When developing a sampling plan or strategy, the sampler should review the specific sampling and analytical methods available for the contaminants of interest. Several organizations have compiled and published collections of sampling and analytical methods for gases and vapors (see the Table).

Table—Available Publications on Sampling/Analytical Methods for Gases/Vapors

NIOSH Manual of Analytical Methods, 4th ed. Centers for Disease Control and Prevention National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, OH 45226

Annual Book of ASTM Standards
American Society for Testing and Materials
100 Barr Harbor Dr.
West Conshohocken, PA 19428

OSHA Analytical Methods Manual
Occupational Safety and Health Administration
OSHA Salt Lake Technical Center
P.O Box 65200
1781 South 300 West
Salt Lake City, UT 84165

Methods of Air Sampling and Analysis
Lewis Publishers/CRC Press Inc.
2000 Corporate Blvd. NW
Boca Raton, FL 33431

For discussion purposes, analytical methods for gases and vapors (vapors are the gaseous phase of a substance that is liquid or solid at normal temperature and pressure; vapors diffuse) are grouped into chromatographic, volumetric, and optical methods. In the following we briefly discuss chromatography.

According to Breysse and Lees (1999), the primary type of analytical equipment used in *chromatography* for the analysis of gases and vapors in air samples is the *gas chromatograph* (GC). The GC is a powerful tool for the analysis of low-concentration air contaminants. It is generally a reliable analytical instrument. GC analysis is applicable to compounds with sufficient vapor pressure and thermal stability to dissolve in the carrier gas and pass through the chromatographic column in sufficient quantity to be detectable. Air samples to be analyzed by GC are typically collected on sorbent tubes and desorbed into a liquid for analysis. It should be noted that the GC instrument can not be used for reliable identification of specific substances. Because of this limitation, the GS is often married to the mass spectrometer (MS) instrument to provide specific results.

As mentioned, the GC is limited in its analysis for contaminant specificity. To correct this limitation, the GC/MS combination is used. When the industrial hygienist or analyst uses the GC instrument to separate compounds before analysis with an MS instrument, a complementary relationship exists. The technician has access to both the retention times and mass spectral data. Many industrial hygienists consider GC/MS analysis as a tool for conclusive proof of identity—the "gold standard" in scientific analysis.

Some common applications of GC/MS include:

1. Evaluation of complex mixtures
2. Identification of pyrolysis and combustion products from fries
3. Analysis of insecticides and herbicides—conventional analytical methods frequently cannot resolve or identify the wide variety of industrial pesticides currently in use, but GC/MS can both identify and quantify these compounds.

Air Monitoring versus Air Sampling

In the practice of industrial hygiene, the terms air monitoring and air sampling are often used interchangeably to mean the same thing. But are they the same? This depends on your choice and use of the vernacular.

In reality, they are different; that is, air monitoring and air sampling are separate functions. The difference is related to time: real time versus time-integration.

Air monitoring is real-time monitoring and generally includes monitoring with hand-held, direct-reading units such as portable gas chromatographs (GC), photoionization detectors (PIDs), flame ionization detectors (FIDs), dust monitors, and colorimetric tubes. Real-time air monitoring instrumentation is generally easily portable and allows the user to collect multiple samples in a relatively short sample period—ranging from a few seconds to a few minutes. Most portable real-time instruments measure low parts per million (ppm) of total volatile organics.

Real-time monitoring methods have higher detection limits than time-integrated sampling methods, react with entire classes of compounds and, unless real-time monitoring is conducted continuously, provide only a "snapshot" of the monitored ambient air concentration. Air monitoring instruments and methods provide results that are generally used for evaluation of short-term exposure limits and can be useful in providing timely information to those engaged in various activities such as confined space entry operations. That is, in confined space operations, proper air monitoring can detect the presence or absence of life-threatening contaminants and/or insufficient oxygen levels within the confined space, alerting the entrants not to enter before making the space safe (e.g., by using forced air ventilation, etc.) for entry.

On the other hand, time-integrated *air sampling* is intended to document actual exposure for comparison to long-term exposure limits. Air sampling data is collected at "fixed" locations along the perimeter of the sample area (work area) and at locations adjacent to other sensitive receptors. Because most contaminants are (or will be) present in ambient air at relatively low levels, some type of sample concentrating is necessary to meet detection limits normally required in evaluating long-term health risks. Air sampling is accomplished using air-monitoring instrumentation designed to continuously sample large volumes of air over extended periods of time (typically from 8-24 hours).

Air sampling methods involve collecting air samples on sampling media designed specifically for collection of the compounds of interest or as whole air samples. Upon completion of the sampling period the sampling media is collected, packaged, and transported for subsequent analysis. Analysis of air samples usually requires a minimum of 48 hours to complete.

To effectively evaluate a potentially hazardous worksite, an industrial hygienist (IH) must obtain objective and quantitative data. To do this, the IH must perform some form of air sampling, dependent upon, of course, the airborne contaminant in question. Moreover, sampling operations involve the use of instruments to measure the concentration of the particulate, gas, or vapor of interest. Many instruments perform both sampling and analysis. The instrument of choice in conducting sampling and analysis typically is a direct-reading-type instrument. The IH must be familiar with the uses, advantages, and limitations of such instruments. In addition, the IH must use math calculations to calculate sample volumes, sample times, TLVs, air concentrations from vapor pressures, and determine the additive effects of chemicals when multiple agents are used in the workplace. These calculations must take into account changing conditions, such as temperature and pressure change in the workplace. Finally, the IH must understand how particulates, gases, and vapors are generated, how they enter the human body, how they impact worker's health, and how to evaluate particulate-, gas-, and vapor-laden workplaces.

Air/Oil Table: The surface between the vadose zone and ambient oil; the pressure of oil in the porous medium is equal to atmospheric pressure.

Air Padding: Pumping dry air into a container to assist with the withdrawal of liquid or to force a liquefied gas such as chlorine out of the container.

Air Permeability: Permeability of soil with respect to air. Important to the design of soil-gas surveys. Measured in darcys or centimeters-per-second.

Air Plenum: Any space used to convey air in a building, furnace, or structure. The space above a suspended ceiling is often used as an air plenum.

Air Pollutants: Generally includes sulfur dioxide, hydrogen sulfide, hydrocarbons, carbon monoxide, ozone, and atmospheric nitrogen, but can include any gaseous substance that contaminates air.

Air Pollution: Contamination of the atmosphere (indoor or outdoor) caused by the discharge (accidental or deliberate) of a wide range of toxic airborne substances.

Air Pollution Control Act: Was the first United States Clean Air Act enacted by Congress in 1955 to address the national environmental problem of air pollution. The act declared that air pollution was a danger to public health and welfare, but preserved the "primary responsibilities and rights of the states and local government in controlling air pollution" (Public Law 84-159, ch. 360, 69 Stat. 322).

Air Pollution Control Device: Mechanism or equipment that cleans emissions generated by a source (e.g., an incinerator, industrial smokestack, or an automobile exhaust system) by removing pollutants that would otherwise be released to the atmosphere.

Air Pollution Episode: A period of abnormally high concentration of air pollutants, often due to low winds and temperature inversion that can cause illness and death.

Air Purifying Respirator (APR): An air-filtering device that covers the nose and mouth and removes contaminants from the surrounding air by passing it through a filter, cartridge, or canister. A variety of filter cartridges are designed to capture specific particles and/or gases. Filters must be replaced once absorption capacity is depleted.

Air Quality: A measurement of the relative presence (or absence) of pollutants in the air; the properties and degree of purity of air to which humans and other organisms are exposed.

Air Quality Act: Law passed in 1967 establishing eight air quality control regions in the Unites States and issuing air quality criteria for specific pollutions. It also authorized expanded studies of pollutant emission inventories, ambient monitoring techniques, and control techniques.

Air Quality Control Region (AQCR): Federally designated area that is required to meet and maintain federal ambient air quality standards. May include nearest states that share common air pollution problems.

Air Quality Criteria: The levels of pollution and lengths of exposure above which adverse health and welfare effects may occur.

Air Quality Index: A standardized indicator of the air quality in a given location.

Air Quality Standards: The level of pollutants prescribed by regulations that are not to be exceeded during a given time in a defined area.

Air Sampling: Safety and environmental health practitioners are interested in knowing what contaminants workers are exposed to, and the contaminant concentrations. Determining the quantities and types of atmospheric contaminants is accomplished by measuring and evaluating a representative sample of air. The types of air contaminants that occur in the workplace depend upon the raw materials used and the processes employed. Air contaminants can be divided into two broad groups, depending upon physical characteristics: (1) gases and vapors and (2) particulates.

Air Sampling for Airborne Particulates: Airborne Particulates (or particulate matter, PM) includes solid and liquid matter such as:

- dusts
- fumes
- mists
- smokes
- bioaerosols

Inhalation of particulates is a major cause of occupational illness and disease. Pneumoconiosis (Gr. 'dusty lung') is a lung disease cause by inhalation.

There are four critical factors that influence the health impact of airborne particulates. Each of these four factors is interrelated in such a way that on one factor can be considered independently of the others:

- The size of the particles
- The duration of exposure time
- The nature of the dust in question
- The airborne concentration of the dust, in the breathing zone of the exposure person.

Note: The *breathing zone* of the worker is described by a hemisphere bordering the shoulders to the top of the head.

Dusts

Dusts are generated by mechanical processes such as grinding or crushing. Dusts range in size from 0.5-50µm in size. Note that dust is a relatively new term used to describe dust that is hazardous when deposited anywhere in the respiratory tree including the nose and mouth. It has a 50 percent cut-point of 10 microns and includes the big and the small particles. The cut-point describes the performance of cyclones and other particle size selective devices. For personal sampling, the 50 percent cut point is the size of the dust that the device collects with 50 percent efficiency.

Alpaugh (1988) points out that common workplace dusts are either inorganic or organic. Inorganic dusts are derived from metallic and non-metallic sources. Non-metallic dusts can be silica bearing; that is, in combined or free silica as crystalline or amorphous form. Organic dusts are either synthetic or natural. Natural organic dust can be animal or vegetable derived.

Examples of organic and inorganic dust would be:

- Sand (inorganic, non-metallic, silica bearing, free silica, crystalline; Beryllium (inorganic, metallic)
- Cotton (organic, naturally occurring, vegetable)

Elsewhere, Grantham (1992) has classified dusts on the basis of their health effects. He identifies dusts as being:

- Innocuous—iron oxide, limestone (may also be considered as nuisance dusts)
- Acute respiratory hazards—cadmium fume
- Chronic respiratory hazards—airborne asbestos fibers
- Sensitizers—many hardwood dusts

Duration of Exposure

The duration of exposure may be *acute* (short term) or it may be *chronic* (long-term).

Some airborne particulates, for example beryllium, may exert a toxic effect after a single acute exposure or metal fume fever may occur following acute exposure to metal fumes.

Other particulates, such as lead or manganese, may exert a toxic effect following a longer period of exposure, maybe several days to several weeks. Such exposures could be termed *sub-chronic*. Chronic lung conditions, such as pneumoconiosis or mesothelioma, may follow prolonged exposure to silica dusts or asbestos (crocidolite or blue asbestos) respectively.

Particle Size

Particle size is critical in determining where particulates will settle in the lung. Smaller particles outnumber larger ones but vary widely in size. Larger particles will settle in the upper respiratory tract in the bronchi and the bronchioles, and will not tend to penetrate the smaller airways found in the alveolar (air sac) region. These are termed *inspirable* particles. Those smaller-sized particles that can penetrate the alveolar (the gas exchange) region of the lungs are termed *respirable* particles.

Particle size is expressed as 'aerodynamic' or 'equivalent' diameter. This is equal to the diameter of spherical particles of unit density that have the same falling velocity (terminal velocity; settling velocity is the same as terminal velocity) in air as the particle in question. The terminal velocity is proportional to the specific gravity of the particle, p, and the square of its diameter, d.

Particles with an aerodynamic diameter greater than approximately 20 microns (µm) will be trapped in the nose and upper airways.

Particles in the region of 7–20 microns will penetrate to the bronchioles and are inspirable, while particles in the size range 0.5–7 microns are respirable. Particles smaller than this will not settle out as their terminal velocity is so small that there is insufficient time for them to be deposited in the alveolus and they are exhaled out again.

An understanding of aerodynamic diameter is important when calculating terminal settling rates of particulates. Constants for these calculations include:

- $1\ \text{gm/cm}^3$ = unit density
- Gravity = $32.2\ \text{ft/sec}^2$ or $98\ \text{cm/sec}^2$

Stoke's Law

Stoke's Law is the relationship that relates the "settling rate" to a particle's density and diameter. Stoke's Law applies to the fate of particulates in the atmosphere. Stoke's Law is given as:

$$u = \frac{gd^2\ \rho_1 - \rho_2}{18\eta}$$

where:

u = settling velocity in cm/s (settling velocity = 0.006 ft/min(specific gravity)d^2)
g = acceleration due to gravity in cm/s^2
d^2 = diameter of particle squared in cm^2
ρ_1 = particle density in g/cm^3
ρ_2 = air density in g/cm^3
η = air viscosity in poise g/cm—s

What Stoke's Law tells us is that, all other things being constant, dense particles settle faster, larger particles settle faster, and denser, more viscous air causes particles to settle slower.

Stoke's Law is used in several ways. We can predict settling rate for a given particle if its diameter and density are known. Another way in which Stoke's Law is used is to estimate particle diameters (called "Stoke's diameter") from observed settling rates.

Airborne Dust Concentration

The concentration of dust to which a person is exposed is a critical factor to the impact on the health of the worker exposed. This is measured in the breathing zone of the worker.

Airborne concentrations of dust are usually assessed by collecting dust on a pre-weighed filter. A known volume of air is drawn through the filter, which is then re-weighed. The difference in weight is the mass of dust, usually in milligrams (mg) or micrograms (μg), and the volume is expressed as cubic meters of air (m^3). Hence, the overall concentration of dust in air is measured in mg/m^3 or $\mu g/m^3$.

Particulate Collection

In order to evaluate workplace atmosphere for particulates a sample must be taken and analyzed. To obtain a sample the following collection mechanisms are used:

- Impaction
- Sedimentation
- Diffusion
- Direct interception
- Electrostatic attraction

The *filter* is the most common particulate collection device. The mixed cellulose ester membrane filter is the most commonly used type of filter. This type filter is used for collecting asbestos and metals. Other filter types include polyvinyl chloride, silver, glass fiber, and Teflon filters.

Analysis of Particulates

There are several methods for analysis of particulates, including:

- Gravimetric—coal dust, free silica, total dust
- Instrumental—atomic absorption (AA) for metals
- Optical microscopy—fibers, asbestos, dust
- Direct-reading instruments—aerosol photometers, piezo-electric instruments
- Wet chemical—lead, isocyanates, free silica

Health and Environmental Impacts of Particulates

Particulates cause a wide variety of health and environmental impacts. Many scientific studies have linked breathing particulates to a series of significant health problems, including:

- aggravated asthma
- increases in respiratory symptoms like coughing and difficult or painful breathing
- chronic bronchitis
- decreased lung function
- premature death

Particulate matter is the major cause of reduced visibility (haze) in parts of the United States, including many of our national parks.

Particles can be carried over long distances by wind and then settle on ground or water. The effects of this settling include:

- making lakes and streams acidic
- changing the nutrient balance in coastal waters and large river basins
- depleting the nutrients in soil
- damaging sensitive forests and farm crops
- affecting the diversity of ecosystems

Soot particulate stains and damages stone and other materials, including culturally important objects such as monuments and statues.

Control of Particulates

As with all other methods of industrial hygiene hazard control, control of particulates is most often accomplished through the use of engineering controls, administrative controls, and PPE.

The best method for controlling particulates is the use of ventilation—an engineering control. To be most effective, the particulate generating process should be totally enclosed with a negative pressure exhaust ventilation system in place.

Administrative controls include using wet methods of housekeeping and wet cleanup methods to minimize dust regeneration and prohibiting the use of compressed air to clean work surfaces.

PPE, used as a last resort, includes equipping workers with proper respiratory protection for prevention of inhalation of particulates and protective clothing to protect worker contact with particulates.

Air Monitoring for Confined Space Entry: When a confined space is to be entered, it is important to remember that one can never rely on his/her senses to determine if the air in the confined space is safe. You cannot see or smell many toxic gases and vapors, nor can you determine the level of oxygen present (Spellman, 1999b). A *confined space* is defined as a space large enough and so configured that an employee can bodily enter and perform assigned work; has limited or restricted means for entry or exit; and is not designed for continuous employee occupancy. A *permit-required confined space* (a permit is a written or printed document provided by the employer to allow and control entry into a permit space) has one or more of the following characteristics: (1) contains or has the potential to contain a hazardous atmosphere; (2) contains a material that has the potential for engulfing an entrant; (3) has a configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross section; or (4) contains any recognized serious safety or health hazard.

Monitoring Procedures

Atmospheric monitoring (testing) is required for two distinct purposes: evaluation of the hazards of the permit space and verification that acceptable entry conditions for entry into that space exist.

1. *Evaluation testing*: The atmosphere of a confined space should be analyzed using equipment of sufficient sensitivity and specificity to identify and evaluate any hazardous atmospheres that may exist or arise, so that appropriate permit entry procedures can be developed and acceptable entry conditions stipulated for that space. Evaluation and interpretation of these data, and development of entry procedure, should be done by, or reviewed by, a technically qualified industrial hygienist based on evaluation of all serious hazards.
2. *Verification testing*: The atmosphere of a permit space that may contain a hazardous substance should be tested for residues of all contaminants identified by evaluation testing using permit-specified equipment to determine that residual concentrations at the time of testing and entry are within the range of acceptable entry conditions. Results of testing (i.e., actual concentrations, etc.) should be recorded on the permit in the space provided adjacent to the acceptable entry condition.
3. *Duration of testing*: Measurement of values for each atmospheric parameter should be made for at least the minimum response time of the test instrument specified by the manufacturer.
4. *Testing stratified atmospheres*: When monitoring for entries involving a descent into atmosphere that may be stratified, the atmospheric envelope should be tested a distance of approximately 4 feet in the direction of travel and to each side. If a sampling probe is used, the entrant's rate of progress should be slowed to accommodate the sampling speed nd detector response.

Air Sampling Calculations:

Note: Gram Molecular Volumes

1 mole = 22.4 liters at STP
1 mole = 24.45 liters at NTP
Standard Pressure is 760 torr (760 mm of mercury (Hg) at sea or atmosphere level)
Standard Temperature is 0° C or 273°K (Kelvin = 273 + x°C).

Sample Conversions and Calculations:

Boyle's Law

1. If 500 ml of oxygen is collected at a pressure of 780 mm Hg, what volume will the gas occupy if the pressure is changed to 740 mm Hg?

   New volume (V_2) = 500 ml × 780 mm Hg/740 mm Hg = 527 ml

2. What is the volume of a gas at a pressure of 90 cm Hg if 300 ml of the gas was collected at a pressure of 86 cm Hg?

   New volume (V_2) = 300 ml × 86 cm Hg/90 cm Hg = 287 ml

3. Calculate the volume of a gas that occupies a volume of 110 ml, if it occupies a volume of 300 ml at a pressure of 80 cm Hg.

   New pressure (P_2) = 80 cm Hg × 300 ml/110 ml = 218 cm Hg

Charles's Law

4. What volume will an amount of gas occupy at 25°C if the gas occupies a volume of 500 ml at a temperature of 0°C? Assume that the pressure remains constant.

   °K = 273° + °C

   New volume (V_2) = 500 ml × 298°K/273°K = 546 ml

5. What is the volume of a gas at –25°C if the gas occupied 48 ml at a temperature of 0°C?

   New volume (V_2) = 48 ml × 248°K/273°K = 43.6 ml

6. If a gas occupies a volume of 800 ml at 15°C, at what temperature will it occupy a volume of 1000 ml if the pressure remains constant?

   New absolute pressure (T_2) = 288°K × 1000 ml/800 ml = 360°K

Boyle's Law and Charles's Law Combined

7. Calculate the volume of a gas at STP if 600 ml of the gas is collected at 25°C and 80 cm Hg.

   New volume (V_2) = 600 ml × 80 cm Hg/76 cm Hg × 273°K/298°K = 578 ml

8. If a gas occupies a volume of 100 ml at a pressure of 76 cm Hg and 25°C, what volume will the gas occupy at 900 mm Hg and 40°C?

   New volume (V_2) = 100 ml × 760 mm Hg/900 mm Hg × 313°K/298°K = 88.7 ml

9. If 500 ml of oxygen is collected at 20°C, and the atmospheric pressure is 725.0 mm Hg, what is the volume of the dry oxygen at STP?

   New volume of dry gas = 500 ml × 725.0 mm Hg/760 mm Hg × 273°K/293°K = 443.5 ml

10. 2.50 g of a gas occupy 240 ml at 20°C and 740 torr. What is the gram molecular weight of the gas?

    Step 1: 240 ml × 273°K/293°K × 740 torr/760 torr = 217 ml

    Step 2: 2.50 g/217 ml × 1000ml/lL × 22.4 L/1 mole = 258 g/mole

Air Sampling for Gases and Vapors: *Gases* and *vapors* are "elastic fluids," so-called because they take the shape and volume to their containers.

A *fluid* is generally termed as gas if its temperature is very far removed from that required for liquefaction; it is called a vapor if its temperature is close to that of liquefaction.

In the industrial hygiene field, a substance is considered a gas if this is its normal physical state at room temperature and atmospheric pressure. It is considered a vapor if, under the existing environmental conditions, conversion of its liquid or solid form to the gaseous state results from its vapor pressure affecting its volatilization or sublimation into the atmosphere of the container, which may be the process equipment or the worksite. Our chief interest in distinguishing between gases and vapors lies in our need to assess the potential occupational hazards associated with the use of specific chemical agents, an assessment which requires knowledge of the physical and chemical properties of these substances. (NIOSH, 2005).

The type of air sampling for gases and vapors employed depends on the purpose of sampling, environmental conditions, equipment available and nature of the contaminant.

Types of Air Samples

No matter the type of air sampling used, workplace samples must be obtained that represent the worker's exposure (i.e., a representative sample).

In taking a *representative sample*, a sampling plan should be used that specifies the following:

- Where to sample
- Whom to sample
- How long to sample
- How many samples to take
- When to sample

Generally, as mentioned previously, two methods of sampling for airborne contaminants are used: Personal air sampling and area sampling. *Personal air sampling* (the worker wears a sampling device that collects an air sample) is the preferred method of evaluating worker exposure to airborne contaminants. *Area monitoring* (e.g., in confined spaces) is used to identify high exposure areas.

Methods of Sampling

Standardized sampling methods provide the information needed to sample air for specific contaminants. Standard air sampling methods specify procedures, collection media, sample volume, flowrate, and chemical analysis to be used. For example, NIOSH's *Manual of Analytical Methods* and OSHA's *Chemical Information Manual* provide the information necessary to sample for air of specific contaminants.

Generally, two methods of sampling are used in sampling for airborne contaminants: grab sampling and continuous (or integrated) sampling.

Grab sampling (i.e., instantaneous sampling) is conducted using a heavy walled evacuated (air removed) flask. The flask is placed in the work area and a valve is opened to allow air to fill the flask. The sample represents a "snapshot" of an environmental concentration at a particular point in time. The sample is analyzed either in the laboratory or with suitable field instruments.

Continuous sampling is the preferred method for determining time-weighted average (TWA) exposures. The sample is taken for a sample air stream.

Air Sampling Collection Processes

Airborne contaminants are collected on media or in liquid media through absorption or adsorption processes.

Absorption is the process of collecting gas or vapor in a liquid (dissolving gas/vapor in a liquid). Absorption theory states that gases and vapors will go into solution up to an equilibrium concentration.

Samplers include gas washing bottles (impingers), fritted bubblers, spiral and helical absorbers, and glass-bead columns.

Gas adsorbents (gas onto a solid) typically use activated charcoal, silica gel, or other materials to collect gases.

Diffusive samplers (passive samplers) depend on flow of contaminant across a quiescent (uses no pump to draw air across adsorbent) layer of air, or a membrane. Diffusion depends on well-established rules from physical chemistry, known as Fick's law.

Calibration of Air Sampling Equipment

In order to gather accurate sampling data, the equipment used must be properly calibrated. The calibration of any instrument is an absolute necessity if the data are to have any meaning. Various devices are used to calibrate air sampling equipment. Calibration is based on primary or secondary calibrations standards.

Primary calibrations standards include:

- soap bubble meter (or frictionless piston meter)
- spirometer (measures displaced air)
- Mariotti bottle (measures displaced water)
- electronic calibrators (provide instantaneous airflow readings)

Secondary calibration standards include:

- wet test meter
- dry gas meter
- rotameters

Air Sparging: Injecting air or oxygen into an aquifer to strip or flush volatile contaminants as air bubbles up through the groundwater and is captured by vapor extraction system.

Air Stripping: A mass transfer process in which a substance in solution in water is transferred to solution in a gas.

Air Toxics: Any air pollutant for which a national ambient air quality standard (NAAQS) does not exist (ie., excluding ozone, carbon monoxide, PM-10, sulfur dioxide, nitrogen oxide) that my reasonably be anticipated to cause cancer; respiratory, cardiovascular, or developmental effects; reproductive dysfunctions, neurological disorders, heritable gene mutations, or other serious or irreversible chronic or acute health effects in humans.

Airtight: A relative term indicating the extent to which a system is resistant to the passage of air.

Air Vapor Barrier: A moisture-impervious layer that is applied to surfaces enclosing a space to limit moisture migration.

Alachlor: A herbicide, marketed under the trade name Lasso, used mainly to control weeds in corn and soybean fields.

Alar: Trade name for daminozide, a pesticide that makes apples redder, firmer, and less likely to drop off trees before growers are ready to pick them. It is also used to a lesser extent on peanuts, tart cherries, concord grapes, and other fruits.

ALARA: "As Low As Is Reasonably Achievable," which is the approach to radiation protection manage an control exposures (both individual and collective) to the work force and to the general public to as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit but has a process which has the objective of attaining does as far below the applicable limits of 10 CFR 835 as is reasonably achievable.

Albedo: Albedo [the ratio of light reflected (reflectivity) from a particle, planet, or satellite to that falling on it] always has a value less than or equal to 1—an object with a high albedo (near 1) is very bright, while a body with a low albedo (near 0) is dark. For example, freshly fallen snow typically has an albedo that is between 75 and 90+ percent; that is, 75 to 95 percent of the solar radiation that is incident on snow is reflected. At the other extreme, the albedo of a rough, dark surface, such as a green forest, may be as low as 5 percent. The albedos of some common surfaces are listed in the Table. The portion of insolation not reflected is absorbed by the earth's surface, warming it. This means earth's albedo plays an important part in the earth's radiation balance and influences the **mean annual temperature** and the **climate**, on both local and global scales.

TABLE—Albedo of Surface Types

The ALBEDO of some surface types in percent reflected

SURFACE	*ALBEDO*
Water (low sun)	10–100
Water (high sun)	3–10
Grass	16–26
Glacier ice	20–40
Deciduous forest	15–20
Coniferous forest	5–15
Old snow	40–70
Fresh snow	75–95
Sea ice	30–40
Blacktopped tarmac	5–10
Desert	25–30
Crops	15–25

Albumin: Protein material found in animal and vegetable fluids that is soluble in pure water.

Alchemy: A form of inquiry that existed about 500 BCE to about 1600 AD, practiced especially in Europe in the Middle Ages and primarily concerned with attempts to transform base metals into gold.

Alcohol (C_2H_5OH): A general class of hydrocarbons that contains a hydroxyl group (OH). There are many types of alcohol (butanol, ethanol, methanol).

Alcohol Poisoning: Poisoning caused by the ingestion of any alcohol, including ethyl, isopropyl, and methyl.

Aldicarb: A white crystalline solid insecticide sold under the trade name Temik. It is made from ethyl isocyanate.

Alert Action: That concentration of pollutants at which first stage control action is to begin.

Algae: 1. Plants, many microscopic, containing chlorophyll. Freshwater algae are diverse in shape, color, size, and habitat. They are the basic ling in the conversion of inorganic constituents in water into organic constituents. 2. The protists that perform photosynthesis are called **algae**. Algae can be both a nuisance and an ally. Many ponds, lakes, rivers, streams, and bays (e.g., Chesapeake Bay) in the United States (and elsewhere) are undergoing **eutrophication**, the enrichment of an environment with inorganic substances (phosphorous and nitrogen). When eutrophication occurs, when filamentous algae like *Caldophora* break loose in a pond, lake, stream or river and washes ashore, algae makes it stinking, noxious presence known. Algae are allies in many wastewater treatment operations. They can be valuable in long-term oxidation ponds where they aid in the purification process by producing oxygen. Before discussing the specifics and different types of algae, it is important to be familiar with algal terminology.

Algal Terminology

- **Algae**—large and diverse assemblages of eukaryotic organisms that lack roots, stems, and leaves but have chlorophyll and other pigments for carrying out oxygen-producing photosynthesis.
- **Algology** or **Phycology**—the study of algae.
- **Antheridium**—special male reproductive structures where sperm are produced.
- **Aplanospore**—nonmotile spores produced by sporangia.
- **Benthic**—algae attached and living on the bottom of a body of water.
- **Binary fission**—nuclear division followed by division of the cytoplasm.
- **Chloroplasts**—packets that contain ***chlorophyll a*** and other pigments.
- **Chrysolaminarin**—the carbohydrates reserve in organisms of division **Chrysophyta**.
- **Diatoms**—photosynthetic, circular, or oblong chrysophyte cells.
- **Dinoflagellates**—unicellular, photosynthetic protistan algae.
- **Epitheca**—the larger part of the frustule (diatoms).
- **Euglenoids**—contain chlorophylls **a** and **b** in their chloroplasts; representative genus is *Euglena*.
- **Fragmentation**—a type of asexual algal reproduction in which the thallus breaks up and each fragmented part grows to form a new thallus.
- **Frustule**—the distinctive two-piece wall of silica in diatoms.
- **Hypotheca**—the small part of the frustule (diatoms).
- **Neustonic**—algae that live at the water-atmosphere interface.
- **Oogonia**—vegetative cells that function as female sexual structures in the algal reproductive system.
- **Pellicle**—a *Euglena* structure that allows for turning and flexing of the cell.
- **Phytoplankton**—made up of algae and small plants.
- **Plankton**—free-floating, mostly microscopic aquatic organisms.
- **Planktonic**—algae suspended in water as opposed to attached and living on the bottom (benthic).
- **Protothecosis**—a disease in humans and animals caused by the green algae, *Prototheca moriformis*.
- **Thallus**—the vegetative body of algae.

Algae are autotrophic, contain the green pigment chlorophyll, and are a form of aquatic plant. Algae differ from bacteria and fungi in their ability to carry out photosynthesis—the biochemical process requiring sunlight, carbon dioxide, and raw mineral nutrients. Photosynthesis takes place in the chloroplasts. The chloroplasts are usually distinct and visible. They vary in size, shape, distribution, and numbers. In some algal types the chloroplast may occupy most of the cell space. They usually grow near the surface of water because light cannot penetrate very far through water. Although in mass (multicellular forms like marine kelp) the unaided eye easily sees them, many of them are microscopic. Algal cells may be nonmotile, motile by one or more flagella, or exhibit gliding **motility** as in diatoms. They occur most commonly in water (fresh and polluted water, as well as in salt water), in which they may be suspended (Planktonic) phytoplanktons or attached and living on the bottom (benthic). A few algae live at the water-atmosphere interface and are termed Neustonic. Within the fresh and saltwater environments, they are important primary producers (the start of the food chain for other organism). During their growth phase, they are important oxygen-generating organisms and constitute a significant portion of the plankton in water.

According to the five kingdom system of Whittaker, the algae belong to seven divisions distributed between two different kingdoms. Although seven divisions of algae occur, only five divisions are discussed in this text:

- **Chlorophyta**—Green algae
- **Euglenophyta**—Euglenids
- **Chrysophyta**—Golden-brown algae, diatoms
- **Phaeophyta**—Brown algae
- **Pyrrophyta**—Dinoflagellates

The primary classification of algae is based on cellular properties. Several characteristics are used to classify algae, including: (1) cellular organization and cell wall structure; (2) the nature of chlorophyll(s) present; (3) the type of motility, if any; (4) the carbon polymers that are produced and stored; and (5) the reproductive structures and methods. The following table summarizes the properties of the five divisions discussed in this text.

Algae show considerable diversity in the chemistry and structure of their cells. Some algal cell walls are thin, rigid structures usually composed on cellulose modified by the addition of other polysaccharides. In other algae, the cell wall is strengthened by the deposition of calcium carbonate. Other forms have chitin present in the cell wall. Complicating the classification of algal organisms are the Euglenids, which lack cell walls. In diatoms the cell wall is composed of silica. The frustules (shells) of diatoms have extreme resistance to decay and remain intact for long periods of time, as the fossil records indicate.

The principal feature used to distinguish algae from other microorganisms (for example, fungi) is the presence of chlorophyll and other photosynthetic pigments in algae. All algae contain chlorophyll a. Some, however, contain other types of chlorophylls. The presence of these additional chlorophylls is characteristic of a particular algal group. In addition to chlorophyll, other pigments encountered in algae include fucoxanthin (brown), xanthophylls (yellow), carotenes (orange), phycocyanin (blue), and phycoerythrin (red).

Many algae have flagella (a threadlike appendage). As mentioned, the flagella are locomotor organelles that may be the single polar or multiple polar types. The *Euglena* is a simple flagellate form with a single polar flagellum. Chlorophyta have either two or four polar flagella. Dinoflagellates have two flagella of different lengths. In some cases, algae are nonmotile until they form motile gametes (a haploid cell or nucleus) during sexual reproduction. Diatoms do not have flagella, but have gliding motility.

Algae can be either autotrophic or heterotrophic. Most are photoautotrophic; they require only carbon dioxide and light as their principal source of energy and carbon. In the presence of light, algae carry out oxygen-evolving photosynthesis; in the absence of light, algae use oxygen. Chlorophyll and other pigments are used to absorb light energy for photosynthetic cell maintenance and reproduction. One of the key characteristics used in the classification of algal groups is the nature of the reserve polymer synthesized as a result of utilizing carbon dioxide present in water.

Algae may reproduce either asexually or sexually. Three types of asexual reproduction occur: binary fission, spores, and fragmentation. In some unicellular algae, binary fission occurs where the division of the cytoplasm forms new individuals like the parent cell following nuclear division. Some algae reproduce through spores. These spores are unicellular and germinate without fusing with other cells. In fragmentation, the thallus breaks up and each fragment grows to form a new thallus.

Sexual reproduction can involve union of cells where eggs are formed within vegetative cells called Oogonia (which function as female structures) and sperm are produced in a male reproductive organ called antheridia. Algal reproduction can also occur through a reduction of chromosome number and/or the union of nuclei.

Comparative Summary of Algal Characteristics

Algal Group	*Common Name*	*Structure*	*Pigments*	*Carbon Reserve*	*Motility*	*Reproduction*
Chlorophyta	Green algae	Unicellular to Multicellular	Chlorophylls a and b, carotenes, xanthophylls	Starch, oils	Most are nonmotile	Asexual and sexual
Euglenophyta	Euglenoids	Unicellular	Chlorophylls a and b, carotenes, xanthophylls	Fats	Motile	Asexual
Chrysophyta	Golden brown algae, diatoms	Multicellular	Chlorophylls a and b, special carotenoids, xanthophylls	Oils	Gliding by diatoms; others by flagella	Asexual and sexual
Phaeophyta	Brown algae	Unicellular	Chlorophylls a and b, carotenoids xanthophylls	Fats	Motile	Asexual and sexual
Pyrrophyta	Dinoflagellated	Unicellular	Chlorophylls A and b, Carotenes, xanthophylls	Starch,	Motile	Asexual; sexual rare

Characteristics of Algal Divisions

- **Chlorophyta** (Green Algae)—the majority of algae found in pounds belong to this group; they also can be found in salt water and soil. Several thousand species of green algae are known today. Many are unicellular; others are multicellular filaments or aggregated colonies. The green algae have chlorophylls a and b, along with specific carotenoids, and they store carbohydrates at starch. Few green algae are found at depths greater than 7-10 meters. Few green algae are found at depths greater than 7-10 meters, largely because sunlight does not penetrate to that depth. Some species have a holdfast structure that anchors them to the bottom of the pond and to other submerged inanimate objects. Green algae reproduce by both sexual and asexual means. Multicellular green algae have some division of labor, producing various reproductive cells and structures.
- **Euglenophyta** (Euglenoids)—are a small group of unicellular microorganisms that have a combination of animal and plant properties. Euglenoids lack a cell wall, possess a gullet, have the ability to ingest food, have the ability to assimilate organic substances, and, in some species, are absent of chloroplasts. They occur in fresh, brackish, and salt waters, and on moist soils. A typical *Euglena* cell is elongated and bound by a plasma membrane; the absence of a cell wall makes them very flexible in movement. Inside the plasma membrane is a structure called the pellicle that gives the organisms a definite form and allows the cell to turn and flex. Euglenoids that are photosynthetic contain chlorophylls a and b, and they always have a red eyespot (**stigma**) that is sensitive to light (photoreceptive). Some Euglenoids move about by means of flagellum; others move about by means of contracting and expanding motions. The characteristic food supply for Euglenoids is a lipopolysaccharide. Reproduction in Euglenoids is by simple cell division.

  ✔ **Interesting Point**: Some autotrophic species of *Euglena* become heterotrophic when light levels are low.

- **Chrysophyta** (Golden Brown Algae)—the Chrysophycophyta group is quite large—several thousand diversified members. They differ from green algae and euglenoids in that: (1) chlorophylls a and c are present, (2) fucoxanthin, a brownish pigment, is present; and (3) they store food in the form of oils and leucosin, a polysaccharide. The combination of yellow pigments, fucoxanthin, and chlorophylls causes mot of these algae to appear golden-brown. The Chrysophycophyta is also diversified in cell wall chemistry and flagellation. The division is divided into three major classes: golden-brown, yellow-brown algae, and diatom.

  Some Chrysophyta lack cell walls; others have intricately patterned coverings external to the plasma membrane, such as walls, plates, and scales. The diatoms are the only group that has hard cell walls of pectin, cellulose, or silicon, constructed in two halves (the epitheca and the hypotheca) called a frustule. Two anteriorly attached flagella are common among Chrysophyta; others have not flagella.

  Most Chrysophyta are unicellular or colonial. Asexual cell division is the usual method of reproduction in diatoms; other forms of Chrysophyta can reproduce sexually.

  Diatoms have direct significance for humans. Because they make up most of the phytoplankton of the cooler ocean parts, they are the ultimate source of food for fish.

  Water and wastewater operators understand the importance of their ability to function as indicators of industrial water pollution. Aw water quality indicators, their specific tolerances to environmental parameters such as pH, nutrients, nitrogen, concentration of salts and temperature have been compiled.

✔ **Interesting Point**: Diatoms secrete a silicon dioxide shell (frustule) that forms the fossil deposits known as diatomaceous earth, which is used in filters and as abrasives in polishing compounds.

- **Phaeophyta** (Brown Algae)—with the exception of a few freshwater species, all algal species of this division exist in marine environments as seaweed. They are a highly specialized group, consisting of multicellular organisms that are sessile (attached and not free-moving). These algae contain essentially the same pigments seen in the golden-brown algae, but they appear brown because of the predominance of and the masking effect of a greater amount of fucoxanthin. Brown algal cells store food as the carbohydrate laminarin and some lipids. Brown algae's reproduce asexually. Brown algae are used in foods, animal feeds, and fertilizers and as source for alginate, a chemical emulsifier added to ice cream, salad dressing, and candy.
- **Pyrrophyta** (Dinoflagellates)—the principal members of this division are the dinoflagellates. The dinoflagellates comprise a diverse group of biflagellated and nonflagellated unicellular, eukaryotic organisms. The dinoflagellates occupy a variety of aquatic environments with the majority living in marine habitats. Most of these organisms have a heavy cell wall composed of cellulose-containing plates. They store food as starch, fats, and oils. These algae have chlorophylls a and c and several xanthophylls. The most

common form of reproduction in dinoflagellates is by cell division, but sexual reproduction has also been observed.

√ **Interesting Point**: Cell division in dinoflagellates differs from most protistans, with chromosomes attaching to the nuclear envelope and being pulled apart as the nuclear envelope stretches. During cell division in most other eukaryotes, the nuclear envelope dissolves.

Algal Bloom: Sudden spurts of algal growth, which can affect water quality adversely and indicate potentially hazardous changes in local water chemistry.

Algicide: Substance or chemical used specifically to kill or control algae.

Aliphatic: Of or pertaining to any open-chain carbon compound.

Aliphatic Hydrocarbons: Any of numerous organic compounds, such as alkanes, alkenes, alkynes, terpenes, and arenas that contain only one hydrogen and one carbon.

Aliquot: A measured portion of a sample taken for analysis. One or more aliquots make up a sample.

Alkali Burn: Damage to tissue caused by exposure to an alkaline compound similar to lye.

Alkali Metals: The group 1 elements of the periodic table.

Alkaline: Sometimes water or soils contain an amount of alkali (strongly basic) substances sufficient to raise the pH value above 7.0 and be harmful to the growth of crops.

Alkaline Battery: A battery that uses sodium or potassium hydroxide as an electrolyte, and nickel-oxide flakes and powdered iron or nickel-cadmium for its active plates.

Alkaline Fuel Cell (AFC): A type of hydrogen/oxygen fuel cell in which the electrolyte is concentrated potassium hydroxide (KOH) and the hydroxide ions (OH) are transported from the cathode to the anode.

Alkaline Soil: Soil having a pH value of >7.3.

Alkalinity: (1) The concentration of hydroxide ions. (2) The capacity of water to neutralize acids because of the bicarbonate, carbonate or hydroxide content. Usually expressed in milligrams per liter of calcium carbonate equivalent.

Alkanes: A class of hydrocarbons (gas, solid, or liquids depending upon carbon content). Its solids (paraffins) are a major constituent of natural gas and petroleum. Alkanes are usually gases at room temperature (methane) when containing less than 5 carbon atoms per molecule.

Alkenes: A class of hydrocarbons (also called olefins); sometimes gases at room temperature, but usually liquids; common in petroleum products. Generally more toxic than alkanes, less toxic than aromatics.

Alkynes: A class of hydrocarbons (formerly known as acetylenes). Unsaturated compounds characterized by one or more triple bonds between adjacent carbon atoms. Lighter alkenes, such as ethyne, are gases; heavier ones are liquids or solids.

Allergen: Because of the presence of allergens on spores, all molds studied to date have the potential to cause allergic reaction in susceptible people. Allergic reactions are believed to be the most common exposure reaction to molds (Rose, 1999).

Allobar: An isotope with a different atomic weight than the naturally occurring form of the same element.

Allochthonous: A type of food material formed from accumulated plant material that was transported from the original place of growth and deposited into an aquatic community (e.g., leaf fall into a stream, river, or lake).

Allotrope: One of the two or more forms of an element differing in either or both physical and chemical properties (e.g., O elemental oxygen, O_3 ozone, and O_2 molecular oxygen).

Allowable Bearing Capacity: The maximum pressure that can be permitted on foundation soil, giving consideration to all pertinent factors, with adequate safety against rupture of the soil mass or movement of the foundation to such an extent that the structure is impaired.

Allowable Error: Amount of error that can be tolerated without invalidating the medical usefulness of the analytical result.

Allowable Stress or Working Stress: The intensity of stress that the material of a structure or a machine is designed to resist.

Alopecia: Loss of hair; baldness.

Alpha: The first letter of the Greek alphabet.

Alpha Emitter: Radioactive substance that gives off alpha particles.

Alpha Particle: A strongly ionizing particle emitted from the nucleus of an atom during radioactive decay, containing 2 protons and neutrons and having a double positive charge.

Alpha Radiation: Alpha radiation is used for air ionization—elimination of static electricity (Po-210), clean room applications, and smoke detectors (Am-241). It is also used in air density measurement, moisture meters, non-destructive testing, and oil well logging. Naturally occurring alpha particles are also used for physical and chemical properties, including uranium (coloring of ceramic glaze, shielding) and thorium (high temperature materials).

The characteristics of Alpha radiation are listed below.

- Alpha (α) radiation is a particle composed of two protons and neutrons with source: Ra-226 → Rn 222 → Accelerators.
- Alpha radiation is not able to penetrate skin.
- Alpha-emitting materials can be harmful to humans if the materials are inhaled, swallowed, or absorbed through open wounds.
- A variety of instruments have been designed to measure alpha radiation. Special training in use of these instruments is essential for making accurate measurements.
- A civil defense instrument (CD V-700) cannot detect the presence of radioactive materials that produce alpha radiation unless the radioactive materials also produce beta and/or gamma radiation.
- Instruments cannot detect alpha radiation through even a thin layer of water, blood, dust, paper, or other material. Because alpha radiation is not penetrating.
- Alpha radiation travels a very short distance through air.
- Alpha radiation is not able to penetrate turnout gear, clothing, or a cover on a probe. Turnout gear and dry clothing can keep alpha emitters off of the skin.

Alpha Radiation Detectors: The types of high sensitivity portable equipment used to evaluate alpha radiation in the workplace include:

- Geiger-Mueller counter
- Scintillators
- Solid-state analysis
- Gas proportional devices

Alphiatic Hydrocarbon: Compound comprised of straight chain molecules as opposed to a ring structure.

Alternate Method: Any method of sampling and analyzing for an air or water pollutant that is not a reference or equivalent method but that has been demonstrated to specific cases to EPA's satisfaction to produce results adequate for compliance monitoring.

Alternate Animal Feedlot: A lot or building or combination of lots and buildings intended for the confined feeding, breeding, raising, or holding of animals and specifically designed as a confinement area where manure may accumulate, or where the concentration of animals is such that vegetative cover cannot be maintained within the enclosure during the months of May, June, July, and August. Open lots used for the feeding and rearing of poultry (poultry ranges) are considered animal feedlots, but pastures are not considered animal feedlots.

Alternate Conservation Practice: alternative method or field-specific condition that provides pollutant reductions equivalent or better than the reductions that would be achieve by the 100-foot setback.

Alternative Compliance: A policy that allows facilities to choose among methods for achieving emission-reduction or risk-reduction instead of command and to control regulations that specify standards and how to meet them. Use of a theoretical emissions bubble over a facility to cap the amount of pollution emitted while allowing the company to choose where an dhow (within the facility) it complies.

Alternative Energy: Any energy system other than the traditional fossil, nuclear, and hydropower energy sources that have been the basis of the growth of industrial society over the past two centuries, e.g., solar, wind, or hydrogen energy.

Alternative Fuels: Substitutes for traditional liquid, oil-derived motor vehicle fuels like gasoline and diesel. Includes mixtures of alcohol-based fuels with gasoline, methanol, ethanol, compressed natural gas, and others.

Alternative Onsite Wastewater Treatment System: An onsite treatment system that includes components different from those used in a conventional septic tank and drain field system. An alternative system is used to achieve acceptable treatment and dispersal/discharge of wastewater where conventional systems may not be capable of meeting established performance requirements to protect public health and water resources (e.g., at sites where high groundwater, low-permeability soils, shallow soils, or other conditions limit the infiltration and dispersal of wastewater or where additional treatment is needed to protect groundwater or surface water quality). Components that might be used in alternative systems include sand filters, aerobic treatment units, disinfection devices, and alternative SWISs such as mounds, gravelless trenches, and pressure and drip distribution.

Alternative Remedial Contract Strategy Contractors: Government contracts who provide project management and technical services to support remedial response activities at National Priorities List sites.

Alum: Any group of double sulfates of a monovalent metal and a trivalent metal. Alum is a common name of commercial aluminum sulfate, which is used in pools to form a gelatinous floc on sand filters or to coagulate and precipitate suspended particles in water.

Alumina: The oxide of aluminum, which occurs in nature as corundum and which is used in its synthetic form for the production of aluminum metal.

Alveoli: Tiny sacks in the lungs where the actual exchange of oxygen and carbon dioxide takes place.

Amalgam: An alloy of mercury with some other metal or metals.

Ambient: Descriptive of any condition of the environment surrounding a given point. For example, ambient air means that portion of the atmosphere, external to buildings, to which the general public has access. Ambient sound is the sound generated by the environment.

Ambient Air: Any unconfined portion of the atmosphere open air, surrounding air.

Ambient Air Quality: Quality of the outdoor air to which humans are exposed during the course of their normal lives.

Ambient Air Quality Standards (AAQS): The limit on the amount of a given pollutant that will be permitted into the ambient air.

Ambient Measurement: A measurement of the concentration of a substance or pollutant within the immediate environs of an organism; taken to relate it to the amount of possible exposure.

Ambient Medium: Material surrounding or contacting an organism (e.g., outdoor air, indoor air, water, or soil, through which chemicals or pollutants can reach the organism).

Ambient Pressure: Atmospheric pressure or pressure in the environment or surrounding area.

Ambient Temperature: Temperature of the surrounding air or other medium.

Amebiasis: A disease caused by a one-celled parasite called *Entamoeba histolytica.*

Amended Water: Water containing surfactants (wetting agents, penetrating agent) to enhance the wetting of asbestos-containing materials (ACM) to reduce the generation of dust.

Amendment: An ingredient, such as waste hay, cotton gin trash, or peanut hulls, added to corral surfaces to improve dust and odor control or to enhance the composting process.

Americium: A human-made radioactive element created by the neutron bombardment of plutonium.

Amines: One of a class or organic compounds derived from ammonia by substituting one or more hydrocarbon radicals for hydrogen atoms.

Amino acids: Organic nitrogen compounds which are the building blocks of proteins.

Ammonia: NH_3, a colorless gas that has a strong, highly irritating odor and an alkaline reaction in water.

Ammonia volatilization: Loss of ammonia (NH_3) to the atmosphere.

Amoebae: (pl.) Amoeba (sing.) One of the simplest living animals, consisting of a single cell and belonging to the protozoa group. The body consists of colorless protoplasm. Its activities are controlled by the nucleus, and it feeds by flowing round and engulfing organic debris. It reproduces by binary fission. Some species of amoeba are harmless parasites.

Amoebic Dysentery: A type of dysentery caused primarily by the amoeba *Entamoeba histolytica*.

Amorphous: Not having a definite shape or structure.

Amphorous Silicon: An alloy of silica and hydrogen, with a disordered, noncrystalline internal atomic arrangement, that can be deposited in thin-layers (a few micrometers in thickness) by a number of a deposition methods to produce thin-film photovoltaic cells on glass, metal, or plastic substrates.

Amphoteric: Having both basic and acidic properties.

Amprometric Titration: A way of measuring concentrations of certain substances in water using an electric current that flows during a chemical reaction.

Ampule: A small glass vial that is sealed after filling; often used as container for a solution to be giving by hypodermic injection.

Amyl Nitrite: The chemical compound the formula $C_5H_{11}ONO$. Amyl nitrite is bioreactive in mammals, being a vasodilator, which is the basis of its use as a prescription medicine.

Anabolism: The process of building up cell tissue, promoted by the influence of certain hormones; the constructive side of metabolism as opposed to catabolism.

Anadromous: Fish that spend their adult life in the sea but swim upriver to fresh water spawning grounds not reproduce.

Anaerobe: An organism that does not require atmospheric oxygen to live.

Anaerobic: Conditions in which no oxygen (free or combined) is available. Also used to describe organisms, biological activity, or treatment processes that function in the absence of oxygen.

Anaerobic Bacteria: Bacteria not requiring the presence of free or dissolved oxygen.

Anaerobic Decomposition: Reduction of the net energy level and change in chemical composition of organic matter caused by microorganisms in an oxygen-free environment.

Anaerobic Digester: A heated, air-tight apparatus that facilitates anaerobic digestion.

Anaerobic Digestion: Conversion of organic matter in the absence of oxygen under controlled conditions to such gases as methane and carbon dioxide.

Anaerobic Lagoon: A facility to treat animal waste by predominantly anaerobic biological action using anaerobic organism, in the absence of oxygen, for the purpose of reducing the strength of the waste.

Anaerobic Process: Any process (usually chemical or biological) carried out without the presence of air or oxygen, for example, in a heavily polluted watercourse with no dissolved oxygen present.

Anaerobic Respiration: Process by which an organism is capable of releasing energy without the use of oxygen.

Anaerobic Upflow Filter: A high-specific-surface anaerobic reactor filled with a solid media through which wastewater flows; used to pretreat high-strength wastewater or to denitrify wastewater.

Analgesic: A drug that alleviates pain without causing loss of consciousness; a pain reliever.

Analysis: The separation of an intellectual or substantial whole into its constituent parts for individual study.

Analyte: A substance measured in the laboratory. A chemical for which a sample (such as water air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Analytic Epidemiologic Study: A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Analytical Tree: Graphical representation of an accident in a deductive approach (general to specific). The structure resembles a tree—that is, narrow at the top with a single event (accident), then branching out as the tree is developed, and identifying root cause at the bottom branches.

Anchorage: Provides optimum solution in cases where suitable anchorage is required for use by a Fall Protection equipment.

Ancillary Services: Operations provided by hydroelectrical plants that ensure stable electricity delivery and optimize transmission system efficiency.

Anemia: An abnormal deficiency in the oxygen-carrying component of the blood, measured in unit volume concentrations of hemoglobin, red blood cell volume, or red blood cell number.

Anesthetic: An agent that causes loss of sensation with or without the loss of consciousness.

Angle of Abduction: Angle between the longitudinal axis of a limb and a sagittal plane.

Angle of Attack: In wind turbine operation, the angle of the airflow relative to the blade.

Angle of Incidence: The angle that a ray of sun makes with a line perpendicular to the surface. For example, a surface that directly faces the sun has a solar angle of incidence of zero, but if the surface is parallel to the sun (for example, sunrise striking a horizontal rooftop), the angle of incidence is 90 degrees.

Angle of Loading: The inclination of a leg or branch of a sling measured from the horizontal or vertical plane.

Angle of Reflection: In physics, the angle forced by the normal line to a surface and the direction of propagation of waves that are reflected from that surface.

Angle of Refraction: In physics, the angle that a ray of light makes with a line perpendicular to a surface separated two media.

Angular Momentum: In physics, for a system of particles, the vector sum of individual angular momentum vectors of all particles in the system. For a single particle moving about an axis, the moment of its linear momentum.

Anhydride: A chemical compound formed from another, often an acid, by the removal of water.

Anhydrous: A substance that contains no water.

Animal Dander: Tiny scales of animal skin, a common indoor air pollutant.

Animal Feeding Operation (AFO)[1]: Any facility that feeds livestock or poultry in confinement such that the animals are not sustained on forages growing in the confinement area or that relies on imported feed.

> As defined by the USEPA (40 CFR 122.23): a "lot or facility" where animals "have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility."

Waste problems and innovative solutions are not new, even in mythical terms. For example, mythical Greek gods had animal housing. The solution to animal waste pile up in ancient Greek animal housing was first formulated by Hercules—arguably the planet's first environmental engineer. The "Hercules" engineering principle states that:

"the solution to pollution is . . . dilution"

This is the principle that the mythical hero Hercules applied when he cleaned up the royal Aegean Stables that had not been cleaned for at least thirty years. He cleaned the stables by diverting the flow of two upstream rivers and directing the combined flow through the stables. Today we call it "flushing." This flushing idea of Hercules worked so well in cleaning the stables, that the same idea was later applied in the design of human toilets, and sewer systems. As the world became industrialized, the Hercules idea was applied just as successfully in the dispersion of air pollutants through tall chimneys. These chimneys are not different from the sewer pipes that take the waste away from the source. Note that the Hercules principle that the solution of pollution is dilution has ample scientific base. It should also be noted that while treating today's massive quantities of animal waste from CAFOs is certainly a Herculean task, unfortunately he is no longer around to solve current problems.

Fast-forwarding from mythical times back to the present, the fact is that other animal waste problems and solutions are, as mentioned earlier, also not new. For example, field spreading of human and animal wastes is accomplished naturally under nomadic and pasture social systems. The early Chinese practiced intentional manure conservation and reuse. In Iceland, slotted floors (allowing waste material to drop below the floor surface) go back to at least two hundred years. From at least the nineteenth century, dairy barns with wastes from scores of animals were contained in one building. Huge poultry centers with wastes concentrated in a small area have been around for decades, as have some very large swine and beef units.

Figuratively speaking, and in general, animal manure deposited by animals managed by standard grazing livestock methods does not create serious environmental problems, especially if the farmer limits herd size to numbers the acreage can support without environmental damage, restricts livestock access to stream beds, and applies practices that include soil erosion prevention methods, such as greenbelts for waterways and shoreline planting. Accidentally stepping into such deposits is an occupational hazard, of course.

It is important to understand that the manure deposited by a large herd of animals that is not assimilated through the soil surface and carried off by storm runoff into local streams or other water bodies being an obvious "isolated incident" problem, small-farm animal manure waste is not the problem we are addressing. Agribusiness and large-scale, factory-farming practices have created a different farm category in CAFOs, the livestock version of factory crop farming, which produce a massive quantity of manure. In the 1920s, no one was capable of spilling millions of gallons of manure into a local stream in a

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[1] From F.R. Spellman and W. *Animal Feeding Operations (CAFOs)*. Boca Raton, FL: CRC Press.

single event. Ikerd (1998) points out that such an event is possible today because of the piling up of too much manure in one place. Simply, the piling up is the result of greater concentration and reduced diversity in farm operations.

Agribusinesses don't use traditional pastures and feeding practices. Typically, the manure is removed from the livestock buildings or feedlots and stored in stockpiles or lagoon/pond systems until it can be spread on farm fields, sold to other farmers as fertilizer, or composted. When properly designed, constructed and managed, CAFO-produced manure is an agronomically important and environmentally safe source of nutrients and organic matter necessary for the production of food, fiber and good soil health. Experience has demonstrated that when properly applied to land, at proper levels, manure will not cause water quality problems. When properly stored or deposited in holding lagoons or ponds, properly conveyed to the disposal outlet, and properly applied to the appropriate end-use, potential CAFO waste environmental problems can be mitigated.

But CAFOs must be monitored and controlled. CAFOs are inherently are potential sources of contaminants (pollutants) to the three environmental mediums: air, water, and/or soil. Let's take a look at manure handling and storage practices recommended by USEPA and USDA (1998) that should be employed to prevent water pollution from CAFOs. In addition to water pollution prevention, it should be noted that manure and wastewater handling, storage, and subsequent application/treatment practices should also consider odor and other environmental and public health problems.

- *Divert clean water*—Siting and management practices should divert clean water from contact with feed lots and holding pens, animal manure, or manure storage systems. Clean water can include rainfall falling on roofs of facilities, runoff from adjacent lands, or other sources.
- *Prevent leakage*—Construction and maintenance of buildings, collection systems, conveyance systems, and permanent and temporary storage facilities should prevent leakage of organic matter, nutrients, and pathogens to ground or surface water.
- *Provide adequate storage*—Liquid manure storage systems should safely store the quantity and contents of animal manure and wastewater produced, contaminated runoff from the facility, and rainfall. Dry manure, such as that produced in certain poultry and beef operations, should be stored n production buildings or storage facilities, or otherwise stored in such a way so as to prevent polluted runoff. Location of manure storage systems should consider proximity to water bodies, floodplains, and other environmentally sensitive areas.
- *Manure treatments*—Manure should be handled and treated to reduce the loss of nutrients to the atmosphere during storage, to make the material a more stable fertilizer when land-applied or to educe pathogens, vector attraction and odors, as appropriate.
- *Management of dead animals*—Dead animals should be disposed of in a way that does not adversely affect ground or surface water or create public health concerns. Composting, rendering, and other practices are common methods used to dispose of dead animals.

According to Sutton & Humenik (2003), "advanced technologies are being developed for the biological, physical, and chemical treatment of manure and wastewaters. Some of these greatly reduce constituents in the treated solids and liquids that must be managed on the farm. Byproduct recovery processes are being developed that transform waste into value-added products that can be marketed off the farm" (p. 2).

Case Study—Animal Waste Treatment: Lagoons

Primarily because it is an economical means of treating highly concentrated wastes from confined livestock operations, the most widespread and common treatment technique for managing animal waste is the use of lagoons. In the late 1960s, considerable attention was paid to the impact of lagoons on surface water quality; since the 1970s that attention has shifted to the potential impacts on groundwater quality. Unfortunately, these lagoons are prone to leaks and breakage. Groundwater has been contaminated with bacteria from them. The lagoons can also be overrun by floods that push the wastes into streams, lakes and oceans. North Carolina, with its concentration of factory farms, has been the focus of massive water contamination due to its waste lagoons. The storage lagoons for factory farms are often stinking manure lakes the size of several football fields, containing millions of gallons of liquefied manure. A single animal factory can generate the waste equivalent of a small town.

In the past thirty years, several studies on the effectiveness of factory farm lagoons, specifically on lagoon liners, in preventing environmental damage have been conducted. Consider the following review of studies on effective lagoon construction versus defective construction.

Sewell et al. (1975) found in his studies on an anaerobic dairy lagoon that the lagoon bottom seals within two months of start up, and little or no pollutants were found in the groundwater after this time. Ritter et al. (1984) studied a two-stage anaerobic swine lagoon for four years and determined that the contaminant concentration increased in wells (50 m from the lagoon) the first year and then steadily decreased afterwards. His data led him to speculate that biological sealing takes place over a period of time depending on the loading rate to a lagoon. (Collins et al. 1975) studied three swine lagoons, each within a high water table area. He found that there was no significant effect on groundwater beyond 3 m from the lagoon edge. Miller et al. (1985) studied the performance of beef lagoons in sandy soil and found that the lagoons had effectively sealed to infiltration within 12 weeks of addition of manure. Humenik et al. (1980) summarized research conducted by others on the subject on lagoon sealing, and he concluded that the studies indicated that lagoon sealing may be expected within about six months after which the area of seepage impact becomes restricted to approximately 10 m.

On the other hand, Hegg et al. (1978; 1981) collected data from a dairy lagoon and from newly established swine lagoons and found that some of the monitoring wells became contaminated while others did not. This led him to conclude that seepage does not occur uniformly over the entire wetted perimeter of the lagoon, but at specific unpredictable sites where sealing has not taken place. Similarly, Ritter et al. (1980) monitored as anaerobic two-stage swine lagoon for two years, and found that one of the wells showed contamination which indicated localized seepage, while the other monitoring well indicted the lagoon system produced a minimum impact on ground water quality and that sealing had gradually taken place.

In many states, notwithstanding USEPA and USDA's manure handling, storage and treatment recommendations, lawsuits against CAFOs for unsound environmental practices demonstrate that CAFO operations are still creating problems. In short, regulations and legislation have fallen behind CAFO creation and operation, enforcement of existing regulations is spotty, and problems associated with CAFOs are still being identified—although you can be sure those who neighbor CAFOs can identify some big issues, both environmental and social. In this book, we discuss these "big issues" in detail.

Did You Know?

From the preceding, it should be apparent that the problem remains that lagoons have the unpredictable potential to affect both groundwater and surface water.

Animal Feedlot: Means a lot or building or combination of contiguous lots and buildings intended for the confined feeding, breeding, raising, or holding of animals and specifically designed as a confinement area where manure may accumulate, or where the concentration of animals is such that vegetative cover cannot be maintained within the enclosure. Open lots used for the feeding and rearing of poultry (poultry ranges) are considered animal feedlots, but pastures are not considered animal feedlots.

Animal Proteins: Livestock feed containing proteins obtained from meat packing or rendering plants, surplus milk or milk products, and marine sources.

Animal Studies: Investigations using animals as surrogates for humans with the expectation that the results are pertinent to humans.

Animal Unit (AU): A unit of measure that is used to compare different animal species:

1. EPA (66FR 2960-3138): 1 cattle excluding mature dairy and veal cattle; 0.7 mature dairy cattle; 2.5 swine weighing over 55 pounds; 10 swine weighing 55 pounds or less; 55 turkeys; 100 chickens; and 1 veal calf.
2. USDA: 1,000 pounds of live animal weight

Animal Waste Area: Means a holding area or lagoon used or intended to be used for the storage or treatment of animal manure and other waste products associated with an animal feedlot.

Animal Wastes: Consists of dung (fecal matter) and urine of animals.

Aniometer: A device that measures the velocity of air. Common types include the swinging vane and the hot-wire anemometer.

Anion: Negatively charged ion that can adsorb to negatively charged particles; an ion that is attracted to the anode. Common soils anions are nitrates and orthophosphates.

Anion Exchange: Ion exchange process in which anions in solution are exchanged for other anions from an ion exchanger.

Anisotropic: Having some physical property that varies with direction from a given location.

Anisotropy: In hydrology, the conditions under which one or more hydraulic properties of an aquifer vary from a reference point.

Annealing: In materials science, the sustained heating of a material, such as metal or glass, at a known high temperature, following by a gradual cooling, in order to reduce hardness or brittle, eliminate various stresses and weakness, or produce other desired qualities.

Annelida (aka ringed worms): A diverse phylum of segmented worms.

Annual Removals: The net volume of growing stock trees removed from the inventory during a specified year by harvesting, cultural operations such as timber land improvement, or land clearing.

Annular Space, Annulus: The space between two concentric tubes or casings, or between the casing and the borehole wall.

Anomie: State of apathy, anxiety, personal disorientation, alienation, and distress resulting from the loss of social norms and goals.

Anopheles: A genus of mosquito.

Anosomia: A lack of functioning olfaction; that is, a inability to perceive odors.

Anoxia: Deficiency of oxygen, especially one so severe as to result in permanent damage.

ANSI: American National Standards Institute.

Antagonism: Interference of inhibition of the effect of one chemical by the action of another.

Antagonist: A chemical that acts within the body to reduce the physiological activity of another chemical substance (as an opiate), especially one that opposes the action on the nervous system of a drug or a substance occurring naturally in the boy by combining with and blocking its nervous receptor.

Antagonistic Effect: A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together.

Antarctic "Ozone Hole": Refers to the seasonal depletion of ozone in the upper atmosphere above a large area of Antarctica.

Anthrax: An acute disease caused by the bacterial Bacillus anthracis.

Anthropogenic: Caused by humans.

Anthroposphere: In environmental science, the part of the biosphere that has been affected by human activity.

Antibiotic: A substance produced by bacteria or fungi that destroys or prevents the growth of other bacteria and fungi.

Antibody: A protein produced by the body's immune system in response to a foreign substance (antigen). Our bodies fight off an infection by producing antibodies. An antibody reacts specifically with the antigen that triggered its formation and its function is to inactivate the antigen.

Anticline: In earth science, an upward fold of stratified rock in which the sides slope down and away from the crest.

Anticoagulant: Any substance that delays, suppresses, or prevents coagulation of the blood.

Anticyclone: High atmosphere areas characterized by clear weather and the absence of rain and violent winds.

Anti-Degradation Clause: Part of federal air quality and water quality requirements prohibiting deterioration where pollution levels are above the legal limit.

Antifungal: A substance that inhibits fungi growth, kills it or inhibits their reproduction or growth.

Antigen: Any human substance, usually a protein that stimulates the body's immune system to produce antibodies.

Anti-Microbial: An agent that kills microbes.

Antioxidant: Compound used to prevent deterioration by oxidation.

Antiseptic: Any antimicrobial substance that is applied to living tissue to reduce the possibility of infection, sepsis, or putrefaction.

Antistatic: In materials science, describes an agent or material that serves to attract moisture from the air to a surface, thus improving the surface conductivity and reducing the likelihood of a spark or discharge.

APHIS: Animal and plant Health Inspection Service, a part of U.S. Department of Agriculture that provides leadership in ensuring the health and care of animals and plants.

Apical: Related to or situated at an apex.

Apoenzyme: The protein part of an enzyme.

Apogee: Point at which a satellite on an elliptical orbit path is farthest from the earth.

Applet: Java programs; an application program that uses the client's web browser to provide a user interface.

Applicable or Relevant and Appropriate Requirements (ARARs): Any state or federal statue that pertains to protection of human life and the environment in addressing specific conditions or use of a particular cleanup technology at a Superfund site.

Applied Dose: In exposure assessment, the amount of a substance in contact with the primary absorption boundaries of an organism (e.g., skin, lung tissue, gastrointestinal tract) and available for absorption.

Applied Population Ecology: *Note*: In attempting to explain any concept, it is always best to do so with an example in mind—an illustrative example. In the following, a stream ecosystem is the illustrative example used to help explain population ecology.

If stream ecology students wanted to study the organisms in a slow moving stream or stream pond, they would have two options. They could study each fish, aquatic plant, crustacean, insect, and macroinvertebrate one by one. In that case, they would be studying individuals. It would be easier to do this if the subject were trout, but it would be difficult to separate and study each aquatic plant.

The second option would be to study all of the trout, all of the insects of each specific kind, all of a certain aquatic plant type in the stream or pond at the time of the study. When stream ecologists study a group of the same kind of individuals in a given location at a given time, they are investigating a population. "Alternately, a population may be defined as a cluster of individuals with a high probability of mating with each other compared to their probability of mating with a member of some other population" (Pianka, 1988). When attempting to determine the population of a particular species, it is important to remember that time is a factor. Whether it is at various times during the day, during the different seasons, or from year to year, time is important because populations change.

When measuring populations, the level of species or density must be determined. Density (D) can be calculated by counting the number of individuals in the population (N) and dividing this number by the total units of space (S) the counted population occupies. Thus, the formula for calculating density becomes:

$$D = N/S$$

When studying aquatic populations, the occupied space (S) is determined by using length, width, and depth measurements. The volumetric space is then measured in cubic units.

Population density may change dramatically. For example, if a dam is closed off in a river midway through spawning season, with no provision allowed for fish movement upstream (a fish ladder), it would drastically decrease the density of spawning salmon upstream. Along with the swift and sometimes unpredictable consequences of change, it can be difficult to draw exact boundaries between various populations. Pianka (1988) makes this point in his comparison of European starlings that were introduced into Australia with starlings that were introduced into North America. He points out that these starlings are no longer exchanging genes with each other; thus, they are separate and distinct populations.

The population density or level of a species depends on natality, mortality, immigration and emigration. Changes in population density are the result of both births and deaths. The birth rate of a population is called natality and the death rate mortality. In aquatic populations, two factors besides natality and mortality can affect density. For example, in a run of returning salmon to their spawning grounds, the density could vary as more salmon migrated in or as others left the run for their own spawning grounds. The arrival of new salmon to a population from other places is termed immigration (ingress). The departure of salmon from a population is called emigration (egress). Thus, natality and immigration increase population density, whereas mortality and emigration decrease it. The net increase in population is the difference between these two sets of factors.

Population regulation is the control the size of a population. Population is limited by various factors. There are basically two different types of population limiting factors—classified according to the types of factors that control the size of the population. The population limiting factors are (1) density-dependent control and (2) density-independent control (Winstead, 2007).

1. **Density-dependent factors**—are ones where the effect of the factor on the size of the population depends upon the original density or size of the population. Density-dependent factors include (Abedon 2007):

   - Density-dependent limits on population growth are ones that stem from intraspecific competition
   - Typically, the organisms best suited to compete with another organism are those from the same species
   - Thus, the actions of conspecifics (again, an organism belonging to the same species as another) can very precisely serve to limit the environment (e.g., eat preferred food, obtain preferred shelter, etc.)
   - Actions of that serve to limit the environment for conspecifics—e.g., eating, excreting wastes, using up non-food resources, taking up space, defend-

ing territories—are those that determine carrying capacity (K)
- They are referred to as *density dependent* because the greater the density of the *population*, the greater their effects
- Density-dependent factors may exert their effect by reducing birth rates, increasing death rates, extending generation times, or by forcing the migration of conspecifics to new regions
- "The impact of disease on a population can be density dependent if the transmission rate of the disease depends on a certain level of crowding the population" (Campbell & Reece 2004)
- "A death rate that rises as population density rise is sad to be density dependent, as in a birth rate that falls with rising density. Density-dependent rates are an example of negative feedback. In contrast, a birth rate or death rate that does into change with population density is said to be density independent. . . . Negative feedback prevents unlimited population growth" (Campbell & Reece 2004)
- Predation can also be density dependent since predators often can switch prey preferences to match whatever prey organisms are more plentiful in a given environment
- "Many predators, for example, exhibit switching behavior: They begin to concentrate on a particularly common species of prey when it becomes energetically efficient to do so" (Campbell & Reece 2004).

2. **Density-Independent factor**—is one "where the effect of the factor on the size of the population is independent and does not depend upon the original density or size of the population. The effect of weather is an example of a density-independent factor. A severe storm and flood coming through an area can just as easily wipe out a large population as small one. Another example would be a harmful pollutant put into the environment, e.g., a stream. The probability of that harmful substance at some concentration killing an individual would not change depending on the size of the population. For example, populations of small mammals are often regulated more by this type of regulation" (Winstead 2007).
   - Density-independent effects on population sizes (or structures) occur to the same extent regardless of population size
   - These can be things like sudden changes in the weather
   - "Over the long term, many populations remain fairly stable in size and are presumably close to a carrying capacity that is determined by density-dependent factors. Superimposed on this general stability, however, are short-term fluctuations due to density-independent factors" (Campbell & Reece 2004).

Applied Water: Water delivered to the user.

Appropriate Doctrine: The system for allocating water to private individuals used in most Western states. The doctrine of Prior Appropriation was in common use throughout the arid west as early settlers and miners began to develop the land. The prior appropriation doctrine is based on the concept of "First in Time, First in Right." The first person to take a quantity of water and put it to Beneficial Use has a higher priority of right than a subsequent user. Under drought conditions, higher priority uses are satisfied before junior users receive water. Appropriative rights can be lost though nonuse; they can also be sold or transferred apart from the land. Contrasts with Riparian Water Rights.

Aquaculture: Farming of plants and animals that live in water, such as fish, shellfish, and algae.

Aquatic Ecology: In ecology, the study of the relationship between aquatic organism and their environment.

Aqueduct: A pipe, conduit, or channel designed to transport water from a remote source, usually be gravity.

Aqueous: Something made up of water.

Aqueous Solubility: The maximum concentration of a chemical that will dissolve in pure water at a reference temperature. Aqueous solubility is based on the chemical's respective Log Kow values:

Log Kow ≤ 1, soluble

Log Kow 1-5, slightly soluble

Log Kow > 5, insoluble

Aqueous Solution: Solution in which the solvent is water.

Aquifer: Any rock water-bearing stratum of permeable sand, rock, or gravel. The rock of an aquifer must be porous and permeable to absorb water.

Aquifer (confined): Soil or rock below the land surface that is saturated with water. There are layers of impermeable material both above and below it and it is under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer.

Aquifer Test: A test to determine hydraulic properties of an aquifer.

Aquifer (unconfined): An aquifer whose upper water surface (water table) is at atmospheric pressure, and thus is above to rise and fall.

Aquitard: A geologic formation, group of formations, or part of a formation through which virtually no water moves.

Arc-Flash Hazard: A dangerous condition associated with the release of energy caused by an electric arc.

Arc Rating: The maximum incident energy resistance demonstrated by a material (or a layered system of materials) prior to breakopen or at the onset of a second-degree skin burn. Arc rating is normally expressed cal/cm^2 (NFPA 70E).

Arc Welding/Torch Cutting Safety: In 29 CFR 1910.254 (Arc Welding and Cutting), OSHA specifically lists various safety requirements that must be followed when arc welding. For example, in equipment selection, OSHA stipulates the welding equipment must be chosen for safe application to the work to be done. Welding equipment must also be installed safely as per manufacturer's guidelines and recommendations. Finally, OSHA specifies that workpersons designated to operate arc-welding equipment must have been properly trained and qualified to operate such equipment. Training and Qualification procedures are important elements that must be included in any Welding Safety Program.

Archimedes Screw: A helix-shaped screw in an inclined cylinder that can manually or mechanically lift water from a lower level to a higher one.

Architectural Coatings: Coverings such as point and roof tar that are used on exteriors of buildings.

Area (A): The cross-sectional area through which air moves. Area may refer to the cross-sectional area of a duct, a window, a door, or any space through which air moves.

Area of Contamination (AOC) Policy: EPA interprets RCRA to allow certain discrete areas of generally dispersed contamination to be considered RCRA units. Therefore consolidation of material with an AOC and treatment of material, in situ, within an AOC does not create a point f hazardous waste generation for purposes of RCRA.

Area Source: Any source of air pollution that is released over a relatively small area but which cannot be classified as a point source. Such sources may include vehicles and other small engines, small businesses and household activities, or biogenic sources such as a forest that releases hydrocarbons.

Argillaceous. Shaly**.**

Argon (Ar - Greek *argos* 'idle'): A colorless, odorless, tasteless, nontoxic, nonflammable gaseous element (Noble gas). It constitutes almost 1% of the Earth's atmosphere and is plentiful compared to the other rare atmospheric gases. It is extremely inert and forms no known chemical compounds. It is slightly soluble in water.

Argon: Physical Properties
The physical properties of argon are noted in the Table.

Argon: Physical Properties

Chemical formula	Ar
Molecular weight	39.95
Density of the gas @ 70°F	0.103 lb/ft^3
Specific gravity of the gas @ 70°F	1.38
Specific volume of the gas @ 70°F	9.71 ft^3/lb
Boiling point at 1 atm	–302.6°F
Melting point at 1 atm	–308.6°F
Critical temperature	–188.1°F
Critical pressure	711.5 psia
Critical Density	33.444 lb/ft^3
Latent heat of vaporization @ boiling point and 1 atm	69.8 But/lb
Latent heat of fusion	12.8 Btu/lb

Argon Uses: is used extensively in filling incandescent and fluorescent lamps and electronic tubes; to provide a protective shield for growing silicon and germanium crystals; and as a blanket in the production of titanium, zirconium, and other reactive metals.

Arithmetic Growth: In measurement, an increase in a quantity at a constant rate per unit time over a specified time period.

Arithmetic Mean: A measurement of average value, calculated by summing all terms and dividing by the number of terms.

Arithmetic Scale: A series of intervals (marks or lines), usually made along the side or bottom of a graph, that represents the range of values of the data. When the marks or lines are equally spaced, it is called an arithmetic scale.

Aromatic Hydrocarbons: Class of hydrocarbons considered to be the most immediately toxic; found in oil and petroleum products; soluble in water. Antonym: aliphatic.

Aromatics: A type of hydrocarbon, such as benzene or toluene, with a specific type of ring structure. Aromatics are sometimes added to gasoline in order to increase octane. Some aromatics are toxic.

Array: In *computer science*, a series or collection of addressable data elements in the form of a grid or matrix; in *energy*, a set of photovoltaic modules or panels assembled for a specific application such as increased voltage or increased current.

Arrhenius Acid: A substance that when added to water increases the concentration of H^{1+} ion present.

Arrhenius Base: A substance that when added to water increases the concentration of OH^{1-} ions present.

Arrhenius Equation: In *chemistry*, an equation that describes the rate of a chemical reaction at a certain temperature, in which the rate is exponentially related to the temperature.

Arrhenius Law: In *chemistry*, states that the rate of chemical reaction is approximately doubled for every 10ºC increase in temperature.

Arrhenius Theory: In *electricity*, theorizes that electrolytes are separated, or dissociated, into electrically charged particles (ions) even when there is no current flowing thrugh the solution.

Arsenic: A highly poisonous metallic element existing in three forms, yellow, black, and gray, of which the brittle, crystalline gray is the most common. Arsenic and its compounds are used in insecticides, weed killers, solid-state doping agents, and various alloys. Absorbed arsenic will reach the liver. Once in the liver, the arsenic is converted to a nontoxic form by an enzyme and is then excreted from the body. In order for this enzyme to work, a chemical known as S-adenosylmethionine (SAM) must be present in the liver. SAM is a derivative of the amino acid methionine, which is essential to our health. There is only a certain amount of SAM in our liver that is available to combine with arsenic and render it nontoxic. If more arsenic enters the liver than the amount of available SAM can handle, then excess non-metabolized arsenic may accumulate in the liver and be distributed to other organs, causing toxic effects. This is known as metabolic saturation. As long as the amount of arsenic (i.e., the dose) is below this saturation level, our liver can detoxify it and no toxic effects will result. It is only when the amount of arsenic overwhelms the metabolic pathway that toxic effects can develop. This illustration of a threshold below which toxic effects do not occur is a key concept in toxicology.

Arsenicals: Pesticides containing arsenic.

Artesian (Aquifer or Well): A well deriving its water from a confined aquifer in which the water level stands above the ground surface; synonymous with flowing well.

Artesian Water: Groundwater that is under pressure when tapped by a well and is able to rise above the level at which it is first encountered. It may or many not flow out at ground level. The pressure in such an aquifer commonly is called artesian pressure, and the formation contain artesian water is an artesian aquifer or confined aquifer.

Artificial Recharge: A process where water is put back into groundwater storage from surface-water suppliers such as irrigation, or induced infiltration from streams or wells.

Asbestos: A broad mineralogical term applied to numerous fibrous silicates composed of silicon, oxygen, hydrogen, and metallic ions like sodium, magnesium, calcium and iron. At least six forms of asbestos occur naturally. Types of asbestos that are currently regulated—Actinolite, Amosite, Anthophylite, Chrysotile, Crocidolite, and Tremolite. In the late 1960s, asbestos use soared based on its insulation properties. Uses during this time-included component of rocket engines used in the space program, paper and cement products, and components of gaskets. Asbestos is naturally found in certain rock types (e.g., serpentinite), and is extracted from the rock and manufactured in indoor factories. Lots of dust containing asbestos was released into the indoor air environment during the process. Several years after people starting working in factories, several cases of a new type of lung cancer called mesothelioma began appearing in these workers. Soon it was determined that the asbestos fibers released into the air and inhaled caused this type of lung cancer. These incidents led to the current restricted use of asbestos by the USEPA. This restriction is the reason why asbestos is being removed from many older buildings. Due to these regulations and the restrictions on asbestos production and use, asbestos-related cancers were estimated to account for only about 5 percent of the approximately 2,000 lung cancers from airborne chemicals (other than cigarette smoke) reported in 1993 (equal to about 100 cases). This is a dramatic reduction from the rates seen in the 1970s and early 1980s. Because many years might elapse between asbestos exposure and cancer, most of these cases likely are related to when asbestos was still manufactured, rather than recent exposure cases.

Asbestos Abatement: Procedures to control fiber release from asbestos-containing materials in a building or to remove them entirely, including removal, encapsulation, repair, enclosure, encasement, and operations and maintenance programs.

Asbestos Assessment: In the asbestos-in-schools program, the evaluation of the physical condition and potential for damage of all friable asbestos containing materials and thermal insulation systems.

Asbestos-Containing Waste Materials (ACWM): Mill tailings or any waste that contains commercial asbestos and is generated by a soruce covered by the Clean Air Act Asbestos NESHAPS.

Asbestos Program Manager: A building owner or designated representative who supervise all aspects of the facility asbestos management and control program.

Asbestosis: A disease associated with inhalation of asbestos fibers. The disease makes breathing progressively more difficult and can be fatal.

A-Scale Sound Level: A measurement of sound approximating the sensitivity of the human ear, used to note the intensity or annoyance level of sounds. **Aseptic:** Free of pathogenic microorganisms.

Ascorbic Acid: Vitamin C.

Asexual Reproduction: The naturally occurring ability of some plant species to reproduce asexually through seeds, meaning the embryos develop without a male gamete. This ensures the seeds will produce plants identical to the mother plant.

Ash: The mineral content of a product remaining after complete combustion.

ASHARA: Passed in 1990, Asbestos School Hazard Abatement Reauthorization Act (ASHARA), required accreditation of personnel working on asbestos activities in schools and public and commercial buildings.

ASM: Aerosol mass spectrometer.

Aspect: Individual azimuthal map projections are divided into three aspects: the polar aspect which is tangent at the pole, the equatorial aspect which is tangent at the equator, and the oblique aspect which is tangent anywhere else.

Aspergillosis: A wide variety of diseases caused by fungi of the genus Aspergillosis.

Asphalt Incorporation: Soil remediation/recycling process whereby contaminated soil is removed from site and fed into an asphalt-making process as part of the aggregated filler substance.

Asphyxiant: A substance capable of inducing asphyxia, which is a lack of oxygen or an excess of carbon dioxide in the body, usually caused by the interruption of breathing and resulting in unconsciousness.

Asphyxiation: Suffocation from lack of oxygen. A substance (e.g., carbon monoxide), that combines with hemoglobin to reduce the blood's capacity to transport oxygen produces chemical asphyxiation. Simple asphyxiation is the result of exposure to a substance (such as methane) that displaces oxygen.

Asphyxiation: Being deprived of oxygen.

Assay: A test for a specific chemical, microbe, or effect.

Assessment Endpoint: In ecological risk assessment, an explicit expression of the environmental value to be protected; includes both an ecological entity and specific attributed thereof entity (e.g., salmon are a valued ecological entity; reproduction and population maintenance—the attribute—form an assessment endpoint.)

Assimilation: The ability of a body of water to purify itself of pollutants.

Assimilative Capacity: The capacity of a natural body of water to receive wastewaters or toxic materials without deleterious effects and without damage to aquatic life or humans who consume the water.

Associated Gas: Natural gas that is in contact with crude oil in the reservoir.

ATM (Atmosphere): In physics, a unit of pressure whereby 1 atmosphere (atm) equals 14.7 pounds per square inch (psi).

Atmosphere: 500-kilometer thick layer of colorless, odorless gases known as air that surrounds the earth and is composed of nitrogen, oxygen, argon, carbon dioxide, and other gases in trace amounts.

Atmospheric Carbon Dioxide: *Carbon dioxide* (CO_2) is a colorless, odorless gas (although it is felt by some persons to have a slight pungent odor and biting taste), slightly soluble in water and denser than air (one and half times heavier than air), and a slightly acid gas. Carbon dioxide gas is relatively non-reactive and nontoxic. It will not burn, and it will not support combustion or life.

CO_2 is normally present in atmospheric air at about 0.035% by volume and cycles through the biosphere (Carbon Cycle). Carbon dioxide, along with water vapor, is primarily responsible for the absorption of infrared energy re-emitted by the Earth and, in turn, some of this energy is reradiated back to the Earth's surface. It is also a normal end product of human and animal metabolism. The exhaled breath contains up to 5.6 percent carbon dioxide. In addition, the burning of carbon-laden fossil fuels releases carbon dioxide into the atmosphere. Much of this carbon dioxide is absorbed by ocean water, some of it is taken up by vegetation through photosynthesis in the carbon cycle, and some remains in the atmosphere. Today, it is estimated that the concentration of carbon dioxide in the atmosphere is approximately 350 parts per million (ppm) and is rising at a rate of approximately 20 ppm every decade. The increasing rate of combustion of coal and oil has been primarily responsible for this occurrence, which (as we will see later in this text) may eventually have an impact on global climate.

Carbon Dioxide: Physical Properties

The physical properties of carbon dioxide are noted in the Table.

Carbon Dioxide: Physical Properties

Chemical formula	CO_2
Molecular weight	44.01
Vapor Pressure @ 70°F	838 psig
Density of the gas @ 70°F & 1 atm	0.1144 lb/ft^3
Specific gravity of the gas @ 70°F & 1 atm (air = 1)	1.522
Specific volume of the gas @ 70°F & 1 atm	8.741 ft^3/lb
critical temperature	–109.3°F
critical pressure	1070.6 psia
critical density	29.2 lb/ft^3
Latent heat of vaporization @ 32°F	100.8 Btu/lb
Latent heat of fusion @ –69.9°F	85.6 Btu/lb

Carbon Dioxide: Uses

Solid carbon dioxide is used quite extensively to refrigerate perishable foods while in transit. It is also used as a cooling agent in many industrial processes, such as grinding, rubber work, cold-treating metals, vacuum cold traps, and so on.

Gaseous carbon dioxide is used to carbonate soft drinks, for pH control in water treatment, in chemical processing, as a food preservative, and in pneumatic devices.

Atmospheric Dispersion Modeling: The mathematical simulation of how air pollutants disperse in the ambient atmosphere.

Atmospheric Helium: *Helium* (He - Greek *helios* 'Sun') is inert (and as a result, does not appear to have any major effect on, or role in, the atmosphere), nontoxic, odorless, tasteless, non-reactive, forms no compounds, colorless and makes about 0.00005 percent (5 ppm) by volume of air in the Earth's atmosphere. Helium, as with neon, krypton, hydrogen, and xenon, is a noble gas. Helium is the second lightest element; only hydrogen is lighter. It is one-seventh as heavy as air. Helium is nonflammable and is only slightly soluble in water.

Helium: Physical Properties

The physical properties of helium are noted in the Table.

Helium: Physical Properties

Chemical formula	He
Molecular weight	4.00
Density of the gas @ 70°F & 1 atm	0.0103 lb/ft^3
Specific gravity of the gas @ 70°F & 1 atm	0.138
Specific volume of the gas @ 70°F & 1 atm	97.09 ft^3/lb
Boiling point @ 1 atm	–452.1°F
Critical temperature	–450.3°F
Critical pressure	33.0 psia
Critical density	4.347 lb/ft^3
Latent heat of vaporization @ boiling point & 1 atm	8.72 But/lb

Atmospheric Hydrogen: *Hydrogen* (H_2 - Greek *hydros* + *gen* 'water generator') is a colorless, odorless, tasteless, nontoxic, flammable gas. It is the lightest of all the elements and occurs on Earth chiefly in combination with oxygen as water. Hydrogen is the most abundant element in the universe, where it accounts for 93 percent of the total number of atoms and 76 percent of the total mass. It is the lightest gas known, with a density approximately 0.07 that of air. Hydrogen is present in the atmosphere, occurring in concentrations of only about 0.5 ppm by volume at lower altitudes.

Hydrogen: Physical Properties

The physical properties of hydrogen are noted in the Table.

Hydrogen: Physical Properties

Chemical formula	H_2
Molecular weight	2.016
Density of the gas @ 70°F & 1 atm	0.00521 lb/ft^3
Specific gravity of the gas @ 70° & 1 atm	0.06960
Specific volume of the gas @ 70°F & 1 atm	192.0 ft^3/lb
Boiling point @ 1 atm	–423.0°F
Melting point @ 1 atm	–434.55°F
Critical temperature	–399.93°F
Critical pressure	190.8 psia
Critical density	1.88 lb/ft^3
Latent heat of vaporization @ boiling point	191.7 Btu/lb
Latent heat of fusion	24.97 Btu/lb

Hydrogen: Uses

Hydrogen is used by refineries, petrochemical, and bulk chemical facilities for hydro-treating, catalytic reforming, and hydro-cracking. Hydrogen is used in the production of a wide variety of chemicals. Metallurgical companies use hydrogen in the production of their products. Glass manufacturers use hydrogen as a protective atmosphere in a process whereby molten glass is floated on a surface of molten tin. Food companies hydrogenate fats, oils, and fatty acids to control various physical and chemical properties. Electronic manufacturers use hydrogen at several steps in the complex processes for manufacturing semiconductors.

Atmospheric Krypton: *Krypton* (Kr–Greek *kryptos* 'hidden') is a colorless, odorless, inert gaseous component of Earth's atmosphere. It is present in very small quantities in the air (about 114 parts per million—ppm).

Krypton: Physical Properties
The physical properties of krypton are noted in the Table.

Krypton: Physical Properties

Chemical formula	Kr
Molecular weight	83.80
Density of the gas @ 70°F & 1 atm	0.2172 lb/ft^3
Specific gravity of the gas @ 70°F & 1 atm	2.899
Specific volume of the gas @ 70°F & 1 atm	4.604 ft^3/lb
Boiling point @ 1 atm	–244.0°F
Melting point @ 1 atm	–251°F
Critical temperature	–82.8°F
Critical pressure	798.0 psia
Critical density	56.7 lb/ft^3
Latent heat of vaporization @ boiling point	46.2 Btu/lb
Latent heat of fusion	8.41 But/lb

Krypton: Uses

Krypton is used principally to fill lamp bulbs and tubes. The electronics industry uses it singly or in mixture in many types of gas-filled electron tubes.

Atmospheric Neon: *Neon* (Ne - Greek *neon* 'new') is a colorless, odorless, gaseous, nontoxic, chemically inert element. Air is about 2 parts per thousand neon by volume.

Neon: Physical Properties
The physical properties of neon are noted in the Table.

Neon: Physical Properties

Chemical formula	Ne
Molecular weight	20.183
Density of the gas @ 70°F & 1 atm	0.05215 lb/ft^3
Specific gravity of the gas @ 70°F & 1 atm	0.696
Specific volume of the gas @ 70°F & 1 atm	19.18 ft^3/lb
Boiling point at 1 atm	–410.9°F
Melting point at 1 atm	–415.6°F
Critical temperature	–379.8°F
Critical pressure	384.9 psia
Critical density	30.15 lb/ft^3
Latent heat of vaporization @ boiling point	37.08 But/lb
Latent heat of fusion	7.14 Btu/lb

Neon: Uses
Neon is used principally to fill lamp bulbs and tubes. The electronics industry uses neon singly or in mixtures with other gases in many types of gas-filled electron tubes.

Atmospheric Nitrogen: Nitrogen (N_2) makes up the major portion of the atmosphere (78.03 percent by volume, 75.5 percent by weight). It is a colorless, odorless, tasteless, nontoxic, and almost totally inert gas. Nitrogen is nonflammable, will not support combustion, and is not life supporting. "Not life supporting?" No, gaseous nitrogen it is not. The obvious question becomes: If gaseous nitrogen does not support life, what is it doing in our atmosphere—what good is it? Logical question. However, the question is incorrect; it implies something that is not true: nitrogen is indeed good and more. Without nitrogen, we could not survive.

Nitrogen is part of Earth's atmosphere primarily because, over time, it has simply accumulated in the atmosphere and remained in place and in balance. This nitrogen accumulation process has occurred because, chemically, nitrogen is not very reactive. When released by any process, it tends not to recombine with other elements and accumulates in the atmosphere. And this is a good thing, because we need nitrogen. No, we don't need it for breathing but we need it for other life-sustaining processes.

Let's take a look at a couple of reasons why gaseous nitrogen is so important to us. Although nitrogen in its gaseous form is of little use to us, after oxygen, carbon, and hydrogen, it is the most common element in living tissues. As a chief constituent of chlorophyll, amino acids and nucleic acids—the "building blocks" of proteins (which are used as structural components in cells)—nitrogen is essential to life. Nitrogen is dissolved in and is carried by the blood. Nitrogen does not appear to enter into any chemical combination as it is carried throughout the body. Each time we breathe, the same amount of nitrogen is exhaled as is inhaled. Animals cannot use nitrogen directly but only when it is obtained by eating plant or animal tissues; plants obtain the nitrogen they need when it is in the form of inorganic compounds, principally nitrate and ammonium.

Gaseous nitrogen is converted to a form usable by plants (nitrate ions) chiefly through the process of nitrogen fixation via the nitrogen cycle.

Via the *nitrogen cycle*, aerial nitrogen is converted into nitrates mainly by microorganisms, bacteria, and blue-green algae. Lightning also converts some aerial nitrogen gas into forms that return to the earth as nitrate ions in rainfall and other types of precipitation. Ammonia plays a major role in the nitrogen cycle. Excretion by animals and anaerobic decomposition of dead organic matter by bacteria produce ammonia. Ammonia, in turn, is converted by nitrification bacteria into nitrites and then into nitrates. This process is known as nitrification. Nitrification bacteria are aerobic. Bacteria that convert ammonia into nitrites are known as nitrite bacteria (*Nitrosococcus* and *Nitrosomonas*). Although nitrite is toxic to many plants, it usually does not accumulate in the soil. Instead, other bacteria (such as *Nitrobacter*) oxidize the nitrite to form nitrate (NO_3^-), the most common biologically usable form of nitrogen.

Nitrogen reenters the atmosphere through the action of denitrifying bacteria, which are found in nutrient-rich habitats such as marshes and swamps. These bacteria break down nitrates into nitrogen gas and nitrous oxide (N_2O), which then re-enter the atmosphere. Nitrogen also reenters the atmosphere from exposed nitrate deposits, emissions from electric power plants, and automobiles, and from volcanoes.

Nitrogen: Physical Properties
The physical properties of nitrogen are noted in the Table

Nitrogen: Physical Properties

Chemical formula	N_2
Molecular weight	28.01
Density of gas @ 70°F	0.072 lb/ft^3
Specific gravity of gas @ 70°F & 1 atm (air = 1)	0.967
Specific volume of gas @ 70°F & 1 atm	13.89 ft^3
Boiling point @ 1 atm	–320.4°F
Melting point @ 1 atm	–345.8°F
Critical temperature	–232.4°F
Critical pressure	493 psia
Critical density	19.60 lb/ft^3
Latent heat of vaporization @ boiling point	85.6 Btu/lb
Latent heat of fusion @ melting point	11.1 Btu/lb

Nitrogen: Uses

In addition to being the preeminent (in regards to volume) component of Earth's atmosphere and providing an essential ingredient in sustaining life, nitrogen gas has many commercial and technical applications. As a gas, it is used in: heat treating primary metals; the production of semi-conductor electronic components, as a blanketing atmosphere; blanketing of oxygen-sensitive liquids and of volatile liquid chemicals; inhibition of aerobic bacteria growth; and the propulsion of liquids through canisters, cylinders, and pipelines.

Atmospheric Oxygen: Oxygen (O_2–Greek *oxys* 'acid' *genes* 'forming') constitutes approximately a fifth (21% by volume and 23.2% by weight) of the air in Earth's atmosphere. Gaseous oxygen (O_2) is vital to life as we know it. On Earth, oxygen is the most abundant element. Most oxygen on Earth is not found in the free state, but in combination with other elements as chemical compounds. Water and carbon dioxide are common examples of compounds that contain oxygen, but there are countless others.

At ordinary temperatures, oxygen is a colorless, odorless, tasteless gas that not only supports life but also combustion. All the elements except the inert gases combine directly with oxygen to form oxides. However, oxidation of different elements occurs over a wide range of temperatures.

Oxygen is nonflammable but it readily supports combustion. All materials that are flammable in air burn much more vigorously in oxygen. Some combustibles, such as oil and grease, burn with nearly explosive violence in oxygen if ignited.

Oxygen: Physical Properties
The physical properties of oxygen are noted in the Table

Oxygen: Physical Properties

Chemical formula	O^2
Molecular weight	31.9988
Freezing point	–361.12°F
Boiling point	–297.33°F
Heat of fusion	5.95 Btu/lb
Heat of vaporization	91.70 Btu/lb
Density of gas @ boiling point	0.268 lb/ft^3
Density of gas @ room temperature	0.081 lb/ft^3
Vapor density (air = 1)	1.105
Liquid-to-gas expansion ratio	875

Oxygen: Uses
The major uses of oxygen stem from its life-sustaining and combustion-supporting properties. It also has many industrial applications (when used with other fuel gases such as acetylene) including metal cutting, welding, hardening, and scarfing.

Atmospheric Particulate Matter: There are significant numbers of particles (particulate matter) suspended in the atmosphere, particularly the troposphere. These particles originate in nature from smokes, sea sprays, dusts, and the evaporation of organic materials from vegetation. There is also a wide variety of nature's living or semi-living particles—spores and pollen grains, mites and other tiny insects, spider webs, and diatoms. The atmosphere also contains a bewildering variety of anthropogenic (man-made) particles produced by automobiles, refineries, production mills, and many other human activities.

Atmospheric particulate matter varies greatly in size (colloidal-sized particles in the atmosphere are called aerosols—usually less than 0.1 μm in diameter); the smallest are gaseous clusters and ions and submicroscopic liquids and solids; somewhat larger ones produce the beautiful blue haze in distant vistas; those 2 to 3 times larger are highly effective in scattering light; and the largest consist of such things as rock fragments, salt crystals, and ashy residues from volcanoes, forest fires, or incinerators.

The numbers of which particulates are concentrated in the atmosphere varies greatly—ranging from more than 10,000,000/cubic centimeter to less than 1/L (0.001/cc). Excluding the particles in gases as well as vegetative material, sizes range from 0.005 to 500 microns, a variation in diameter of 100,000 times.

The largest number of airborne particulates is always in the invisible range. These numbers vary from less than 1 liter to more than a half million per cubic centimeter in heavily polluted air, and to at least 10 times more than that when a gas-to-particle reaction is occurring (Schaefer & Day, 1981).

Based on particulate level, there are two distinct regions in the atmosphere: very clean and dirty. In the clean parts there are so few particulates that they are almost invisible, making them hard to collect or measure. In the dirty parts of the atmosphere—the air of a large metropolitan area—the concentration of particles includes an incredible variety of particulates from a wide variety of sources.

Atmospheric particulate matter performs a number of functions and undergoes several processes, and is involved in many chemical reactions in the atmosphere. Probably the most important function of particulate matter in the atmosphere is their action as nuclei for the formation of water droplets and ice crystals. Much of the work of Vincent J. Schaefer (inventor of cloud seeding) involved using dry ice in early attempts, but later evolved around the addition of condensing particles to atmospheres supersaturated with water vapor and the use of silver iodide, which forms huge numbers of very small particles. Another important function of atmospheric particulate matter is that they help determine the heat balance of the Earth's atmosphere by reflecting light. Particulate matter is also involved in many chemical reactions in the atmosphere such as neutralization, catalytic effects, and oxidation reactions. These chemical reactions will be discussed in greater detail later.

Atmospheric Pressure: The pressure exerted in all directions by the atmosphere. At sea level, mean atmospheric pressure is 29.92 in HG, 14.7 psi, 407 in w.g., or 760 mm HG.

Atmospheric Stability: A property that depends on inversion strength—how rapidly air temperature rises with altitude (in units of degrees Celsius per 100 m). Strong inversions near the ground tend to stabilize the atmosphere, trap emissions, and result in higher pollutant concentrations. For a discussion of meteorological effects on carbon monoxide concentrations, see NRC (2002).

Atmospheric Water: Leonardo da Vinci understood the importance of water when he said: "Water is the driver of nature." da Vinci was actually acknowledging what most scientists and many of the rest of us have come to realize: Water, propelled by the varying temperatures and pressures in Earth's atmosphere, allows life as we know it to exist on our planet (Gradel & Crutzen, 1995).

The water vapor content of the lower atmosphere (troposphere) is normally with a range of 1–3 percent by volume with a global average of about 1%. However, the percentage of water in the atmosphere can vary from as little as 0.1 percent or as much as 5 percent water, depending upon altitude; water in the atmosphere decreases with increasing altitude. Water circulates in the atmosphere in the hydrologic cycle.

Water vapor contained in Earth's atmosphere plays several important roles: (1) it absorbs infrared radiation; (2) it acts as a blanket at night, retaining heat from the Earth's surface; and (3) it affects the formation of clouds in the atmosphere.

Atmospheric Xenon: *Xenon* (Xe - Greek *xenon* 'stranger') is a colorless, odorless, nontoxic, inert, heavy gas that is present in very small quantities in the air (about 1 part in 20 million).

Xenon: Physical Properties
The physical properties of xenon are noted in the Table.

Xenon: Physical Properties

Chemical formula	Xe
Molecular weight	131.3
Density of the gas @ 70°F & 1 atm	0.3416 lb/ft^3
Specific gravity of the gas @ 70°F & 1 atm	4.560
Specific volume of the gas @ 70°F & 1 atm	2.927 ft^3/lb
Boiling point at 1 atm	–162.6°F
Melting point at 1 atm	–168°F
Critical temperature	61.9°F
Critical pressure	847.0 psia
Critical density	68.67 lb/ft^3
Latent heat of vaporization at boiling point	41.4 Btu/lb
Latent heat of fusion	7.57 Btu/lb

Xenon: Uses
Xenon is used principally to fill lamp bulbs and tubes. The electronics industry uses it singly or in mixtures in many types of gas-filled electron tubes.

Atom: Smallest particle of an element that still retains the characteristics of that element.

Atomic Number: The number of protons in the nucleus of an atom.

Atomic Orbitals/Electron Shells: The region around the nucleus of an atom in which an electron is most likely to be found.

Atomic Theory: The ancient Greek philosophers believed that all the matter in the universe was composed of four elements: earth, fire, air, and water. Today we know of more than 100 different elements and scientists are attempting to create additional elements in their laboratories. An **element** is a substance from which no other material can be obtained.

Today, we know that ***atoms*** are the basic building blocks of all *matter*. ***Atoms*** equal the smallest particle of matter with constant properties. Atoms are so small that it would take approximately TWO THOUSAND MILLION atoms side by side to equal one meter in length! Atoms are so small that scientists were forced to devise special weights and measures

- Mass/weight: **atomic units** (**au**)

» $1 \text{ au} = 1.6604 \times 10^{-24}$ g

- Length: ***Angstrom (Å)***

» $1 \text{ Å} = 10^{-8}$ cm

It is interesting to note that scientists used to believe that atoms were *indivisible*, but we now know that they are made up of many **subatomic particles.** Chemistry primarily deals with three *subatomic particles:* ***protons, neutrons,*** and ***electrons.***

- ***Protons*** and ***neutrons*** are located in the nucleus (center) of the atom
- ***Electrons*** are located in "orbitals" around the nucleus

Particle	**Charge**	**Mass**
Proton (P)	+	1 atomic unit
Neutron (N)	no charge	1 atomic unit
Electron (e)	–	(none)

- **Key Point:** An atom contains sub-atomic particles including:

Protons (+) positively charged particle

Electrons (-) negatively charged particle
Neutrons (0) have no charge

The ***stability*** of a nucleus depends on the balance between:

- Attractive gravitational forces ↓ →← ↑
- Repulsive electronic forces ↑ ←→ ↓
- The ratio of protons to neutrons

✔ **Key Point:** In a stable atom (or neutral atom), the number of electrons = the number of protons.

Atomic Weight: The sum number of protons and the number of neutrons in the nucleus of an atom.

Atomize: To divide a liquid into extremely minute particles, either by impact with a jet of steam or compressed air, or by passage through some mechanical device.

Atomizer: A device for reducing a liquid and ejecting it as a fine mist, spray or vapor.

Atrophy: The partial or complete wasting away of a part of the body.

Attainment Area: An area considered to have air quality as good as or better than the national ambient air quality standards as defined in the Clean Air Act. An area may be an attainment area for one pollutant and a non-attainment area for others.

Attenuation: 1. The reduction of the intensity at a designated first location as compared with intensity at a second location, which is farther from the source (reducing the level of noise by increasing distance from the source is a good example). 2. Attenuation: Real Ear Attenuation at Threshold (REAT)—A standardized procedure for conducting psychoacoustic tests on human subjects designed to measure sound protection features of hearing protective devices. Typically, these measures are obtained in a calibrated sound field, and represent the difference between subjects' hearing thresholds when wearing a hearing protector vs. not wearing the protector. 3. Attenuation: *Real-World*—Estimated sound protection provided by hearing protective devices as worn in "real-world" environments.

Attractant: A chemical or agent that lures insects or other pests by stimulating their sense of smell.

Attribution: Concept employed in understanding the human versus natural causes of climate change.

Attrition: Wearing or grinding down of a substance by friction. Dust from such processes contributes to air pollution.

Atwater System: Used for the available energy in foods; that is, describes the available caloric value of different types of foods.

Audible Range: The frequency range over which normal hearing occurs—approximately 20 Hz through 20,000 Hz. Above the range of 20,000 Hz, the term ultrasonic is used. Below 20 Hz, the term subsonic is used.

Audible Sound: The sound that contains frequency components between 20 and 20,000 Hz.

Audiogram: A record of hearing loss or hearing level measured at several different frequencies—usually 500 to 6000 Hz. The audiogram may be presented graphically or numerically. Hearing level is shown as a function of frequency.

Audiometric Testing: Audiometric testing is the objective measuring of a person's hearing sensitivity. By recording the response to a measured signal, a person's level of hearing sensitivity can be expressed in decibels, as related to an audiometric zero, or no-sound base. Audiometric testing is an important element of the Hearing Conservation Program for two reasons: It helps to determine the effectiveness of hearing protection and administrative and/or engineering controls. Audiometric surveillance also helps to detect hearing loss before it noticeably affects the employee and before the loss becomes legally compensable under workers' compensation. Audiometric examinations are usually done by an outside contractor, but can be done in-house with the proper equipment. Wherever they are done, they require properly calibrated equipment used by a trained and certified audiometric technician.

The importance of audiometric evaluations cannot be overstated. Not only do they satisfy the regulatory requirement, but they also work to tie the whole program together. One thing is certain—if the Hearing Conservation Program is working, employees' audiometric results will not show changes associated with on-the-job noise-induced hearing damage. If suspicious hearing changes are found, the audiometric technician and the audiologist who reviews the record can counsel the employee to wear hearing protection devices more carefully, can assess whether better hearing protection devices are needed, and can use the test results to point out to the employee the need to be more careful in protecting his or her hearing—both on and off the job.

Audiometric Zero: The threshold of hearing; 0.0002 μbar of sound pressure.

Audit: The independent collection of records to assess their veracity and completeness.

Audit Trail: In computer security systems, a chronological record of when users log in, how long they arc engaged in various activities, what they were doing, whether any actual or attempted security violations occurred. An audit trail may be on paper or on disk.

Auger: A tool used to bore holes in soil to capture a sample.

Authentication: The process of confirming the correctness of the claimed identity.

Authorized Person: A person designated or assigned by an employer or supervisor to perform a specific type of duty or duties, to use specified equipment, and/or to be present in a given location at specified times. For example, in lockout/tagout, a person who locks out or tags out machines or equipment to perform servicing or maintenance on that machine or equipment. An affected employee becomes an authorized person when that person's duties include performing servicing or maintenance covered under the organization's lockout/tagout program.

Authorized User: An employee who is approved by the RSO and RSC and is ultimately responsible for the safety of those who use radioisotopes under his/her supervision.

Auto-Ignition Temperature: The lowest temperature at which a vapor-producing substance or a flammable gas will ignite even without the presence of a spark or flame.

Automatic Samplers: Devices that automatically take samples from a wastestream.

Autotrophic Organisms: An self-feeding organism that can synthesize organic molecules needed for growth from inorganic compounds using light or another source of energy.

Availability Session: Informal meeting at a public location where interested citizens can talk with EPA and stat officials on a one-to-one basis.

Available Chlorine: A measure of the amount of chlorine available in chlorinated lime, hypochlorite compounds, and other materials used as a source of chlorine when compared with that of liquid or gaseous chlorines.

Available Energy: In *thermodynamics*, the potential do to work; the maximum amount of energy able to be utilized for work.

Available Heat: In *thermodynamics*, the gross quantity of heat released within a combustion chamber minus the sensible heat carried away by the dry flue gases, the latent heat, and the sensible heat carried away in water vapor contained in the flue gases.

Available Nitrogen: For of nitrogen that is immediately available for plant growth.

Available Nutrient: A nutrient molecule that can be adsorbed and assimilated by growing plants.

Available Phosphorus: Forms of phosphorus that can be immediately used for plant growth.

Availability Factor: A percentage representing the number of hours a generating unit is available to produce power (regardless of the amount of power) in a given period, compared to the number of hours in the period.

Available Water Capacity (available moisture capacity): The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil. The capacity, in inches, in a 60-inch profile is expressed as:

Very low	0 to 3 inches
Low	3 to 6 inches
Moderate	6 to 9 inches
High	9 to 12 inches
Very high	> 12 inches

Avogadro's Number: The number of carbon atoms in 12 g of the carbon-12 isotope (6.022045×10^{23}). The relative atomic mass of any element, expressed in grams, contains this number of atoms.

Awareness Level Training: First responders at the awareness level are those persons who, in the course of their normal duties may be the first on the scene of an emergency involving hazardous materials. First responders at the awareness level are expected to recognize hazardous materials presence, protect themselves, call for trained personnel, and secure the area (NFPA 472).

Axon: A long, thread-like part of a nerve cell that carries an impulse away from the nerve body.

Azimuth: The angle measured in degrees between base line radiating from a center point and another line radiating from the same point. Normally, the base line points North and degrees are measured clockwise from the base line.

Azimuth Angle: The angle between true south and the point on the horizon directly below the sun.

B

B20: In *biomass*, a mixture of 20 percent biodiesel and 80 percent petroleum diesel based on volume.

Babbit: An alloy of tine, antimony, copper, and lead used for bearings.

Bacillary Dysentery: A severe form of shigellosis (bacterial infection of the mucosal surface of the intestines).

Bacilli (pl.), ***Bacillus*** (sing): Members of a group of rodlike bacteria that occur everywhere in soil and air. Some are responsible for diseases such as anthrax or for causing food spoilage.

Back Pressure: A pressure that can cause water to backflow into the water supply when a user's waste water system is at a higher pressure than the public system.

Back Pressure Turbine: In *energy conversion*, a type of turbine used in combined heat and power operations, in which the turbine generator is employed to extract more energy from low-pressure steam in a steam distribution pipeline.

Backfit: The imposition of a new or proposed nuclear safety requirement which dictates the modification of, or addition to: (1) systems, structures, and components of a facility; (2) the existing or approved design of a facility; or (3) the procedures or organization required to design, construct, or operate a facility (EH62dd1).

Backflow/Back Siphonage: A reverse flow condition created by a difference in water pressure that causes water to flow back into the distribution pipes of a drinking water supply from any source other than the intended one.

Background Level: 1. The concentration of a substance in an environmental media (air, water, or soil) that occurs naturally or is not the result of human activities. 2. In exposure assessment, the concentration of a substance in a defined control area, during a fixed period of time before, during, or after a data-gathering operation.

Background Noise: All of the sources of interference (noise coming from sources other than the source being monitored) in a system used for the production, detection, measurement, or recording of a sign, independent of the presence of a signal.

Background Radiation: Low-intensity ionizing radiation arising from radioactive material other than that being directly considered.

From:

(i) Naturally occurring radioactive materials which have not been technological enhanced
(ii) Cosmic sources
(iii) Global fallout as it exists in the environment (such as from the testing of nuclear explosive devices)
(iv) Radon and its progeny in concentrations or levels exiting in buildings or the environment which have not been elevated as a result of current or prior activities
(v) Consumer products containing nominal amounts of radioactive material or producing nominal amounts of radiation (10 CFR 835.20).

Backwashing: Reversing the flow of water back through the filter media to remove entrapped solids.

BACT (Best Available Control Technology): An emission limitation based on the maximum degree of emission reduction (considering energy, environmental, and economic impacts) achievable through application of production processes and available methods, systems, and techniques. BACT does not permit emissions in excess of these allowed under any applicable Clean Air Act provisions. Use of the BACT concept is allowable on a case-by-case basis for major new or modified emissions sources in attainment areas and applies to each regulated pollutant.

Bacteria (**Singular: bacterium):** The simplest wholly contained life systems are *bacteria or prokaryotes*, which are the most diverse group of microorganisms. They are single-cell, microscopic living organisms (single-celled microorganisms) that possess rigid cell walls. They may be aerobic, anaerobic, or facultative; they can cause disease; and some are important in pollution control.

Bacteria are among the most common microorganisms in water and contain about 85 percent water and 15 percent ash or mineral matter. The ash is largely composed of sulfur, potassium, sodium, calcium, and chlorides, with small amounts of iron, silicon and magnesium. Bacteria reproduce by binary fission.

Note: Binary fission occurs when one organism splits or divides into two or more new organisms.

Bacteria, once called the smallest living organisms (now it is known that smaller forms of matter exhibit many of the characteristics of life), range in size from 0.5–2 microns in diameter and about 1–10 microns long.

Note: A *micron* is a metric unit of measurement equal to 1 thousandth of a millimeter. To visualize the size of bacteria, consider that about 1,000 bacteria lying side-by-side would reach across the head of a straight pin.

Bacteria are categorized into three general groups based on their physical form or shape (though almost every variation has been found; see Table). The simplest form is the sphere. Spherical-shaped bacteria are called *cocci*. Cocci mean "berries." They are not necessarily perfectly round, but may be somewhat elongated, flattened on one side, or oval. Rod shaped bacteria is called *bacilli*. Spiral shaped bacteria (called Spirilla), which have one or more twists and are never straight, make up the third group. Such formations are usually characteristic of a particular genus or species. Within these three groups are many different arrangements. Some exist as single cells; others as pairs, as packets of four or eight, as chains, and as clumps.

Forms of Bacteria

	Technical Name		
Form	*Singular*	*Plural*	*Example*
Sphere	Coccus	Cocci	Streptococcus
Rod	Bacillus	Bacilli	Bacillus typhosis
Curved or spiral	Spirillum	Spirilla	Spirillum cholera

Most bacteria require **organic food** to survive and multiply. Plant and animal material that gets into the water provides the food source for bacteria. Bacteria convert the food to energy and use the energy to make new cells. Some bacteria can use inorganics (e.g., minerals such as iron) as an energy source and exist and multiply even when organics (pollution) are not available.

Several factors affect the rate at which bacteria grow, including temperature, pH, and oxygen levels. The warmer the environment, the faster the rate of growth. Generally, for each increase of 10°C, the growth rate doubles. Heat can also be used to kill bacteria.

Most bacteria grow best at neutral pH. Extreme acidic or basic conditions generally inhibit growth, though some bacteria may require acidic and some require alkaline conditions for growth.

Bacteria are aerobic, anaerobic, or facultative. If *aerobic*, they require free oxygen in the aquatic environment. *Anaerobic* bacteria exist and multiply in environments that lack dissolved oxygen. *Facultative* bacteria (e.g., iron bacteria) can switch from an aerobic to anaerobic growth or grow in an anaerobic or aerobic environment.

Under optimum conditions, bacteria grow and reproduce very rapidly. As stated previously, bacteria reproduce by *binary fission*.

An important point to consider in connection with bacterial reproduction is the rate at which the process can take place. The total time required for an organism to reproduce and the offspring to reach maturity is called **generation time**. Bacteria growing under optimal conditions can double their number about every 20 to 30 minutes. Obviously, this generation time is very short compared with that of higher plants and animals. Bacteria continue to grow at this rapid rate as long as nutrients hold out—even the smallest contamination can result in a sizable growth in a very short time.

Bactericide: A pesticide used to control or destroy bacteria, typically in the home, schools, or hospitals.

Bacteriophage: A virus that infects bacteria; often called a *phage*.

Baffle: A flat board or plate, deflector, guide, or similar device constructed or placed in flowing water or slurry systems to cause more uniform flow velocities to absorb energy and to divert, guide, or agitate liquids.

Baffle Block: In *hydropower*, one of a series of upright obstructions designed to dissipate the energy of water flowing at high velocity.

Baffle Chamber: For incinerator design, a chamber designed to promote the settling of fly ash and coarse particulate matter by changing the direction and/or reducing the velocity of the gases produced by the combustion of the reuse or sludge.

Bagasse: The fibrous material remaining after the extraction of juice from sugarcane; often burned by sugar mills as a source of energy.

Baghouse: Term commonly used for the housing containing bag filters for recovery of fumes from arsenic, lead, sulfa, etc. Many different trade meanings, however.

Baghouse Filter: A closely woven bag for removing dust from dust- laden gas streams. The fabric allows passage of the gas with retention of the dust.

Baling: Compacting solid waste into blocks to reduce volume and simplify handling.

Ballistic Separator: A machine that sorts organic from inorganic matter for composting.

Bamboo: In *biomass*, a group of large, fast-growing woody grasses widely used for fiber and food, especially in Asia; may also have potential as a bioenergy source.

Banana Oil: A liquid with a strong smell of bananas, used to check for general sealing of a respirator during fit-testing.

Band Application: The spreading of chemicals over, or next to, each row of plants in a field.

Bandwidth: Commonly used to mean the capacity of a communication channel to pass data through the channel in a given amount of time. Usually expressed in bits per second.

Banking: A system for recording qualified air emission reductions for later use in bubble, offset, or netting transactions.

Bar: A unit of pressure equal to one atmosphere (14.7 pounds per square inch).

Bar Screen: In wastewater treatment, a device used to remove large solids.

Bare Rock Succession: Bare rock succession, sometimes called primary succession, occurs on surfaces such as hardened volcanic lava, bare rock, and sand dunes, where no soil exists, and where nothing has ever grown before. Obviously, in order to grow, plants need soil. Thus, soil must form on the bare rock before succession can begin. Usually this soil formation process results from weathering. Atmospheric exposure—weathering, wind, rain, and frost—forms tiny cracks and holes in rock surfaces. Water collects in the rock fissures and slowly dissolves the minerals out of the rock's surface. A pioneer soil layer is formed from the dissolved minerals and supports such plants as lichens. Lichens gradually cover the rock surface and secrete carbonic acid, which dissolves additional minerals from the rock. Eventually, the lichens are replaced by mosses. Organisms called decomposers move in and feed on dead lichen and moss. A few small animals such as mites and spiders arrive next. The result is what is known as a pioneer community. The pioneer community is defined as the first successful integration of plants, animals, and decomposers into a bare-rock community.

Barrel Sampler: Open-ended steel tube used to collect soil samples.

Barrels of oil equivalent (BOE): The amount of natural gas that has the same heat content as an average barrel of oil. It is about 6000 cf of gas.

Barrier: Anything used to control, prevent, or impede energy flows. Common types of barriers include equipment, administrative procedures and process, supervision/ management, warning devices, knowledge and skills, and physical objects. Barriers may be either control or safety (DOE G 225.1A-1).

Barrier Coating(s): A layer of a material that obstructs or prevents passage of something though a surface that is to be protected; e.g., grout, caulk, or various sealing compounds; sometimes used with polyurethane membranes to prevent corrosion or oxidation of metal surfaces, chemical impacts on various materials, or, for example, to prevent radon infiltration through walls, cracks, or joints in a house.

Basal Application: In pesticides, the application of a chemical on plant stems or tree trunks just about the soil line.

Basalt: A general term for dark-colored iron- and magnesium-rich igneous rocks, commonly extrusive, but locally intrusive. It is the principal rock type making up the ocean floor.

Base: Any substance that releases hydroxyl ions (OH^-) when it dissociates in water.

Baseflow: Water that having infiltrated the soil surface, percolates to the ground water table and moves laterally to reappear as surface runoff.

Baseline: A quantitative expression of projected costs, schedule, and technical requirements; the established plan against which the status of resources and the progress of a project can be measured.

Baseline Data: Data collected prior to a project for later use in describing conditions before the project began. Also commonly used to describe the first audiogram given (within six months) to a worker after he or she has been exposed to the action level (85 dBA)—to establish his or her baseline for comparison to subsequent audiograms for comparison.

Baseline Emissions: In *environmental science*, the average amount of emissions that would occur over a given period if no changes in policy take place that would affect emission level either negatively or positively.

Base Load: The minimum amount of electrical power delivered or required over a given period of time at a steady rate.

Baseload Plants: Electricity-generating units that are operated to meet the constant or minimum load on the system. The cost of energy from such units is usually the lowest available to the system.

Basic Sediment: In *oil and gas exploration*, a term for soil impurities and salt water that are mixed with crude oil.

BAT: Best available technology (economically achievable).

Batch Sample: Collection of substances or products of the same category or subgroup drawn for a batch and from which text samples are taken.

Beam: A *beam* is a structural member whose length is large compared to its transverse dimensions and is subjected to forces acting transverse to its longitudinal axis (Tapley 1990). Safety engineers and professionals are primarily interested in beams because the load on a beam induces stresses in the material—stresses that could be dangerous. The structural aspect of beams is most important to the safety engineer, because the strength of the beam material and the kind of loading determine the size of load that it can safely carry. For example, in the construction of the storage mezzanine discussed earlier, and in the construction of other load-bearing structures, the beams used to support the load are an important (critical) consideration.

In determining the load that can be carried, two properties of the beam are important: the moment of inertia (**I**) and the section modulus (**Z**). The moment of inertia (**I**) is the sum of differential areas multiplied by the square of the distance from a reference plane (usually the neutral axis) to each differential area. Note that the strength of a beam increases rapidly as its cross section is moved farther from the neutral axis because the distance is squared. This is why a rectangular beam is much stronger when it is loaded along its thin dimension than along its flat dimension. The section modulus **(Z**) is the moment of inertia, divided by the distance from the neutral axis to the outside of the beam cross section. Allowable loads differ from maximum loads that produce failure by some appropriate factor of safety (Brauer 1994). The following types of beams are approximations of actual beams used in practice (Tapley 1990).

- **Simple beams**—are supported beams that have a roller support at one end and pin support at the other. The ends of a simple beam cannot support a bending moment but can support upward and downward vertical loads. Stated differently, the ends are free to rotate but cannot translate in the vertical direction. The end with the roller support is free to translate in the axial direction.
- **Cantilever beams**—are beams rigidly supported on only one end. The beam carries the load to the support where it is resisted by moment and shear stress.
- **Continuously supported beam**—is a beam resting on more than two supports.
- **Fixed beam**—is rigidly fixed at both ends.
- **Restrained beam**—is rigidly fixed at one end and simply supported at the other.
- **beam** projects beyond one or both ends of its supports.

Beam Angle: In *lighting*, the angle between the two directions for which the candlepower (intensity) is 50 percent of the maximum intensity, as measured in a plane though the nominal beam centerline.

Beam Axis: A line from the source through the centers of the x-ray fields.

Bean Sheet: Common term for a pesticide data package record.

Bearing Capacity: The maximum load per unit area that a material can safely support before failing.

Beaufort Scale: In *meteorology*, an empirical system (measure) for describing wind speed based mainly on observed sea conditions.

Bed Load: Sediment particles resting on or near the channel bottom that are pushed or rolled along by the flow of water.

Bedrock: The solid rock that underlies that soil and other unconsolidated material or that is exposed at the surface.

Bedrock Aquifer: An aquifer located in the solid rock underlying unconsolidated surface material s(i.e., sediment). Solid rock can bear water when it is fractured.

BEI: Biological Exposure Index.

Bel: A unit equal to 10 decibels (see decibel).

BEN: EPA's computer model for analyzing a violator's economic gain for not complying with the law.

Benchmarking: 1. In *business*, a process for rigorously measuring company performance vs. "best-in-class" companies, and using analysis to meet and exceed the best in class. 2. *GIS systems*, the administration of a standardized test procedure that provides a system means of comparing the performance levels of competing systems. 3. In *management*, benchmarking, a relatively new buzzword, is a valuable tool for use under any management system. For safety management, benchmarking is defined as a process for rigorously measuring your safety program vs. "best-in-class" programs, and for using the analysis to meet and exceed the best in class. Benchmarking vs. best practices gives organizations a way to evaluate their safety programs—how effective and how cost effective they are. Benchmarking also shows companies both how well their programs stack up, and how well those programs are implemented. Simply, (1) benchmarking is a new way of doing business; (2) it is an objective-setting process; (3) it forces an external view to ensure correctness of objective-setting; (4) it forces internal alignment to achieve company safety goals; and (5) it promotes teamwork by directing attention to those practices necessary to remain competitive. The benchmarking process is shown:

Start—Plan—Research—Observe—Analysis—Adapt

What Benchmarking can reveal:

- how effective the organization or process is;
- how cost effective the organization or process is;
- Benchmarking shows safety engineers both how well their operations stack up, and how well those operations are implemented.

Potential results of benchmarking**:**

- Benchmarking is an objective-setting process;
- Benchmarking is a new way of doing business;
- Benchmarking forces an external view to ensure correctness of objective setting;
- Benchmarking forces internal alignment to achieve plant goals;
- Benchmarking promotes teamwork by directing attention to those practices necessary to remain competitive;
- Benchmarking may indicate direction of required change rather than specific metrics:
  - ○ costs must be reduced;
  - ○ customer saisfaction must be increased;
  - ○ return on assets must be increased;
  - ○ improved maintenance;
  - ○ improved operational practices;
  - ○ Best practices translated into operational units of measure.

Targets

- Consideration of available resources converts benchmark findings to targets;
- A target represents what can realistically be accomplished in given time frame;
- Can show progress toward benchmark practices and metrics;
- Quantification of precise targets should be based on achieving benchmark.

Benchmarking Steps

Step 1	Planning	Managers must select a process (or processes) to be benchmarked. A benchmarking team should be formed. The process of benchmarking must be thoroughly understood and documented. The performance measure for the process should be established (i.e., cost, time, and quality).
Step 2	Research	Information on the "best-in-class" performer must be determined through research. The information can be derived from the industry's network, industry experts, industry and trade associations, publications, public information, and other award-winning operations.
Step 3	Observation	The observation step is a study of the benchmarking subject's performance level, processes, and practices that have achieved those levels, and other enabling factors.
Step 4	Analysis	In this phase, comparisons in performance levels among facilities are determined. The root causes for the performance gaps are studied. To make accurate and appropriate comparisons, the comparison data must be sorted, controlled for quality, and normalized.
Step 5	Adaptation	This phase is putting what is learned throughout the benchmarking process into action. The findings of the benchmarking study must be communicated to gain acceptance, functional goals must be established, and a plan must be developed. Progress should be monitored and, as required, corrections in the process made.

Note: Benchmarking should be interactive. It should also recalibrate performance measures and improve the process itself.

NOTE: Benchmarking can be performance-based, process-based, or strategic-based and can compare financial or operational performance measures, methods or practices, or strategic choices.

Benchmarking: The Process
When forming a benchmarking team, the goal should be to provide a benchmark that allows the safety engineer to evaluate and compare. For example, a benchmarking process could be used to evaluate privatized and re-engineered operations and then compared to your operation, as a way to determine how your company/organization/facility can be more efficient, remain competitive, and make continual improvements. Benchmarking is more than simply setting a performance reference or comparison; it is a way to facilitate learning for continual improvements. The key to the learning process is looking outside one's own plant to other plants that have discovered better ways of achieving improved performance, and determining how to apply those more effective methods to your own operation. Benchmarking steps are shown in the Table.

Bench-Scale Tests: Laboratory testing of potential cleanup technologies.

Bending Moment: A *bending moments* (or internal torque) exists in a structural element when a moment is applied to the element so that the element bends. In engineering design (and safety engineering), it is important to determine the point(s) along a beam where the bending moment (and shear force) is maximum since it is at these points that the bending stresses reach their maximum values. When a beam is in equilibrium, the sum of all moments about a particular point is zero.

In determining the maximum bending moment (uniform loading), we use the following equation:

$$M = wl^2/8$$

Where
M = the Maximum Bending Moment (ft-lb)
w = the uniform weight loading per foot of the beam (lb/ft)
l = the length of the beam (ft)

Example
Problem:
An 11 ft. long beam supported at two points, one at each end, is uniformly loaded at a rate of 250 lb/ft. What is the maximum bending moment in this bean?

Solution:
$M = wl^2/8$
M = ?
w = 250 lb/ft
l = 11 ft
$M = (250 \text{ lb/ft})(11 \text{ ft})^2/8$
= 3781 ft-lb.

To determine the bending moment (concentrated load at center) the following equation can be used.

$$M = Pl/4$$

Where
M = Maximum bending moment (ft-lbs)
P = the concentrated load applied at the center of the beam (lb)
l = the length of the beam (ft)

Example
Problem:
A 10 ton hoist is suspended at the mid-point of a 10 ft. long beam that is support at each end. What is the maximum bending moment in this beam? (Neglect the weight of the beam).

Solution:
M = ?
P = 10 tons = 20,000 lbs.
l = 10 ft.
M = Pl/4
M = (20,000 lbs.) (10 ft.) / 4
= 50,000 ft-lb

To determine the bending moment (concentrated load off-center) the following equation can be used.

$$M = Pab/l$$

Where
M = the Maximum Bending Moment (ft-lb)
P = a concentrated load on the beam (lb.)
a + b = the respective distances from the left and right supports of the beam (ft)
l = the length of the beam (ft)

Example
Problem:
A 10 ft. long beam supported at each end is loaded with a weight of 1400 lb. at a point 2 ft. left of its center. What is the maximum bending moment in this beam? (Note: Neglect weight of the beam).

Solution:
M = ?
P = 1400 lb.
a = 2 ft.
b = 8 ft.
l = 10 ft.

M = Pab/l
M = (1400 lb) (2 ft) (8ft) / 10 ft
= (1400 lb)(2 ft)(8 ft)/10 ft
= 2240 ft-lb

Bending Strength: That quality that resists forces from causing a member to bend or deflect in the direction in which the load is applied—actually a combination of tensile and compressive stresses.

Beneficial Reuse: The practice of reusing a typical waste product in a beneficial manner, for example, wastewater biosolids to compost.

Benefit-Cost Analysis: An economic method for assessing the benefits and costs of achieving alternative health-based standards at given levels of health protection.

Benthic/Benthos: The term originates from the Greek word for bottom and broadly includes aquatic organisms living on the bottom or on submerged vegetation.

Benthic Region: The bottom layer of a body of water.

Bentonite: A colloidal clay, expansible when moist, commonly used to provide a tight seal around a well casing.

Berm: In *earth science*, a temporary bench, shelf, ledge, or narrow terrace on the shore of a beach above the high tide line, formed by the action of waves. In *engineering*, a stabilizing earthwork, such as the shoulder of a road, or a mound of earth placed against a building wall for stabilization, wind protection, or insulation.

Bernoulli's Equation: In a hydraulic system, total energy head is equal to the sum of three individual energy heads. This can be expressed as

Total Head = Elevation Head + Pressure Head + Velocity Head

where
elevation head—pressure due to the elevation of the water
pressure head—the height of a column of water that a given hydrostatic pressure in a system could support
velocity head—energy present due to the velocity of the water

This can be expressed mathematically as

$$E = z + \frac{p}{w} + \frac{v^2}{2g}$$

where
E = total energy head
z = height of the water above a reference plane, ft
p = pressure, psi
w = unit weight of water, 62.4 lb/ft^3
v = flow velocity, ft/s
g = acceleration due to gravity, 32.2 ft/s^2

Bernoulli's equation.

$$z_A = \frac{P_A}{w} + \frac{v_A{}^2}{2g} = z_B + \frac{P_B}{w} + \frac{V_B{}^2}{2g}$$

We can simplify Bernoulli's equation because $z_A = z_B$.

Because they are equal, the elevation heads cancel out from both sides, leaving:

$$\frac{P_A}{w} + \frac{v_A{}^2}{2g} + \frac{P_B}{w} + \frac{v_B{}^2}{2g}$$

The fact that the pressure in the narrower pipe section (constriction) is less than the pressure in the bigger section seems to defy common sense. However, it does follow logically from continuity of flow and conservation of energy. Because there is a pressure difference allows measurement of flow rate in the closed pipe.

Bernoulli's Principle: In *physics*, Nathanson (1997) points out that Swiss physicist and mathematician Samuel Bernoulli developed the calculation for the total energy relationship from point to point in a steady state fluid system in the 1700's. Before discussing Bernoulli's energy equation, it is important to understand the basic principle behind Bernoulli's equation.

Water (and any other hydraulic fluid) in a hydraulic system possesses two types of energy—kinetic and potential. *Kinetic energy* is present when the water is in motion. The faster the water moves, the more kinetic energy is used. *Potential energy* is a result of the water pressure. The total energy of the water is the sum of the kinetic and potential energy. Bernoulli's principle states that the total energy of the water (fluid) always remains constant. Therefore, when the water flow in a system increases, the pressure must decrease. When water starts to flow in a hydraulic system, the pressure drops. When the flow stops, the pressure rises again.

Note: The basic principle explained above ignores friction losses from point to point in a fluid system employing steady state flow.

Beryllium: Elemental beryllium and any insoluble beryllium compound or alloy containing 0.1 percent beryllium or greater that may be released as an airborne particulate.

Best Available Control Measures (BACM): A term used to refer to the most effective measures (according to EPA guidance) for controlling small or dispersed particulates and other emissions from sources such as roadway dust, soot and ash from woodstoves and open burning of rush, timber, grasslands, or trash.

Best Available Technology (BAT): Essentially a refinement of best practicable means whereby a greater degree of control over emissions to land, air, and water may be exercised using currently available technology.

Best Demonstrated Available Technology (BDAT): As identified by EPA, the most effective commercially available means of treating specific types of hazardous waste. The BDATs may charge with advances in treatment technologies.

Best Management Practice (BMP): NPDES regulations define BMPs as schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage (40 CFR 122.2).

Beta Particle: An ionizing charge particle emitted from the nucleus of an atom during radioactive decay, equal in mass and charge to an electron.

Beta Radiation: Beta radiation is used for thickness measurements for coating operations; radioluminous signs; tracers for research; and for air ionization (gas chromatograph, nebulizers).

The characteristics of Beta radiation are listed below.

- Beta (β) is a high energy electron particle with source: Sr-90 → Y-90 → Electron beam machine.
- Beta radiation may travel meters in air and is moderately penetrating.
- Beta radiation can penetrate human skin to the "germinal layer," where new skin cells are produced. If beta-emitting contaminants are allowed to remain on the skin for a prolonged period of time, they may cause skin injury.
- Beta-emitting contaminants may be harmful if deposited internally.
- Most beta emitters can be detected with a survey instrument (such as a DC V-700), provided the metal probe cover is open). Some beta emitters, however, produce very low energy, poorly penetrating radiation that may be difficult or impossible to detect. Examples of these are carbon-14, tritium, and sulfur-35
- Beta radiation cannot be detected with an ionization chamber such as CD V-715.
- Clothing and turnout gear provide some protection against most beta radiation. Turnout gear and dry clothing can keep beta emitters off of the skin.
- Beta radiation present two potential exposure methods, external and internal. External beta radiation hazards are primarily skin burns. Internal beta radiation hazard are similar to alpha emitters.

Beta Radiation Detection Instrumentation: The types of equipment used to evaluate beta radiation in the workplace include:

- Geiger-Mueller counter
- Gas proportional devices
- Scintillators
- Ion chambers
- Dosimeters

Betz Limit: Generally, when we think or talk about efficiency we think about input vs. output and know that if we put 100 percent into something and get 100 percent output, we have a very efficient machine, operation, or process. In engineering, we can approximate efficiency input vs output by performing mass balance calculations. In using these calculations, we know that according to the laws of conservation, materials cannot disappear or be destroyed; thus, they must exist and be somewhere. However, in this input vs. output concept there a couple of views on maximum rotor efficiency that the ill-informed or misinformed have taken; and neither makes sense but are stated here to point out what really does make sense. The two wrong assumptions: First, it can be assumed that downwind velocity is zero; the turbine extracted all of the power from the wind; second, downwind velocity is the same as the upwind velocity—turbine extracted no power. Again, in a word: Wrong! It was Albert Betz in 1919 that set the record straight when he theorized that there must be some ideal slowing of the wind so that the turbine extracts the maximum power. Betz theorized in his wind turbine efficiency theory (i.e., to their power input vs power output and overall efficiency in general) that the efficiency rule or laws of conservation, as stated above, do not apply. Betz's law states the maximum possible energy that can be derived from a wind turbine. To understand Betz's law and its derivation, we have provided the following explanation.

Derivation of Betz's Law

To understand Betz's law we must first understand the constraint on the ability of a wind to convert kinetic energy in the wind into mechanical power. Visualize wind passing through a turbine—it slows down and the pressure is reduced so it expands.

The equation below is used to determine power extracted by the blades; another step in the derivation of Betz's law.

$$P_b = \tfrac{1}{2}\, m\, (v^2 - v_d^2)$$

where

m = mass flow rate of air within stream tube
v = upwind undisturbed windspeed
v_d = downwind windspeed

Using the equation below, determining mass flow rate, is the next step in the Betz' law derivation. In making the determination, it is easiest to use the cross sectional area A at the plane of the rotor because we know what this value is. The mass flow rate is

$$m = p\, A v_b$$

Assume the velocity through the rotor v_b is the average of upwind velocity v and downwind velocity v_d:

$$v_b = \frac{v + v_d}{2} \longrightarrow m = \rho\, A \left(\frac{v + v_d}{2}\right)$$

The equation becomes

$$P_b = \tfrac{1}{2}\, \rho A \left(\frac{V + v_d}{2}\right) (v^2 - v_d^2)$$

Before moving on in the derivation process it is important that we define speed/windspeed ratio, λ.

$$\lambda = \frac{v_d}{v}$$

Then we rewrite this equation:

$$P_b = \tfrac{1}{2}\, \rho A \underbrace{\left(\frac{v + \lambda v}{2}\right) (v^2 - \lambda^2 v^2)}_{\downarrow}$$

$$\left(\frac{v + \lambda v}{2}\right) (v^2 - \lambda^2 v^2) = \frac{v^3}{2} - \frac{\lambda^2 v^3}{2} + \frac{\lambda v^3}{2} - \frac{\lambda^3 v^3}{2}$$

$$= \frac{v^3}{2}\, [(1 + \lambda) - \lambda^2 (1 + \lambda)]$$

$$= \frac{v^3}{2} [(1 + \lambda)\, (1 - \lambda^2)]$$

$$\longrightarrow P_b = \underbrace{(\tfrac{1}{2}\, \rho\, A v^3)}_{P_W \,=\, \text{Power in the Wind}}\ \underbrace{\tfrac{1}{2}\, [(1 + \lambda)(1 - \lambda^2)]}_{C_P \,=\, \text{Rotor Efficiency}}$$

The next step is to find the speed windspeed ratio λ which maximizes the rotor efficiency, C_P

$$C_P = \tfrac{1}{2}\, [(1 + \lambda)(1 - \lambda^2)] = \tfrac{1}{2} - \frac{\lambda^2}{2} + \frac{\lambda}{2} - \frac{\lambda^3}{2}$$

Set the derivative of rotor efficiency to zero and solve for λ:

$$\frac{\partial C_P}{\partial \lambda} = -\, 2\lambda + 1 - 3\lambda^2 = 0$$

$$\frac{\partial C_P}{\partial \lambda} = 3\lambda^2 + 2\lambda - 1 = 0$$

$$\frac{\partial C_P}{\partial \lambda} = (3\lambda - 1)(\lambda + 1) = 0 \longrightarrow \lambda = 1/3$$

Maximizes rotor efficiency

When we plug the optimal value for λ back into C_P to find the maximum rotor efficiency:

$$C_P = \tfrac{1}{2}\, [(1 + 1/3)\, (1 - 1/3)] = 16/27 = 59.3 \text{ percent}$$

The maximum efficiency of 59.3 percent occurs when air is slowed to 1/3 of its upstream rate. Again, this factor and value is called the "Betz efficiency" or "Betz's law" (Betz 1966). In plain English, Betz's law states that all wind power cannot be captured by the rotor otherwise air would be completely still behind the rotor and not allow more wind to pass through. For illustrative purposes, in the Table, we list wind speed, power of the wind and power of the wind based on Betz limit (59.3 percent).

Betz Limit for 80 M Rotor Turbine

Wind Speed mph/ms	*Power (kW) of Wind*	*Power (kW) Betz Limit*
5/2.2	36	21
10/4.5	285	169
15/6.7	962	570
20/8.9	2280	1352
25/11.2	4453	2641
28/12.5	6257	3710
30/13.4	7695	4563
35/15.6	12220	7246
40/17.9	18241	10817
45/20.1	25972	15401
50/22.4	35626	21126
55/24.6	47419	28119
*56/25.0	50053	29681
60/26.8	61563	36507

Source: Adapted from Devlin, L, 2007. *Wind Turbine Efficiency. Accessed* @ http://k0lee.com/2007/11/wind-turbine-efficiency/

Bi-fuel Vehicle: In *renewable energy*, a vehicle capable of operating either on a conventional fuel, an alternative fuel, or both, either by simultaneously using two separate fuel systems for the conventional and alternative fuels, or by using a mixture of gasoline or diesel fuel and an alternative fuel in the same fuel tank .

Binary Cycle: Binary geothermal systems use the extracted hot water or steam to heat a secondary fluid to drive the power turbine.

Binomial System of Nomenclature: A system used to classify organisms; organisms are generally described by a two-word scientific name, the *genus* and *species*.

Bioaccumulation: The biological concentration mechanism whereby filter feeders such as limpets, oysters and other shellfish concentrate heavy metals or other stable compounds present in dilute concentrations in sea or fresh water.

Bioaerosol: Particulate matter in the atmosphere containing materials of biological origin that may cause disease, such as toxins, allergens, viruses, bacteria, and fungi.

Bioassay: 1. Radiation: The determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Bioavailability: Degree of ability to be absorbed and ready to interact in organism metabolism.

Biobased Product: The term 'biobased product,' as defined by Farm Security and Rural Investment Act (FSRIA), means a product determined by the U.S. Secretary of Agriculture to be a commercial or industrial product (other than food or feed) that is composed, in whole or in significant part, of biological products or renewable domestic agriculture materials (including plant, animal, and marine materials) or forestry materials.

Biochemical Conversion: The use of fermentation or anaerobic digestion to produce fuels and chemicals from organic sources.

Biochemical Oxygen Demand (BOD): A commonly used gross measurement of the concentration of biodegradable organic impurities in wastewater. The amount of oxygen, expressed in milligrams per liter (mg/L), required by bacteria while stabilizing, digesting, or treating organic matter under aerobic conditions is determined by the availability of material in the wastewater to be used as biological food and the amount of oxygen used by the microorganism during oxidation.

Biochemistry: The study of the chemistry of living organisms and other chemical constituents and vital processes.

Biocidal: Destructive to living organisms.

Bioconcentration: The accumulation of a chemical in tissues of a fish or other organism to levels greater than in the surrounding medium.

Biocontrol: In *ecology*, deliberated use by humans of one species of organism to eliminate or control another, as in the control of undesirable weeds or insects by the use of natural parasites, diseases, or predators rather than by herbicides and pesticides.

Biodegradable: A material capable of being broken down, usually by microorganisms, into basic elements.

Biodegradation: The ability of natural decay processes to break down man-made and natural compounds to their constituent elements and compounds, for assimilation in, and by, the biological renewal cycles, for example, as wood is decomposed to carbon dioxide and water.

Biodiversity: The earth contains a diverse array of organisms whose species diversity, genetic diversity and ecosystems are together called biodiversity. UNEP (1995) defines biodiversity as the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

USAID (2007) defines biodiversity as the variety and variability of life on Earth. This includes all of the plants and animals that live and grow on the earth, all of the habitats that they call home, and all of the natural processes of which they are a part. The earth supports an incredible array of biodiversity with plants and animals of all shapes and sizes in between. This fantastic variety of the life is found in diverse habitats ranging from the hottest desert to tropical rainforests to the arctic tundra. Biodiversity is essential to every aspect of the way that humans live around the world. Plants and animals provide people with food and medicine, trees play an important role in absorbing greenhouse gases and cleaning the air we breathe, and rivers and watersheds provide the clean water that we drink.

Unfortunately, however we define it, the fact is the earth's biodiversity is disappearing, with an estimated 1,000 species per year becoming extinct. Conversing biodiversity is especially crucial in developing countries where people's livelihoods are directly dependent on natural resources such as forests, fisheries, and wildlife.

The Tragedy of the Commons

After the introduction of the term "biodiversity," several researchers set out to define the term. During the defining stages, several buzzwords and interesting points of view on the subject area developed. One of the interesting concepts to come forth is known as the "tragedy of the commons." Simply, the tragedy of the commons, developed by Garrett Hardin, concerns how groups of people treat common resources—air, freshwater, biodiversity—they the must share: each individual person or nation will use as much of the common resource a possible to maximize their benefit from that resource (the "use it or lose it" mentality).

In the following, Hardin (1968) describes how the tragedy of the commons develops:

Picture a pasture pen to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.

As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks," What is the utility to me of adding one more animal to my head?" This utility has one negative and one positive component.

1. The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.
2. The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of –1.

Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another, and another. . . . But this is the conclusion reached by each and every national herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which al men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.

In its simplest terms, biodiversity is the variety of life at all levels; it includes the array of plants and animals; the genetic differences among individuals; the communities, ecosystems, and landscapes in which they occur; and the variety of process on which they depend (LaRoe 1993).

Biodiversity is important for several reasons. Its value is often reported in economic terms: for example Keystone Center (1991) and Wilson (1992) report that about half of all medicinal drugs come from—or were first found in—natural plants and animals, and therefore these resources are critical for their existing and as yet undiscovered medicinal benefits. Moreover, most foods were domesticated from wild stocks, and interbreeding of different, wild genetic stocks is often used to increase crop yield. LaRoe (1995) reports that today we use but a small fraction of the food crops used by Native cultures: many of these underused plants may become critical new food sources for the expanding human population or in times of changing environmental conditions.

It should be noted that it is the great variety of life that makes existence on earth possible; thus, pointing out the greater importance of biodiversity. As a case in point, consider that plants convert carbon dioxide to oxygen during the photosynthetic process; animals breathe this fresh air releasing energy and providing the second level of the food chain. In turn, animals convert oxygen back to carbon dioxide, providing the building blocks for the formation of sugars during photosynthesis by plants. Decomposers (microbes: fungi, bacteria, and protozoans) break down the carcasses of dead organisms, recycling the minerals to make them available for new life; along with some algae and lichens, they create soils and improve soil fertility (LaRoe 1995).

Additionally, biodiversity provides the reservoir for change in our life-support systems, allowing life to adapt to changing conditions. This diversity is the basis not only for short-term adaptation to changing conditions, but also for long-term evolution.

Humans cannot survive in the absence of nature. We depend on the diversity of life on earth for about 25 percent of our fuel (wood and manure in Africa, India, and much of Asia); more than 50 percent of our fiber (for clothes and construction); almost 50 percent of our medicines; and, of course, for all our food (Miller et al. 1985).

Some people believe that because extinction is a natural process, we therefore should not worry about endangered species or the loss of biodiversity (LaRoe 1993).

✔ **Important Point**: NPG= Negative Population Growth. This means that the birth rate has fallen below replacement levels, as human longevity increases and the death rate falls—due to industrialized medicine, use of contraception, improved education, increased social opportunities for women, and economic stability—leading to a graying and shrinking population.

Biodiversity and Stability: Biodiversity promotes stability. Meffe and Carroll (1997) purport a major benefit of biodiversity is that more diverse ecosystems may be more stable or more predictable through time when compared to species-poor ecosystems. Stability can be defined at the community level as fewer invasions and less extinction, meaning that a more stable community will contain a more stable composition of species. Stated differently, the stability of a system is an inherent property of its component populations and communities and it is a measure of the ability of that system to accommodate environmental change (Jones, 1997). Three main components of stability are:

- **persistence** (inertia): the ability of a community or ecosystem to resistant disturbance or alteration
- **constancy**: the ability to maintain a certain size or maintain its number within limits—system remains unchanged.
- **resilience**: is the tendency of a system to return to a previous state after a perturbation.

Biodiversity: Estimated Decline
In this section the estimated decline (USGS 1995) of biodiversity with emphasis on the United States is presented. Estimated decline includes area loss and degradation.

Fifty United States
85 percent of original primary (virgin) forest destroyed by late 1980s (Postel and Ryan 1991)
90 percent loss of ancient (old-growth) forests (World resources Institute 1992)
30 percent loss of wetlands from 1780s to 1980s (Dahl 1990)
12 percent loss of forested wetlands from 1940 to 1980 (Abernethy and Turner 1987)
81 percent of fish communities are adversely affected by anthropogenic limiting factors (Judy et al. 1982).

Forty-eight Conterminous States
ca. 95-98 percent of virgin forests destroyed by 1990 (Postel and Ryan 1991)
99 percent loss of primary (virgin) astern deciduous forest (Allen and Jackson 1992)
>70 percent loss of riparian forests since presettlement time (Brinson et al. 1981)
23 percent loss of riparian forest since the 1950's (Abernethy and Turner 1987)
53 percent loss of wetlands from 1780's to 1980's (Dahl 1990)
2.5 percent loss of wetlands between mid-1970s and mid-1980s (Dahl and Johnson 1991)
98 percent of an estimated 5.2 million km of streams are degraded enough to be unworthy of federal designation as wild or scenic rivers (Benke 1990).

Biodiversity: Loss Of: According to USGS (1995), loss of biodiversity is real. Biologists have alerted each other and much of the general public to the contemporary mass extinction of species. Less recognized is loss of biodiversity at the ecosystem level, which occurs when distinct habitats, species assemblages, and natural processes are diminished or degraded in quality. Tropical forests, apparently the most species-rich terrestrial habitats on Earth, are the most widely appreciated, endangered ecosystems; they almost certainly are experiencing the highest rates of species extinction today (Myers 1984, 1988; Wilson 1988). However, biodiversity is being lost more widely than just in the tropics. Moyle and Williams (1990) point out that some temperate habitats, such as freshwaters in California and old-growth forests in the Pacific Northwest (Norse 1990) to name but two, are being destroyed faster than most tropical rainforests and stand to lose as great a proportion of their species. Because so much of the temperate zone has been settled and exploited by humans, losses of biodiversity at the ecosystem level have been greatest there so far.

Ecosystems can be lost or impoverished in basically two ways. USGS (1995) reports that the most obvious kind of loss is quantitative—the conversion of a native prairie to a corn field or to a parking lot. Quantitative losses, in principle, can be measured easily by a decline in a real extent of a discrete ecosystem type (i.e., one that can be mapped). The second kind of loss is qualitative and involves a change or degradation in the structure, function, or composition of an ecosystem (Franklin et al. 1981; Noss 1990a). At some level of degradation, an ecosystem ceases to be natural. For example, a ponderosa pine forest may be high-graded by removing the largest healthiest, and frequently, the genetically superior trees; a sagebrush steppe may be grazed so heavily that native perennial grasses are replaced by exotic annuals; or a stream may become dominated by trophic generalist and exotic fishes. Qualitative changes may be expressed quantitatively, for instance, by reporting that 99 percent of the sagebrush steppe is affected by livestock grazing, but such estimates are usually less precise than estimates of habitat conversion. In some cases, as in the conversion of an old-growth of rest to a tree farm, the qualitative changes in structure and function are sufficiently severe to qualify as outright habitat loss.

Several biologists (Ehrlich and Ehrlich 1981; Diamond 1984; Wilson 1985; Wilcox and Murphy 1985; Ehrlich and Wilson 1991; Soule 1991) agree that the major proximate causes of biotic impoverishment today are habitat loss, degradation, and fragmentation. Hence, modern conservation is strongly oriented toward habitat protection. The stated goal of the Endangered Species Act of 1973 is "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved" (P.L. 94-325, as amended). The mission of The Nature Conservancy, the largest private land-protection organization in the United States, is to save "the last of the least and the best of the rest" (Jenkins 1985:21) by protecting natural areas that harbor rare species and communities and high-quality samples of all natural communities.

USGS 1995 reports that despite the many important accomplishments of natural-area programs in the United States, areas selected under conventional inventories tend to be small. As predicted by island biogeographic theory (MacArthur and Wilson 1967) and, more generally, by species-area relationships, smaller areas tend to have fewer species. All else being equal, smaller areas hold smaller populations, each of which is more vulnerable to extinction than larger populations (Soule 1987). Recognizing that small natural areas that are embedded in intensely used landscapes seldom maintain their diversities for long, scientists called for habitat protection and management at broad spatial scales such as landscapes and regions (Noss 1983, 1987, 1992; Harris 1984; Scott et al. 1991a, 1991b). In practice, however, most modern conservation continues to focus on local habitats of individual species and not directly on communities, ecosystem or landscapes (Noss and Harris 1986).

✔ **Important Point**: According to Homer-Dixon (1995), there are three types of scarcity: Demand-induced, supply-induced, and structural scarcity. Demand-induced scarcity refers to the relative lack of a resource (oil) due to its overuse by consumers. Supply-induced scarcity refers to the lack of a resource due to degradation or depletion, such as fresh water, as pollution and inefficient conservation have caused supplies to dwindle. Finally, structural scarcity refers to lack of resources due to a nature or human system: one country upstream (A) of another (B) may build a dam and cut off water flow to the downstream nation, resulting in a structural scarcity of water in country B.

Ecosystem conservation is a complement to—not a substitute for—species-level conservation. Protecting and restoring ecosystems serve to protect species about which little is known and to provide the opportunity to protect species while they are still common. Yet, ecosystems remain less tangible than species (Noss 1991a). And as USGS (1995) points out that the logic behind habitat protection as a means of conserving biodiversity is difficult to refute, conservationists face a major hurdle: convincing policy makers that significantly more and different kinds of habitat must be designated as reserves or otherwise managed for natural values. Scientists cannot yet say with accuracy how much land or what percentage of an ecosystem type must be kept in a natural condition to maintain viable populations of a given proportion of the native biota or the ecological processes of an ecosystem. However, a few biologists doubt that the current level of protection is inadequate. Estimates of the fraction of major terrestrial ecosystem types that are not represented in protected areas in the United States range from 21 to 52 percent (Shen 1987). Probably a smaller percentage is adequately protected. For example, 60 percent of 261 major terrestrial ecosystems in the United States and in Puerto Rico, defined by the Bailey-Kuchler classification were represented in designated wilderness areas in 1988 (Davis 1988). Only 19 percent of those ecosystem types, however, were represented in units of 100,000 ha or more and only 2 percent in unit of 1 million ha or more—all of them in Alaska (Noss 1990b). Because the size of an area has a pronounced effect on the viability of species and on ecological processes, representation of ecosystem types in small units, in most cases, cannot be considered adequate protection.

Biogas (Methane CH_4): Primarily known as a fuel for interior heating systems, methane or biogas can also be used as a replacement for natural gas—a fossil fuel for electricity generation and for cooking and heating—and as an alternative fuel to gasoline. Methane is a natural gas produced by the breakdown of organic material in the absence of oxygen in termite mounds, wetlands, and by some animals. Humans are also responsible for the release of methane through biomass burning, rice production, cattle, and release from gas exploration. Methane can also be obtained directly from the earth; however, other methods of production have been developed, most notably the fermentation or composting of plant and animal waste.

The reasons for considering Biogas (methane) as a possible biofuel include:

- It is a viable because of its potential use as an alternative fuel source.
- It is a viable alternative fuel to use to improve air quality.
- It can be produced locally reducing the need to use imported natural gas.

Methane is produced under anaerobic (no oxygen) conditions where organic material is biodegraded or broken down by a group of microorganisms.

Anaerobic Digestion

Anaerobic digestion is the traditional method of managing waste, sludge stabilization, and/or to release energy. It involves using bacteria that thrive in the absence of oxygen and is slower than aerobic digestion, but has the advantage that only a small percentage of the wastes are converted into new bacterial cells. Instead, most of the organics are converted into carbon dioxide and methane gas.

Cautionary Note: In an anaerobic digester, the entrance of air should be prevented because of the potential for air mixed with the gas produced in the digester which could create an explosive mixture.

USEPA (1979; 2006) points out that there are four key biological and chemical stages of anaerobic digestion:

1. Hydrolysis—occurs during which the proteins, cellulose, lipids, and other complex organics are broken down into smaller molecules and become soluble by utilizing water to split the chemical bonds of the substances
2. Acidogenesis—occurs during which the products of hydrolysis are converted into organic acids (where monomers are converted to fatty acids)
3. Acetogenesis—occurs during which the fatty acids are converted to acetic acid, carbon dioxide, and hydrogen
4. Methanogenesis—during which the organic acids produced during the fermentation step are converted to methane and carbon dioxide.

The efficiency of each phase is influenced by the temperature and the amount of time the process is allowed to react. For example, the organisms that perform hydrolysis and volatile acid fermentation (often called the acidogenic bacteria) are fast-growing microorganisms that prefer a slightly acidic environment and higher temperatures than the organism that perform the methane formation step (the methanogenic bacteria).

A simplified generic chemical equation for the overall processes outlined above is as follows:

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$

Biogas is the ultimate waste product of the bacteria feeding off the input biodegradable feedstock, and is mostly methane and carbon dioxide, with a small amount of hydrogen and trace hydrogen sulfide (see the Table; Spellman, 2009). Keep in mind that the ultimate output from a wastewater digester is water; biogas is more of an off-gas that can be used as an energy source. We discuss wastewater digestion and production of biogas in the next section.

Typical Contents of Biogas

Matter	Percentage (%)
Methane, CH_4	50–75
Carbon Dioxide, CO_2	25–50
Nitrogen, N_2	0–10
Hydrogen, H_2	0–1
Hydrogen Sulfide, H_2S	0–3
Oxygen, O_2	0–2

Anaerobic Digestion of Sewage Biosolids (Sludge)

Equipment used in anaerobic digestion typically includes a sealed digestion tank with either a fixed or a floating cover or an inflatable gas bubble heating and mixing equipment, gas storage tanks, solids and supernatant withdrawal equipment and safety equipment (e.g., vacuum relief, pressure relief, flame traps, explosion proof electrical equipment).

In operation, process residual (thickened or unthickened sludge) is pumped into the sealed digester. The organic matter digests anaerobically by a two-stage process. Sugars, starches and carbohydrates are converted to volatile acids, carbon dioxide and hydrogen sulfide. The volatile acids are then converted to methane gas. This operation can occur in a single tank (single stage) or in two tanks (two stages). In a single stage system, supernatant and/or digested solids must be removed whenever flow is added. In a two-stage operation, solids and liquids from the first stage flow into the second stage each time fresh solids are added. Supernatant is withdrawn from the second stage to provide additional treatment space. Periodically, solids are withdrawn for dewatering or disposal. The methane gas produced in the process may be used for many plant activities.

Note: The primary purpose of a secondary digester is to allow for solids separation.

Various performance factors affect the operation of the anaerobic digester. For example, percent Volatile Matter in raw sludge, digester temperature, mixing, volatile acids/alkalinity ratio, feed rate, percent solids in raw sludge and pH are all important operational parameters that the operator must monitor.

Along with being able to recognize normal/abnormal anaerobic digester performance parameters, digester operators must also know and understand normal operating procedures. Normal operating procedures include sludge additions, supernatant withdrawal, sludge withdrawal, pH control, temperature control, mixing, and safety requirements. Important performance parameters are listed in the Table (Spellman 2009).

Sludge must be pumped (in small amounts) several times each day to achieve the desired organic loading and optimum performance.

Anaerobic Digester—Sludge Parameters

Raw Sludge Solids	Impact
< 4% Solids	Loss of alkalinity Decreased sludge retention time Increased heating requirements Decreased Volatile Acid: Alk Ratio
4 - 8% Solids	Normal Operation
> 8% Solids	Poor mixing Organic Overloading Decreased Volatile Acid: Alk Ratio

Note: Keep in mind that in fixed cover operations additions must be balanced by withdrawals. If not, structural damage occurs.

Supernatant withdrawal must be controlled for maximum sludge retention time. When sampling, sample all drawoff points and select level with the best quality. Digested sludge is withdrawn only when necessary—always leave at least 25 percent seed. pH should be adjusted to maintain 6.8 to 7.2 pH by adjusting feed rate, sludge withdrawal or alkalinity additions.

Note: The buffer capacity of an anaerobic digester is indicated by the volatile acid/alkalinity relationship. Decreases in alkalinity cause a corresponding increase in ratio.

If the digester is heated, the temperature must be controlled to a normal temperature range of 90–95°F. Never adjust the temperature by more than 1°F per day. If the digester is equipped with mixers, mixing should be accomplished to ensure organisms are exposed to food materials. Anaerobic digesters are inherently dangerous—several catastrophic failures have been recorded. To prevent such failures, safety equipment such as pressure relief and vacuum relief valves, flame traps, condensate traps, and gas collection safety devices are installed. It is important that these critical safety devices be checked and maintained for proper operation.

Note: Because of the inherent danger involved with working inside anaerobic digesters, they are automatically classified as permit-required confined spaces. Therefore, all operations involving internal entry must be made in accordance with OSHA's confined space entry standard.

During operation, anaerobic digesters must be monitored and tested to ensure proper operation. Testing should be accomplished to determine supernatant pH, volatile acids, alkalinity, BOD or COD, total solids and temperature. Sludge (in & out) should be routinely tested for percent solids and percent volatile matter.

Anaerobic Digestion of Agricultural Wastes

Animal waste accounts for 10 percent of methane emissions in the United States. When not correctly managed, farm waste slurries can also seriously pollute local watercourses. Small anaerobic digesters have been installed on farms to treat excess animal slurries which can't be placed on the land. The biogas formed is normally used for heat but can also be used to fuel engines and other on-site energy needs such as electricity and heating. On-site biogas production and management also reduce offensive odors from overloaded or improperly managed manure storage facilities. These odors impair air quality and may be a nuisance to nearby communities. Anaerobic digestion of animal waste reduces these offensive odors because the volatile organic acids, the odor causing compounds, are consumed by biogas producing bacteria. In addition to biogas, another important by-product of anaerobic digestion is ammonium, which is the major constituent of commercial fertilizer, which is readily available and utilized by crops. The bottom line on the production of biogas on the farm: Biogas recovery can improve profitability while improving environmental quality.

Landfill Biogas

Landfills can be a source of energy. Landfills produce methane as organic waste decomposes in the same anaerobic digestion process used in converting wastewater and farm waste slurries into biogas. Most landfill gas results from the degradation of cellulose contained in municipal and industrial solids waste. Unlike animal manure digesters, which control the anaerobic digestion process, the digestion occurring in landfills is an uncontrolled process of biomass decay. To be technically feasible, a landfill must be at least 40 feet deep and have at least one million tons of waste in place for landfill gas collection.

The efficiency of the process depends on the waste composition and moisture content of the landfill, cover material, temperature and other factors. The biogas released from landfills, commonly called "landfill gas," is typically 50-percent methane, 45 percent carbon dioxide and 5-percent other gases. The energy content of landfill gas is 400 to 550 Btu per cubic foot.

A landfill energy system consists of a series of wells drilled into the landfill. A piping system connects the wells and collects the gas. Dryers remove moisture from the gas and filters remove impurities. The gas typically fuels an engine-generator set or gas turbine to produce electricity. The gas can also fuel a boiler to produce heat or steam. Further gas cleanup improves biogas to pipeline quality, the equivalent of natural gas. Reforming the gas to hydrogen would make possible the production of electricity using fuel cell technology.

Biogenic: A direct product of the physiological activities of organisms.

Biogeochemical Cycles: *Bio* refers to living organisms and *geo* to water, air, rocks or solids. *Chemical* is concerned with the chemical composition of the earth. Biogeochemical cycles are driven by energy, directly or indirectly, from the sun.

Biohazard: Organisms or products of organisms that present a risk to humans.

Biologic Indicators of Exposure Study: A study that uses (a) biomedical testing or (b) the measurement of a substance (an analyte), its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a hazardous substance.

Biologic Monitoring: Measuring hazardous substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

Biologic Uptake: The transfer of substances from the environment to plants, animals, and humans.

Biological Aerosols: Naturally occurring biologically generated and active particles, small enough to become suspended in air. These include mold spores, pollen, viruses, bacteria, insect parts, animal dander, etc.

Biological Agent: A living organism that can cause disease, sickness, and mortality in humans.

Biological Contaminant: Living organisms or derivates (e.g., viruses, bacteria, fungi, and mammal and bird antigens) that can cause harmful health effects when inhaled, swallowed, or otherwise taken into the body.

Biological Control: In pest control, the use of animals and organisms that eat or otherwise kill or out-compete pests.

Biological Half-Life: Length of time required for on-half of a radioactive substance to be biologically eliminated from the body.

Biological Integrity: The ability to support and maintain balanced, integrated, functionality in the natural habitat of a given region. Concept is applied primarily in drinking water management.

Biological Magnification: Refers to the process whereby certain substances such as pesticides or heavy metals more up the food chain, work their way into rivers or lakes, and are eaten by aquatic organism such as fish, which in turn are eaten by large birds, animals or humans. The substances become concentrated in tissues or internal organs as they move up the chain.

Biological Measurement: A measurement taken in a biological medium. For exposure assessment, it is related to the measurement is taken to relate it to the established internal dose of a compound.

Biological Medium: One of the major components of an organism; e.g., blood, fatty tissue, lymph nodes or breath, in which chemicals can be stored or transformed.

Biological Monitoring: Analyzing chemicals, hormone levels, or other substances in biological materials (blood, Urine, breath, etc.) as a measure of chemical exposure, health status, etc. in humans or animals. A blood test for lead is an example of biological monitoring.

Biological Oxidation: Decomposition of complex organic materials by microorganisms. Occurs in self-purification of water bodies and in activated sludge wastewater treatment.

Biological Oxidation: The way bacteria and microorganism feed on and decompose complex organic materials. Used in self-purification of water bodies and in activated slugged wastewater treatment.

Biological Oxygen Demand (BOD): The amount of dissolved oxygen taken up by microorganisms in a sample of water. It usually reflects the amount of oxygen consumed in five days by biological processes breaking down organic waste.

Biological Pesticides: Certain microorganisms, including bacteria, fungi, viruses, and protozoa that are effective in controlling pests. These agents usually do not have toxic effects on animals and people and do not leave toxic or persistent chemical residues in the environment.

Biological Stressors: Organisms accidentally or intentionally dropped into habitats in which they do not evolve naturally; e.g., gypsy moths, Dutch elm disease, certain types of algae, and bacteria.

Biological Treatment: Process by which hazardous waste is rendered non-hazardous or reduced in volume by the actions of microorganisms.

Biological Treatment Process: Includes such treatment processes as activated sludge, aerated lagoon, trickling filters, waste stabilization ponds, and anaerobic digestion.

Biological Wastewater Treatment: Forms of wastewater treatment in which bacterial or biochemical action is intensified to stabilize or oxidize the unstable organic matter present. Oxidation ditches, aerated lagoons, anaerobic lagoons, and anaerobic digesters are examples.

Biologically Effective Dose: The amount of a deposited or absorbed compound reaching the cells or target sites where adverse effect occur, or where the chemical interacts with a membrane.

Biologicals: Vaccines, cultures and other preparations made from living organism and their products, intended for use in diagnosing, immunizing, or treating humans or animals, or in related research.

Biology: The science of life.

Biomagnification: The process by which toxic substances become concentrated in animal and plant tissues.

Biomass: *Biomass* (all Earth's living matter) consists of the energy from plants and plant-derived organic-based materials; it is essentially stored energy from the sun. Biomass can be biochemically processed to extract sugars, thermochemically processed to produce biofuels or biomaterial, or combusted to produce hear to electricity. Biomass is also an input into other end-use markets, such as forestry products (pulpwood) and other industrial applications. This complicates the economics of biomass feedstock and requires that we differentiate between what is technically possible from what is economically feasible, taking into account relative prices and intermarket competition.

Biomass has been used since people began burning wood to cook food and keep warm. Trees have been the principal fuel of almost every society for over five thousand years, from the Bronze Age until the middle of the nineteenth century (Perlin 2005). Wood is still the largest biomass energy resource today, but other sources of biomass can also be used. These include food crops grassy and woody plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes. Even the fumes from landfills (which are methane, a natural gas) can be used as a biomass energy source. It excludes organic material which has been transformed by geological processes into substances such as coal or petroleum. The biomass industry is one of the fastest-growing industries in the United States.

Biomass Feedstock Types: A variety of biomass feedstocks can be used to produce transportation fuels, biobased products, and power. Feedstocks refer to the crops or products, like waste vegetable oil, that can be used as or converted into biofuels and bioenergy. With regard to the advantages or disadvantages of one type of feedstock as compared to another, this is gauged in terms of how much usable material they yield, where they can grow and how energy and water-intensive they are. Feedstock types are listed as first-generation or second generation feedstocks. First-generation feedstocks include those that are already widely grown and used for some from of bioenergy or biofuel production, which means that there are possible foods versus fuel conflicts. First generation feedstocks include sugars (sugar beets, sugar cane, sugar palm, sweet sorghum, and nypa palm), starches (cassava, corn, milo, sorghum, sweet potato, and wheat), waste feedstocks such as whey and citrus peels, and oils and fats (coconut oil, oil palm, rapeseed, soy beans, sunflower seed, castor beans, jatropha, jojoba, karanj, waste vegetable oil, and animal fat). Second-generation feedstocks refers broadly to crops that have high potential yields of biofuels, but that are note widely cultivated, or not cultivated as an energy crop. It refers to cellulosic feedstocks or conventional crops such as miscanthus, prairie grass, and switch grass, will and hybrid popular trees. Algae and halophytes (saltwater plants) are other second-generation feedstocks.

Currently, a majority of the ethanol produced in the U.S. is made from corn or other starch-based crops. The present focus, however, is on the development of cellulosic feedstocks—non-grain, non-food-based feedstocks such as switchgrass, corn stover, and wood material—and on technologies to convert cellulosic material into transportation fuels and other products. Using cellulosic feedstocks can not only alleviate the potential concern of diverting food crops to produce fuel, but also has a variety of environmental benefits (EERE 2008).

Because such a wide variety of cellulosic feedstocks can be used for energy production, potential feedstocks are grouped into categories—or pathways. The ease with which biomass can be converted to useful products or intermediates is determined by the composition of the biomass feedstock. Biomass contains a variety of components, some of which are readily accessible and others that are much more difficult and costly to extract. The composition and subsequent conversion issues for current and potential biomass feedstock compounds are listed and described below.

- Starch (Glucose)—is readily recovered and converted from grain (corn, wheat, rice) into products. Starch from corn grain provides the primary feedstock for today's existing and emerging sugar-based bioproducts, such as polylactide as well as the entire fuel ethanol industry. Corn grain serves as the primary feedstock for starch used to manufacture today's biobased products. Core wet mills use a multi-step process to separate starch from the germ, gluten (protein), and fiber components of corn grain. The starch streams generated by wet milling are highly pure, and acid of enzymatic hydrolysis is used to break the glycosidic linkages of starch to yield glucose. Glucose is then converted into a multitude of useful products.
- Lignocellulosic Biomass—the non-grain portion of biomass (e.g., cobs, stalks), often referred to as agricultural stover or resides, and energy crops such as switchgrass also contain valuable components, but they are not as readily accessible as starch. These lignocellulosic biomass resources (also called cellulosic) are comprised of cellulose, hemicellulose, and lignin. Generally, lignocellulosic material contains 30–50 percent cellulose, 20–30 hemicellulose, and 20–30

percentlignin. Some exceptions to this are cotton (98 percent cellulose) and flax (80 percent cellulose). Lignocellulosic biomass is perceived as a valuable and largely untapped resource for the future bioindustry. However, recovering the components in a cost-effective way represents a significant technical challenge.

- Cellulose—is one of nature's polymers and is composed of glucose, a six-carbon sugar. The glucose molecules are joined by glycosidic linkages which allow the glucose chains to assume an extended ribbon conformation. Hydrogen bonding between chains leads to the formation of the flat sheets that lay on top of one another in a staggered fashion, similar to the way staggered bricks add strength and stability to a wall. As a result, cellulose is very chemically stable and insoluble and serves as a structural component in plant walls.
- Hemicellulose—is a polymer containing primarily 5-carbon sugars such as xylose and arabinose with some glucose and mannose dispersed throughout. It forms a short-chain polymer that interacts with cellulose and lignin to form a matrix in the plant wall, strengthening it. Hemicellulose is more easily hydrolyzed than cellulose. Much of the hemicellulose in lignocellulosic material is solubilized and hydrolyzed to pentose and hexose sugars
- Lignin—helps bind the cellulosic/hemicellulose matrix while adding flexibility to the mix. The molecular structure of lignin polymers is very random and disorganized and consists primarily of carbon ring structures (benzene rings with methoxyl, hydroxyl, and propyl groups) interconnected by polysaccharides (sugar polymers. The ring structures of lignin have great potential as valuable chemical intermediates. However, separation and recovery of the lignin is difficult.
- Oils and Protein—the seeds of certain plants offer two families of compounds with great potential for bioproducts: oils and protein. Oils and protein are found in the sees of certain plants (soybeans, castor beans), and can be extracted in a variety of ways. Plants raised for this purpose include soy, corn, sunflower, safflower, rapeseed, and others. A large portion of the oil and protein recovered from oilseeds and corn is processed for human or animal consumption, but they can also serve as raw materials for lubricants, hydraulic fluids, polymers, and a host of other products.
- Vegetable Oils—are composed primarily of triglycerides, also referred to as triacylglycerols. Triglycerides contain a glycerol molecule as the backbone with three fatty acids attached to glycerol's hydroxyl groups.
- Proteins—are natural polymers with amino acids as the monomer unit. They are incredibly complex materials and their functional properties depend on molecular structure. There are twenty amnion acids each differentiated by their side chain or R-group and they can be classified as nonpolar and hydrophobic, polar uncharged, and ionizable. The interactions among the side chains, the amide protons, and the carbonyl oxygen help create the protein's 3-D shape.

Biomass for Biopower: In addition to advanced fuels, biomass can also be used for the production of biopower. This can be done in several ways, including direct combustion of biomass in dedicated power plants, co-firing biomass with coal, biomass gasification in a combined cycle plant to produce steam and electricity, or via anaerobic digestion (EPRI, 1997).

Combustion is the burning of biomass in air. This involves the conversion of chemical energy stored in biomass into heat, mechanical power or electricity (McKendry, 2002). While it is possible to use all types of biomass, combustion is preferable when biomass is more than 50 percent dry. High-moisture biomass is better suited for biological conversion processes. Net bioenergy conversion efficiencies for biomass combustion power plants range from 20 percent to 40 percent. Higher efficiencies are obtained with the combined heat and power (CHP) facilities and with large size power-only system (over 100 Mega-Watt-electrical—Mwe), or when the biomass is co-fired with coal in power plants (McKendry, 2002).

Co-firing biomass with coal is a straightforward and inexpensive way to diversity the fuel supply, reduce coal plant air emissions (NO_x, SO_2, CO_2), divert biomass from landfills, and stimulate the biomass power industry (Hughes, 2000). Moreover, biomass is the only renewable energy technology that can directly displace coal. Given the dominance of coal-based power plants in U.S. electricity production, co-firing with biomass fuel is the most economical way to reduce greenhouse gas emissions. Possible biomass fuel for co-firing includes wood waste, short-rotation woody crops, switchgrass, alfalfa stems, various types of manure, landfill gas, and wastewater treatment gas (Tillman, 2000). In addition, agricultural residues such as straw can also be used for co-firing.

A promising technology development currently at demonstration stage is biomass integrated gasification/combined cycle (BIG/CC), where a gas turbine converts the gaseous fuel to electricity with a high conversion efficiency, reaching 40 to 50 percent of the heating value of he incoming gas (McKendry, 2002). An important advantage of gasification is the ability to work with a wider variety of feedstocks, such as high alkali fuels that are problematic with direct combustion. High alkali fuels such as switchgrass, straw, and other agricultural residues often cause corrosion, but the gasification systems can easily remove the alkali species from the fuel gas before it is combusted. High silica, also a problem with grasses can result in slagging in the reactor.

NREL (1993) points out that the slagging problem is not unique to one form of biomass but instead is common with many different types of biomass fuels. Slagging deposits can reduce heat transfer, reduce combustion efficiency, and damage combustion chambers when large particles break off. Research has focused on two alkali metals, potassium and sodium, and silica, all elements commonly found in living plants. In general, it appears that faster growing plants (or faster growing plant components such as seeds) tend to have higher concentrations of alkali metal and silica. Thus material such as straw, nut hulls, fruit pits, weeds, and grasses tend to create more problems when burned than wood from a slow growing tree.

Potassium and sodium metals, whether in the form of oxides, hydroxides, or metallo-organic compounds tend to lower the melting point of ash mixtures containing various other minerals such as silica (SiO2). The high alkali content (up to 35 percent) in the ash from burning annual crop residues lowers the fusion or ‘sticky temperature’ of these ashes from 2200ºF for wood ash to as low as 1300ºF. This results in serious slagging on the boiler grate or in the bed and fouling of convection heat transfer surfaces. Even small percentages (10 percent) of some of these high alkali residues burned with wood in conventional boilers will cause serious slagging and fouling in a day to two, necessitating combustion system shutdown.

A method to predict slagging and fouling from combustion of biomass fuels has been adapted from the coal industry. The method involves calculating the weight in pounds of alkali (K20 + Na2O) per million Btu in the fuel as follows:

$$\frac{1 \times 10^{6}}{\text{Btu/lb}} \text{X \% Ash X \% Alkali of the Ash} = \frac{\text{lb Alkali}}{\text{MM Btu}}$$

This method combines all the pertinent data into one Index Number. A value below 0.4 lb/MM Btu (MM Btu = thousand thousand Btu) is considered a fairly low slagging risk. Values between 0.4 and 0.8 lb/MM Btu will probably slag with increasing certainty of slagging as 0.8 lb/MM Btu is approached. Above 0.8 lb/MM Btu, the fuel is virtually certain to slag and foul (see the Table on next page).

As mentioned, another process for biomass is the application of anaerobic digestion to produce biogas (methane) for electricity generation. Anaerobic digestion involves the controlled breakdown of organic wastes by bacteria in the absence of oxygen. Major agricultural feedstocks for anaerobic digestion include food processing wastes and manure from livestock operations. The Energy Information Agency also projects a significant increase in generation of electricity from municipal waste and landfill gas—to about 0.5 percent of U.S. electricity consumption (EIA, 2006)

Alkali Content and Slagging Potential of Various Biofuels

Fuel	*Total Alkali (lb/MM Btu)*	*Slagging Potential*
WOOD		
Pine Chips	0.07	Minimal
White Oak	0.14	Minimal
Hybrid Poplar	0.46	Probable
Urban Wood Waste	0.46	Probable
Clean Tree Trimmings	0.73	Probable
PITS, NUTS, SHELLS		
Almond Shells	0.97	Certain
Refuse Derived Fuel	1.60	Certain
GRASSES		
Switch Grass	1.97	Certain
Wheat Straw-average	2.00	Certain
Wheat Straw-hi alkali	5.59	Certain
Rice Straw	3.80	Certain

Source: Adaptation from Miles et al., 1993.

Biomass for Bioproducts[1]: Bioproducts are industrial and consumer goods manufactured wholly or in part from renewable biomass (pant-based resources). Today’s industrial bioproducts are amazingly diverse, ranging from solvents and paints to pharmaceuticals, soaps, cosmetics and building materials (see the Table). Industrial bioproducts are integral to our way of life—few sectors of the economy do not rely in some way on products made from biomass.

Common Products from Biomass

Biomass Resource	*Uses*
Corn	Solvents, pharmaceuticals, adhesives, starch, resins, Binders, polymers cleaners, ethanol.
Vegetable Oils	Surfactants in soaps and detergents, pharmaceuticals (inactive ingredients), inks, paints, resins, cosmetics, fatty acids, lubricants, biodiesel
Wood	Paper, building materials, cellulose for fibers and polymers, resins, binders, adhesives, coatings, paints, ins, fatty acids, road and roofing pitch

Source: USDOE (2003).

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[1] Information in this section from USDOE (2003) *Industrial Bioproducts: Today and Tomorrow*. Washington, DC: Office of the Biomass program.

Corn, wood, soybeans, and plant oils are the primary resources used to create this remarkable diversity of industrial and consumer goods. In some cases, it is not readily apparent that a product is derived in part from biomass. Biomass components are often combined with other materials such as petrochemicals and minerals to manufacture the final product. Soybean oil, for example, is blended with other components to produce paints, toiletries, solvents, inks, and pharmaceuticals. Some products, such as starch adhesives, are derived entirely from biomass.

The many derivatives of corn illustrate the diversity of products that can be obtained from a single biomass resource. Besides being an important source of food and feed, corn serves as a feedstock for ethanol and sorbitol (a sweetish, crystalline alcohol), industrial starches and sweeteners, citric and lactic acid, and many other products.

Biomass, which is comprised of carbohydrates, can be used to produce some of the products that are commonly manufactured from petroleum and natural gas, or hydrocarbons. Both resources contain the essential elements of carbon and hydrogen. In some cases, both resources have captured a portion of market share (see the Table).

Products from Hydrocarbons versus Carbohydrates

Product	*Total Production (millions of tons)*	*% Derived from Plants*
Adhesives	5.0	40
Fatty Acids	2.5	40
Surfactants	3.5	35
Acetic Acid	2.3	17.5
Plasticizers	0.8	15
Activated Carbon	1.5	12
Detergents	12.6	11
Pigments	15.5	6
Dyes	4.5	6
Wall Points	7.8	3.5
Inks	3.5	3.5
Plastics	30	1.8

Source: ILSR 1992

Classes of Bioproducts

The thousands of different industrial bioproducts produced today can be categorized into five major areas:

- ***Sugar and starch bioproducts*** derived through fermentation and thermochemical processes include alcohols, acids, starch, xanthum gum, and other products derived from biomass sugars. Primary feedstocks include sugarcane, sugarbeets, corn, wheat, rice, potatoes, barley, sorghum grain, and wood.
- ***Oil- and lipid-based bioproducts*** include fatty acids, oils, alkyd resins, glycerine, and a variety of vegetable oils derived from soybeans, rapeseed, or other oilseeds.
- ***Gum and wood chemicals*** include tall oil (liquid rosin), alkyd resins, rosins, pitch, fatty acids, turpentine, and other chemicals derived from trees.
- ***Cellulose derivatives, fibers and plastics*** include products derived from cellulose, including cellulose acetate (cellophane) and triacetate, cellulose nitrate, alkali cellulose, and regenerated cellulose. The primary sources of cellulose are bleached wood pulp and cotton linters.
- ***Industrial enzymes*** are used as biocatalysts for a variety of biochemical reactions in the production of starch and sugar, alcohols, and oils. They are also used in laundry detergents, tanning of leathers and textile sizing (Uhlig 1998).

Biomass: Plant Basics[2]**:** To optimize plant biomass for more efficient processing requires a better understanding of plants and plant cell-wall structure and function. The plant kingdom ranks second in importance only to the animal kingdom (at least from the human point of view). The importance of plants and plant communities to humans, bioenergy production, and their environment cannot be overstated. Some of the important things plants provide are listed below.

- **Aesthetics**—plants add to the beauty of the places we live.
- **Medicine**—80 percent of all medicinal drugs originate in wild plants.
- **Food**—90 percent of the world's food comes from only twenty plant species.
- **Industrial Products**—plants are very important for goods they provide (e.g., plant fibers provide clothing) and wood is used to build homes.
- **Recreation**—plants form the basis for many important recreational activities, including fishing, nature observation, hiking, and hunting.
- **Air Quality**—the oxygen in the air we breathe comes from the photosynthesis of plants.
- **Water Quality**—plants aid in maintaining healthy watersheds, streams, and lakes by holding soil in place, controlling stream flows, and filtering sediments from water.
- **Erosion Control**—plant cover helps to prevent wind or water erosion of the top layer of soil that we depend on.
- **Climate**—regional climates are impacted by the amount and type of plant cover.
- **Fish and Wildlife Habitat**—plants provide the necessary habitat for wildlife and fish populations.
- **Ecosystem**—every plant species serves an important role or purpose in their community.

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[2] This section adapted from F.R. Spellman (2009) *Biology for the Non-Biologist*. Lanham, Maryland: Government Institutes Press.

- **Feedstock for bioenergy production—**some important fuel chemicals come from plants, such as ethanol from corn and soy diesel from soybeans.

Though both are important kingdoms of living things, plants and animals differ in many important aspects. Some of these differences are summarized in chart below.

Plants	*Animals*
Plants contain chlorophyll and can make their own food.	Animals cannot make their own food and are dependent on plants and other animals
Plants give off oxygen and take in carbon dioxide given off by animals.	Animals give off carbon dioxide which plants need to make food and take in oxygen which they need to breathe.
Plants generally are rooted in one place and do not move on their own.	Most animals have the ability to move fairly freely.
Plants have either no or very basic ability to sense.	Animals have a much more highlydeveloped sensory and nervous system.

Before discussing the basic specifics of plants, it is important to first define a few key plant terms.

Plant Terminology

- **Apical meristem**—consists of meristematic cells located at tip (apex) of a root or shoot.
- **Cambium**—the lateral meristem in plants.
- **Chloroplasts**—disk-like organelles with a double membrane found in eukaryotic plant cells.
- **Companion cells**—specialized cells in the phloem that load sugars into the sieve elements.
- **Cotyledons**—leaf-like structure (sometimes referred to as seed leaf) that is present in the seeds of flowering plants.
- **Dicot**—one of the two min types of flowering plants; characterized by having two cotyledons.
- **Diploid**—having two of each kind of chromosome (2n).
- **Guard cells**—specialized epidermal cells that flank stomata and whose opening and closing regulate gas exchange and water loss.
- **Haploid**—having only a single set of chromosomes (n).
- **Meristem**—group of plant cells that can divide indefinitely provides new cells for the plant.
- **Monocots**—one of two main types of flowering plants; characterized by having a single cotyledon.
- **Periderm**—a layer of plant tissue derived from the cork cambium, and then secondary tissue, replacing the epidermis.
- **Phloem**—complex vascular tissue that transports carbohydrates throughout the plant.
- **Sieve cells**—conducting cells in the phloem of vascular plants.
- **Stomata**—pores on the underside of leaves that can be opened of closed to control gas exchange and water loss.
- **Thallus**—main plant body, not differentiated into a stem or leaves.
- **Tropism**—plant behavior; controlling the direction of plant growth.
- **Vascular tissue**—tissues found in the bodies of vascular plants that transport water, nutrients, and carbohydrates. The two major kinds are xylem and phloem.
- **Xylem**—vascular tissue of plants that transports water and dissolved minerals from the roots upwards to other parts of plant. Xylem often also provides mechanical support against gravity.

Although not typically acknowledged, plants are as intricate and complicated as animals. Plants evolved from photosynthetic protists and are characterized by photosynthetic nutrition, cell walls made from cellulose and other polysaccharides, lack of mobility and a characteristic life cycle involving an alternation of generations. The phyla/division of plants and examples are listed in the Table.

The Main Phyla/Division of Plants

Phylum/Division	*Examples*
Bryophyta	mosses, liverworts and hornworts
Coniferophyta	conifers such as redwoods, pines and firs
Cycadophyta	cycads, sago palms
Gnetophyta	shrub trees and vines
Ginkophyta	*Ginkgo* is the only genus
Lycophyta	lycopods (look like mosses)
Pterophyta	ferns and tree-ferns
Anthophyta	flowering plants including oak, corn, maize and herbs

A brief summary of plant cells is provided here.

- *Plants have all the organelles animal cells have* (i.e., nucleus, ribosomes, mitochondria, endoplasmic reticulum, Golgi apparatus, etc.).
- *Plants have chloroplasts*. Chloroplasts are special organelles that contain chlorophyll and allow plants to carry out photosynthesis.
- *Plant cells can sometimes have large vacuoles for storage*.
- *Plant cells are surrounded by a rigid cell wall made of cellulose,* in addition to the cell membrane that surrounds animal cells. Those walls provide support.

Vascular Plants

Vascular plants, also called **Tracheophytes**, have special vascular tissue for transport of necessary liquids and minerals over long distances. Vascular tissues are composed of specialized cells that create "tubes" through which materials can flow throughout the plant body. These vessels are continuous throughout the plant, allowing for the efficient and controlled distribution of water and nutrients. In addition to this transport function, vascular tissues also support the plant. The two types of vascular tissue are xylem and phloem.

- **Xylem** consists of a tube or a tunnel (pipeline) in which water and minerals are transported throughout the plant to leaves for photosynthesis. In addition to distributing nutrients, xylem (wood) provides structural support. After a time, the xylem at the center of older trees ceases to function in transport and takes on a supportive role only.
- **Phloem** tissue consists of cells called *sieve tubes* and *companion cells.* Phloem tissue moves dissolved sugars (carbohydrates), amino acids and other produces of photosynthesis from the leaves to other regions of the plant.

The two most important Tracheophytes are gymnosperms (gymno = naked; sperma = seed) and angiosperms (angio = vessel, receptacle, container).

- **Gymnosperms**—the plants we recognize as gymnosperms represent the sporophyte generation (i.e., the spore-producing phase in the life cycle of a plant that exhibits alternation of generation). Gymnosperms were the first tracheophytes to use seeds for reproduction. The seeds develop in protective structures called cones. A gymnosperm contains some cones that are female and some that are male. Female cones produce spores that, after fertilization, become eggs enclosed in seeds that fall to the ground. Male cones produce pollen, which is taken by the wind and fertilizes female eggs by that means. Unlike flowering plants, the gymnosperm does not form true flowers or fruits. Coniferous tress such as firs and pines are good examples of gymnosperms.
- **Angiosperms**—the flowering plants, are the most highly evolved plants and the most dominant in present times. They have stems, roots, and leaves. Unlike gymnosperms such as conifers and cycads, angiosperm's seeds are found in a flower. Angiosperm eggs are fertilized and develop into a seed in an ovary that s usually in a flower.

  There are two types of angiosperms: monocots and dicots.

  - **Monocots**—these angiosperms start with one seed-leaf (cotyledon); thus, their name, which is derived from the presence of a single cotyledon during embryonic development. Monocots include grasses, grains, and other narrow-leaved angiosperms. The main veins of their leaves are usually parallel and unbranched, the flower parts occur in multiples of three, and a fibrous root system is present. Monocots include orchids, lilies, irises, palms, grasses, and wheat, corn and oats.
  - **Dicots**—angiosperms in this group grow two seed-leaves (two cotyledons). Most plants are dicots and include maples, oaks, elms, sunflowers, and roses. Their leaves usually have a single main vein or three of more branched veins that spread out from the base of the leaf.

Leaves

The principal function of leaves is to absorb sunlight for the manufacturing of plant sugars in photosynthesis. The leaves broad, flattened surfaces gather energy from sunlight, while apertures on their undersides bring in carbon dioxide and release oxygen. Leaves develop as a flattened surface in order to present a large area for efficient absorption of light energy. On its two exteriors, the leaf has layers of epidermal cells that secrete a waxy, nearly impermeable cuticle (chitin) to protect against water loss (dehydration) and fungal or bacterial attack. Gases diffuse in or out of the leaf through **stomata**, small openings on the underside of the leaf. The opening or closing of the stomata occurs through the swelling or relaxing of **guard cells**. If the plant wants to limit the diffusion of gases and the transpiration of water, the guard cells swell together and close the stomata. Leaf thickness is kept to a minimum so that gases that enter the leaf can diffuse easily throughout the leaf cells.

Chlorophyll/Chloroplast

The green pigment in leaves is **chlorophyll**. Chlorophyll absorbs red and blue light from the sunlight that falls on leaves. Therefore, the light reflected by the leaves is diminished in red and blue and appears green. The molecules of chlorophyll are large. They are not soluble in the aqueous solution that fills plant cells. Instead, they are attached to the membranes of disc-like structures, called **chloroplasts**, inside the cells. Chloroplasts are the site of photosynthesis, the process in which light energy is converted to chemical energy. In chloroplasts, the light absorbed by chlorophyll supplies the energy used by plants to transform carbon dioxide and water into oxygen and carbohydrates.

Chlorophyll is not a very stable compound; bright sunlight causes it to decompose. To maintain the amount of chlorophyll in their leaves, plants continuously synthesize it. The synthesis of chlorophyll in plants requires sunlight and warm temperatures. Therefore, during summer chlorophyll is continuously broken down and regenerated in the leaves of trees.

Photosynthesis

Because our quality of life, and indeed our very existence, depends on photosynthesis, it is essential to understand it. In photosynthesis, plants (and other photosynthetic autotrophs) use the energy from sunlight to create the carbohydrates necessary for cell respiration. More specifically, plants take water and carbon dioxide and transform them into glucose and oxygen:

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Did You Know?

Charles Darwin was the first to discuss how plants respond to light. He found that the new shoot of grasses bend toward the light because the cells on the dark side grow faster than the lighted side.

This general equation of photosynthesis represents the combined effects of two different stages. The first stage is called the light reaction and the second stage is called the dark reaction. The **light reaction** is the photosynthesis process in which solar energy is harvested and transferred into the chemical bonds of ATP; can only occur in light. The **dark reaction** is the process in which food (sugar) molecules are formed from carbon dioxide from the atmosphere with the use of ATP; can occur in dark as long as ATP is present.

Roots

Roots absorb nutrients and water, anchor the plant in the soil, provide support for the stem, and store food. They are usually below ground and lack nodes, shoots and leaves. There are two major types of root systems in plants. Taproot systems have a stout main root with a limited number of side-branching roots. Examples of taproot system plants are nut trees, carrots, radishes, parsnips and dandelions. Taproots make transplanting difficult. The second type of root system, fibrous, has many branched roots. Examples of fibrous root plants are most grasses, marigolds and beans. Radiating from the roots is a system of root hairs, which vastly increase the absorptive surface area of the roots. Roots also anchor the plant in the soil.

Growth in Vascular Plants

Vascular plants undergo two kinds of growth (growth is primarily restricted to meristems), primary and secondary growth. **Primary growth** occurs relatively close to the tips of roots and stems. It is initiated by apical meristems and it is primarily involved in the extension of the plant body. The tissues that arise during primary growth are called primary tissues and the plant body composed of these tissues is called the primary plant body. Most primitive vascular plants are entirely made up of primary tissues. **Secondary growth** occurs in some plants; secondary growth thickens the stems and roots. Secondary growth results from the activity of lateral meristems. Lateral meristems are called **cambia** (cambium) and there are two types:

1. **Vascular cambium**—gives rise to secondary vascular tissues (secondary xylem and phloem). The vascular cambium gives rise to xylem to the inside and phloem to the outside.
2. **Cork cambium**—which forms the **periderm** (bark). The periderm replaces the epidermis in woody plants.

Plant Hormones

Plant growth is controlled by plant hormones, which influence cell differentiation, elongation, and division. Some plant hormones also affect the timing of reproduction and germination.

- **Auxins**—affect cell elongation (tropism), apical dominance, and fruit drop or retention. Auxins are also responsible for root development, secondary growth in the vascular cambium, inhibition of lateral branching, and fruit development. Auxin is involved in absorption of vital minerals and fall color. As a leaf reaches its maximum growth auxin production declines. In deciduous plants this triggers a series of metabolic steps which causes the reabsorption of valuable materials (such as chlorophyll) and their transport into the branch or stem for storage during the winter months. Once chlorophyll is gone and the other pigments typical of fall color become visible.
- **Kinins**—promote cell division and tissue growth in leaf, stem, and root. Kinins are also involved in the development of chloroplasts, fruits, and flowers. In addition, they have been shown to delay senescence (aging), especially in leaves, which is one reason that florists use cytokinins on freshly cut flowers—when treated with cytokinins they remain green, protein synthesis continues, and carbohydrates do not breakdown.
- **Gibberellins—**produced in the root growing tips and acts as a messenger to stimulate growth, especially elongation of the stem, and can also end the dormancy period of seeds and buds by encouraging germination. Additionally, gibberellins play a role in root growth and differentiation.

- **Ethylene**—controls the ripening of fruits. Ethylene may insure that flows are carpelate (female) while gibberellin confers maleness on flowers. It also contributes to the senescence of plants by promoting leaf loss and other changes.
- **Inhibitors**—restrain growth and maintain the period of dormancy in seeds and buds.

Tropisms: Plant Behavior

Tropism is the movement (and growth in plants) of an organism in response to an external stimulus. For example, tropisms, controlled by hormones, are a unique characteristic of sessile organisms such as plants that enable them to adapt to different features of their environment—gravity, light, water and touch—so that they can flourish. There are three main tropisms:

- **Phototropism**—the tendency of plants growing or bending (moving) in response to light. Phototropism results from the rapid elongation of cells on the dark side of the plant, which causes the plant to bend in the opposite direction. For example, the stems and leaves of a geranium plant growing on the windowsill always turn toward the light.
- **Gravitropism**—refers to a plant's tendency to grow toward or against gravity. A plant that displays positive gravitropism (plant roots) will grow downward, toward the center of earth. That is, gravity causes the roots of plants to grow down so that the plant is anchored in the ground and has enough water to grow and thrive. Plants that display negative gravitropism (plant stems) will grow upward, away from the earth. Most plants are negatively gravitropic. Gravitropism is also controlled by auxin. In a horizontal root or stem, auxin is concentrated in the lower half, pulled by gravity. In a positively gravitropic plant, this auxin concentration will inhibit cell growth on the lower side, causing the stem to bend downward. In a negatively gravitropic plant, this auxin concentration will inspire cell growth on that lower side, causing the stem to bend upward.
- **Thigmotropism**—some people notice that their houseplants respond to thigmotropism (i.e., growing or bending in response to touch), growing better when they touch them and pay attention to them. Touch causes parts of the plant to thicken or coil as they touch or are touched by environmental entities. For instance, tree trunks grow thicker when exposed to strong winds and vines tend to grow straight until they encounter a substrate to wrap around.

Photoperiodism

Photoperiodism is the response of an organism (e.g., plants) to naturally occurring changes in light during a 24-hour period. The site of perception of photoperiod in plants is leaves. For instance, sunflowers are known for their photoperiodism, or their ability to open and close in response to the changing position of the sun throughout the day.

All flowering plants have been placed in one of three categories with respect to photoperiodism: short-day plants, long-day plants, and day-neutral plants.

- **Short-day plants**—flowering promoted by day lengths shorter than a certain critical day length—includes poinsettias, chrysanthemums, goldenrod, and asters
- **Long-day plants**—flowering promoted by day lengths longer than a certain critical day length—includes spinach, lettuce, and most grains
- **Day-neutral plants**—flowering response insensitive to day length—includes tomatoes, sunflowers, dandelions, rice, and corn

Plant Reproduction

Plants can reproduce both sexually and asexually. Each type of reproduction has its benefits and disadvantages. A comparison of sexual and asexual plant reproduction is provided in the following.

- Sexual Reproduction:
  - Sexual reproduction occurs when a sperm nucleus from the pollen grain fuses with egg cell from ovary of pistil (pistil defined: the female reproductive structures in flowers, consisting of the stigma, style, and ovary).
  - Each brings a complete set of genes and produces genetically unique organisms.
  - The resulting plant embryo develops inside the seed and grows when seed is germinated.
- Asexual reproduction:
  - Occurs when a vegetative part of a plant, root, stem or leaf, gives rise to new offspring plant whose genetic content is identical to the "parent plant". An example would be a plant reproducing by root suckers, shoots that come from the root system. The breadfruit tree is an example.
  - Asexual reproduction is also called vegetative propagation. It is an important way for plant growers to get many identical plants from one very quickly.
  - By sexual reproduction plants can spread and colonize an area quickly (e.g., crab grass).

Biomass Plant Cell Walls

Plants consist of basic organelles within a standard plant cell, including the cell wall. It should be pointed out, however, that plants can have two types of cell walls, primary and secondary. Primary cell walls contain cellulose consisting of hydrogen-bonded chains of thousands of glucose molecules, in addition to hemicellulose and other materials all woven into a network. Certain types of cells, such as those in vascular tissues, develop secondary walls inside the primary wall after the cell has stopped growing. These cell-wall structures also contain lignin, which provides rigidity and resistance to compression. The area formed by two adjacent plant cells, the middle lamella, typically is enriched with pectin.

Cellulose in higher plants is organized into microfibrils, each measuring about 3 to 6 nm in diameter and containing up to 36 glucan chains having thousands of glucose residues. Like steel girders stabilizing a skyscraper's structure, the primary cell wall's mechanical strength is due mainly to the microfibril scaffold (i.e., crystalline cellulose core) (USDOE 2007).**Biomat:** The layer of biological growth and inorganic residue that develops at the wastewater soil interface and extends up to about 1 inch into the soil matrix. The biomat controls the rate at which pretreated wastewater moves through the infiltrative surface/zone for coarse- to medium-textured soils. This growth may not control fluxes thrugh fine clay soils, which are more restrictive to wastewater flows than the biomat.

Biomaterials: Products derived from organic (as opposed to petroleum-based) products.

Biome: Entire community of living organisms in a single major ecological area.

Biomechanics: Subdivision of ergonomics concerned with mechanical properties of human tissue, particularity the resistance of tissue to mechanical stresses.

Biomedical Testing: Testing of persons to find out whether a change in a body function might have occurred because of exposure to a hazardous substance.

Biometrics: Access system that uses physical characteristics of the users to determine access.

Biomonitoring: 1. Analysis of blood, urine, tissues, etc. to measure chemical exposure in humans. 2. The use of living organisms to test the suitability of effluents for discharge into receiving waters and to test the quality of such waters downstream for the discharge. Thus, biomonitoring is the assessment of a water body ecosystem based on organisms living in it. The assessment of the system based on its physical characteristics is called a habitat assessment. Biomonitoring and habitat assessments are two tools that stream ecologists use to assess the water quality of a water body. Biological monitoring involves the use of organisms (called assemblages)—periphytons, fish, and macroinvertebrates—to assess environmental condition. Biological observation is more representative as it reveals cumulative effects as opposed to chemical observation, which is representative only at the actual time of sampling. Again, the presence of different assemblages of organisms is used in conducting biological assessments and/or biosurveys. In selecting the appropriate for a particular biomonitoring situation, the advantages of using each assemblage must be considered along with the objectives of the program.

Bio-oil: Intermediate fuel derived from fast pyrolysis.

Biopower: The use of biomass feedstock to produce electric power to heat through direct combustion of the feedstock, through gasification and then combustion of the resultant gas, or through other thermal conversion processes. Power is generated with engines, turbines, fuel cells, or other equipment.

Bioremediation: Any process that uses microorganisms, fungi, green plants or their enzymes to return the natural environment altered by contaminants to its original condition.

Biosensor: Analytical device comprising a biological recognition element (e.g., enzyme, receptor, DNA, antibody, or microorganism) in intimate contact with an electrochemical, optical, thermal, or acoustic signal transducer that together permit analyses of chemical properties or quantities. Shows potential development in some areas, including environmental monitoring.

Biosolids: A term that refers to water or sewage sludge. Biosolids treatment process normally include conditioning, thickening, dewatering, disposal by incineration, composting, land application or land burial.

Biosphere: The region of the earth and its atmosphere in which life exists, an envelope extending from up to 6000 meters above to 10,000 meters below sea level that embraces all life from alpine plant life to the ocean deeps.

Biostabilizer: A machine that converts solid waste into compost by grinding and aeration.

Biostimulent: A chemical that can stimulant growth, phosphates or nitrates in a water system, for example.

Biota: The animal and plant life of a particular region considered as a total ecological entity.

Biotechnology: Techniques that use living organisms or parts of organisms to produce a variety of products (from medicines to industrial enzymes) to improve plants or animals or to develop microorganisms to remove toxics from bodies of water, or act as pesticides.

Biotic: Pertaining to life or specific life conditions.

Biotic Community: A naturally occurring assemblage of plants and animals that live in the same environment and are mutually sustaining and interdependent.

Biotic Index: The biotic index is a systematic survey of macroinvertebrates organisms. Because the diversity of species in a stream is often a good indicator of the presence of pollution, the biotic index can be used to correlate with stream quality. Observation of types of species present or missing is used as an indicator of stream pollution. The biotic index, used in the determination of the types, species, and numbers of biological organisms present in a stream, is commonly used as an auxiliary to BOD determination in determining stream pollution.

The biotic index is based on two principles:

1. A large dumping of organic waste into a stream tends to restrict the variety of organisms at a certain point in the stream.
2. As the degree of pollution in a stream increases, key organisms tend to disappear in a predictable order. The disappearance of particular organisms tends to indicate the water quality of the stream.

There are several different forms of the biotic index. In Great Britain, for example, the Trent Biotic Index (TBI), the Chandler score, the Biological Monitoring Working Party (BMWP) score, and the Lincoln Quality Index (LQI) are widely used. Most of the forms use a biotic index that ranges from 0 to 10. The most polluted stream, which therefore contains the smallest variety of organisms, is at the lowest end of the scale (0); the clean streams are at the highest end (10). A stream with a biotic index of greater than 5 will support game fish; on the other hand, a stream with a biotic index of less than 4 will not support game fish.

As mentioned, because they are easy to sample, macroinvertebrates have predominated in biological monitoring. In addition, macroinvertebrates can be easily identified using identification keys that are portable and easily used in field settings. Present knowledge of macroinvertebrate tolerances and response to stream pollution is well documented. In the United States, for example, the Environmental Protection Agency (EPA) has required states in incorporate narrative biological criteria into its water quality standards by 1993. The National Park Service (NPS) has collected macroinvertebrate samples from American streams since 1984. Through their sampling effort, NPS has been able to derive quantitative biological standards (Huff 1993).

Macroinvertebrates are a diverse group. They demonstrate tolerances that vary between species. Thus, discrete differences tend to show up, containing both tolerant and sensitive indicators.

The biotic index provides a valuable measure of pollution. This is especially the case for species that are very sensitive to lack of oxygen. An example of an organism that is commonly used in biological monitoring is the stonefly. Stonefly larvae live underwater and survive best in well-aerated, unpolluted waters with clean gravel bottoms. When stream water quality deteriorates due to organic pollution, stonefly larvae cannot survive. The degradation of stonefly larvae has an exponential effect upon other insects and fish that feed off the larvae; when the stonefly larvae disappears, so in turn do many insects and fish (O'Toole 1986).

The Table shows a modified version of the BMWP biotic index. Considering that the BMWP biotic index indicates ideal stream conditions, it takes into account the sensitivities of different macroinvertebrate species are represented by diverse populations and are excellent indicators of pollution. These aquatic macroinvertebrates are organisms that are large enough to be seen by the unaided eye. Moreover, most aquatic macroinvertebrates species live for at least a year; and they are sensitive to stream water quality both on a short-term basis and over the long term. For example, mayflies, stoneflies, and caddisflies are aquatic macroinvertebrates that are considered clean-water organisms; they are generally the first to disappear from a stream if water quality declines and are, therefore, given a high score. On the other hand, tubificid worms (which are tolerant to pollution) are given a low score.

BMWP Score System (Modified for illustrative purposes).

Families	*Common-Name Examples*	*Score*
Heptageniidae	Mayflies	10
Leuctridae	Stoneflie	9–10
Aeshnidae	Dragonflies	8
Polycentropidae	Caddisflies	7
Hydrometridae	Water Strider	6–7
Gyrinidae	Whirligig beetle	5
Chironomidae	Mosquitoes	2
Oligochaeta	Worms	1

In the Table, a score from 1-10 is given for each family present. A site score is calculated by adding the individual family scores. The site score or total score is then divided by the number of families recorded to derive the Average Score Per Taxon (ASPT). High ASPT scores result due to such taxa as stoneflies, mayflies, and caddisflies being present in the stream. A low ASPT score is obtained from streams that are heavily polluted and dominated by tubificid worms and other pollution-tolerant organism.

From the Table, it can be seen that those organisms having high scores, especially mayflies and stoneflies, are the most sensitive, and others, such as dragonflies and caddisflies, are very sensitive to any pollution (deoxygenation) of their aquatic environment.

Biotoxin: A substance produced by a living organism, such as a plant or fish that has toxic effects.

Biotransformation: Conversion of a substance into other compounds by organisms; includes biodegradation.

Blackbody: An ideal substance that absorbs all radiation falling on it, and reflecting nothing.

Black Liquor (Pulping Liquor): The alkaline spent liquor removed from the digesters in the process of chemically pulping wood. It consists mainly of the lignin that remains after the separation of cellulose to form paper fibers. After evaporation, the liquor is burned as a fuel in a recovery furnace that permits the recovery of certain basic chemicals.

Black Lung: A disease of the lungs caused by habitual inhalation of coal dust.

Blackwater: Water that contains liquid and solid animal, human, or food waste.

Blanching: 1. Whitening of the skin. 2. Operation in which raw food material is immersed in hot water or exposed to live steam.

Blanking: In OSHA's lockout-tagout procedure, the absolute closure of a pipe, line, or duct by the fastening of a solid plate (such as a spectacle blind or a skillet blind) that completely covers the bore, and that is capable of withstanding the maximum pressure of the pipe, line, or duct with nor leakage beyond the plate.

Blasting Abrasive: A chemical contaminant composed of silica, silicates, carbonates, lead, cadmium, or zinc and classified as a dust.

BLEVE: An acronym for Boiling Liquid Expanding Vapor Explosion. Materials which BLEVE may cause storage containers and parts of containers to rocket great distances, in many directions. Any liquid may cause a BLEVE.

Blister Agent: A substance that causes blistering of the skin and mucous membranes. Exposure is though liquid or vapor contact with any tissue (i.e., eyes, skin, lungs).

Bloodborne Pathogens: Microorganisms in the blood or other body fluids that an cause illness and disease in people.

Bloom: A proliferation of algae and/or higher aquatic plants in a body of water; often related to pollution, especially when pollutants accelerate growth.

Blowby: In an internal combustion engine, blowby occurs as gases from the piston ring area pass into the crankcase.

BOD5: In *water science*, biochemical oxygen demand is the amount of dissolved oxygen consumed in five days by biological process breaking down organic matter.

Body Burden: The amount of a chemical stored in the body at a given time, especially a potential toxin in the body as the result of exposure.

Body's Response to Heat: Operations involving high air temperatures, radiant heat sources, high humidity, direct physical contact with hot objects, or strenuous physical activities have a high potential for inducing heat stress in employees engaged in such operations. Industries that involve processes that create such environments include: Iron and steel foundries, nonferrous foundries, brick-firing and ceramic plants, glass products facilities, rubber products factories, electrical utilities (particularly boiler rooms), bakeries, confectioneries, commercial kitchens, laundries, food canneries, chemical plants, mining sites, smelters, and steam tunnels.

Outdoor operations conducted in hot weather, such as construction, refining, asbestos removal, and hazardous waste site activities, especially those that require workers to wear semipermeable or impermeable protective clothing, are also likely to cause heat stress among exposed workers (OSHA, 2003).

The human body is equipped to maintain an appropriate balance between the metabolic heat it produces and the environmental heat to which it is exposed. Sweating and the subsequent evaporation of the sweat are the body's way of trying to maintain an acceptable temperature balance.

According to Alpaugh (1988), this balance can be expressed as a function of the various factors in the following equation.

$$H = M \pm R \pm C\ E$$

where
H = body heat
M = internal heat gain (metabolic)
R = radiant heat gain
C = convection heat gain
E = evaporation (cooling)

The ideal balance when applying the equation is no new heat gain. As long as heat gained from radiation, convection, and metabolic processes does not exceed that lost through the evaporation induced by sweating, the body experiences no stress or hazard. However, when heat gain from any source of sources is more than the body can compensate for by sweating, the result is heat stress.

Heat stress involves several causal factors. These include:

- Age, weight, degree of physical fitness, degree of acclimatization, metabolism, use of alcohol or drugs, and a variety of medical conditions (such as hypertension) all affect a person's sensitivity to heat. However, even the type of clothing worn must be considered. Prior heat injury predisposes an individual to additional injury.
- Predicting just who will be affected and when is difficult, because individual susceptibility varies widely. In addition, environmental factors include more than the ambient air temperature. Radiant heat, air movement, conduction, and relative humidity all affect an individual's response to heat (OSHA, 2003).

The American Conference of Governmental Industrial Hygienists (1992) states that workers should not be permitted to work when their deep body temperature exceeds 38°C (100.4°F).

Boil: To change from a liquid state to a gaseous state.

Boiling Point: The temperature at which a substance changes from a liquid to a gas.

Bond: In *chemistry,* the attractive force that links atoms together in a molecule or an ionic structure, so that they act as a unit.

Bonding: A bond is a mechanical connection that provides a low-resistance path to electrical current flow between two surfaces are physically separated or that my become separated.

Bone Dry: Having zero-percent moisture content.

Boom: 1. A floating device used to contain oil on a body of water. 2. A piece of equipment used to apply pesticides for a tractor or truck.

Borrelia: A genus of bacteria of the spirochete phylum. It causes borreliosis, a zoonotic, vector-borne disease transmitted primarily by ticks and some by lice, depending on the species.

Botanical Pesticide: A pesticide whose active ingredient is a plant produced chemical such as nicotine or strychnine.

Bottom Ash: The non-airborne combustion residue from burning pulverized coal in a boiler; the material which falls to the bottom of the boiler and is removed mechanically; a concentration of non-combustible materials, which may include toxics.

Bottom Land Hardwoods: Forested freshwater wetlands adjacent to rivers in the southeastern United States, especially valuable for wildlife breeding, nets, and habitat.

Bottom water: A mixture of fresh water and brine.

Botulism (Latin, *botulus*, "sausage"): A rare but serious paralytic illness caused by botulinum toxin, which is produced by the bacterium *Clostridium botulinum* under anaerobic conditions.

Bounding Estimate: An estimate of exposure, dose, or risk that is higher tan that incurred by the person in the population with the currently higher exposure, dose, or risk. Bound estimates are useful in developing statements that exposures, doses, or risks are "not greater than" and estimated value.

Boyle's Law: The product of a given pressure and volume is constant with a constant temperature.

Brackish Water: Water (non-potable) containing between 100 and 10,000 ppm of total dissolved solids.

Breaker: A fracturing fluid additive that is added to break down the viscosity of the fluid.

Breakpoint Chlorination: To produce a free chlorine residual, enough chlorine must be added to the water to produce what is referred to as breakpoint chlorination [i.e., the point at which near complete oxidation of nitrogen compounds is reached; any residual beyond breakpoint is mostly free chlorine. When chlorine is added to natural waters, the chlorine begins combining with and oxidizing the chemicals in the water before it begins disinfecting. Although residual chlorine will be detectable in the water, the chlorine will be in the combined form with a weak disinfecting power. Adding more chlorine to the water at this point actually decreases the chlorine residual as the additional chlorine destroys the combined chlorine compounds. At this stage, water may have a strong swimming pool or medicinal taste and odor. To avoid this taste and odor, and still more chlorine to produce a free residual chlorine. Free chlorine has the highest disinfecting power. The point at which most of the combined chlorine compounds have been destroyed and the free chlorine starts to form is the breakpoint.

The chlorine breakpoint of water can only be determined by experimentation. This simple experiment requires 20 1,000-ml breakers and a solution of chlorine. Place the raw water in the beakers and dose with progressively larger amounts of chlorine. For instance, you might start with zero in the first beaker, then 0.5 mg/l and 1.0 mg/l, and so on. After a period of time, say 20 minutes, test each beaker for total chlorine residual and plot the results.

Breathing Zone: A hemisphere forward of the shoulders, centered on the mouth and noise, with a radius of 6 to 9 inches. Breathing zone samples provide the best representation of actual exposure.

Bremsstrahlung: Electromagnetic (x-ray) radiation associated with the deceleration of charged particles passing through matter.

Bridle Rope Sling: A wire rope formed by plaiting component wire ropes.

Brightness Temperature: A measure of the intensity of radiation thermally emitted by an object given in units of temperature.

Brine: A geothermal solution containing more than 100,000 ppm of total dissolved solids (salt—NaCl), which can yield salt after evaporation.

Brine Mud: Waste material, often associated with well-drilling or mining, composed of mineral salts or other inorganic compounds.

British Thermal Unit (BTU): British Thermal Unit, a measuring unit of heat. It is the equated with the amount of heat energy equal to the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit at seal level. 1 Btu = 1055 joules.

Brittle Limit: Stress limit beyond which a material fractures.

Brittleness: Condition whereby a metal will easily fracture under low stress.

Brownfields: Abandoned, idled, or under used industrial and commercial facilities/sites where expansion or redevelopment is complicated by real or perceived environmental contamination. They can be in urban, suburban, or rural areas. EPA's Brownfields initiative helps communities mitigate potential health risks and restore the economic viability of such areas or properties.

Brucella: A genus of Gram-negative bacteria; it causes brucellosis, which is a zoonosis.

Brucellosis: A systemic bacterial disease with ache or insidious onset of irregular fever, headache, weakness, profuse sweating, chills, depression, weight loss, and aching.

Brute Force: A cryptanalysis technique or other kind of attack method involving an exhaustive procedure that tries all possibilities, one-by-one.

Budding: Type of asexual reproduction in which an outgrowth develops from a cell to form a new individual. Most yeasts reproduce in this way.

Buffer: A solution or liquid whose chemical makeup is such that it minimizes changes in pH when acids or bases are added to it.

Buffer Overflow: Occurs when a program or process tries to store more data in a buffer (temporary data storage area) than it was intended to hold. Since buffers are created to contain a finite amount of data, the extra information—which has to go somewhere—may overflow into adjacent buffers, corrupting or overwriting the valid data held in them.

Buffer Solution: In *chemistry*, a solution to which small amounts of an acid or base can be added without appreciatively changing its hydrogen ion—concentration.

Buffer Strips: Strips of grass or other erosion-resisting vegetation between or below cultivated strips or fields.

Building Cooling Load: The hourly amount of heat that must be removed from a building to maintain indoor comfort. Measure in British thermal units (Btus).

Building Envelope: The exterior surface of aa building's construction—the walls, windows, floors, roof, and floor.

Building-Related Illness: Diagnosable illness whose cause and symptoms can be directly attributed to a specific pollutant source within a building (e.g., Legionnaires's disease, hypersensitivity, pneumonitis).

Bulk Density: Weight per unit of volume, usually specified in pounds per cubic foot.

Bulk Sample: A small portion (usually thumbnail size) of a suspect asbestos-containing building material collected by an asbestos inspector for laboratory analysis to determine asbestos content.

Bulking Agent: A fine, solid material added to a wastewater steam to produce clarification of coagulation by adding bulk to the solids.

Bulking Sludge: Sludge floating in the air that occurs throughout secondary clarifiers and sludge thickeners when the sludge becomes too light and will not settle properly.

Bulky Waste: Large items of waste materials, such as appliances, furniture, large auto parts, trees, stumps.

Bung: A closure to seal a container, such as a bottle, tube or barrel.

Burette: A piece of laboratory equipment used to deliver a wide range of volumes accurately.

By-Product: Material, other that the principal product, generated as a consequence of an industrial process or as a breakdown product in a living system.

Byssinosis (Brown Lung Disease): An occupational lung disease caused by exposure to cotton dust in inadequately ventilated working environments.

C

^{14}C Method: A method of determining the age, in years, of organic matter by calculating the amount of radioactive carbon still remaining as compared to the stable isotope ^{12}C.

CAA: Clean Air Act.

Cadmium (Cd): A heavy metal that accumulates in the environment.

Calibration: To adjust and/or determine either:

1. The response or reading of an instrument relative to a standard (e.g., primary, secondary, or tertiary) or to a series of conventionally true values; or
2. The strength of a radiation source relative to a stand (e.g., primary, secondary, or tertiary) or conventionally true value (10 CFR 835.2).

Calorie: The amount of energy in terms of quantity.

Camphor: An aromatic crystalline compound, obtained naturally from the wood or leaves of the camphor tree or synthesize and used as an insect repellent, in the manufacture of film, plastics, lacquers, and explosives, and in medicine chiefly in external preparations to relive mild pain and itching.

Cancellation: Refers to Section 6 (b) of the Federal Insecticide, Fungicide and Rodenticide act (FIFRA) which authorizes cancellation of a pesticide registration if unreasonable adverse effects to the environment and public health develop when a product is used according to widespread and commonly recognized practice, or if its labeling or other material required to be submitted does not comply with FIFRA provisions.

Cancer: Cancer toxicity is exhibited by the formation of tumors. Cancer is defined as uncontrolled cell division. The vast majority of cancers are as yet unrelated to chemical exposure. Currently in the United States, approximately one in three (31 percent) people develop cancer over their lifetimes. Of those people developing cancer, the death rate is about 30 percent across all types of cancers. As of 1996, cancer was still the second leading cause of death in the United States (behind only heart disease).

There are many types of cancers, which are typically classified both by the organ primarily affected (e.g., lung, breast) and the type of tumor produced. Although many types of cancers are often fatal, several types are typically not fatal (e.g., skin melanomas from ultraviolet light exposure due to sunlight).

Historically, it was thought that if a chemical could cause cancer, it could lead directly to tumor formation. However, it has more recently been learned that there are multiple stages to the development of cancer. As we learn more about specific chemicals, we are realizing that only a few chemicals are what are known as complete carcinogens; that is, one chemical can lead a tissue through all four stages of carcinogenesis. Many chemicals are known to be initiators (e.g., benzo(a)pyrene), and some are promoters (saccharin, phenol). For chemicals that are not complete carcinogens, other actions need to occur for cancer to develop from chemical exposure.

For example, a chemical might initiate a cell to become cancerous. By itself, this does not cause cancer. Cells have internal repair mechanisms to fix such damage. However, if another agent, which could be a chemical, causes the initiated cell to be promoted (e.g., cell division occurs from the damaged cell), then tumor formation might occur.

This is one reason why cancer treatment is so difficult. There are many stages of carcinogenesis and many agents that act at different stages. In addition, there are multiple types of mechanisms at each stage, complicating drug therapy that often requires knowledge of such mechanisms to be effective.

Another differentiation between chemicals that might be considered carcinogenic lies in their general mode of action. Some chemicals directly act on DNA; these are called genotoxic chemicals. This interference with DNA can lead to changes in DNA by many different mechanisms, but all of these mechanisms eventually involve affects to DNA. Examples of such chemicals include nickel and chromium, which are elements of the earth's crust and are often used in industrial processes; vinyl chloride, an industrial chemical used to make polyvinyl chloride (PVC) and a breakdown product of common solvents such as trichloroethylene (TCE); and benzo(a) pyrene, a component of petroleum formed during burning of organic material.

Other chemicals do not directly act on DNA, but exert their carcinogenic effects by targeting other systems linked with protein production and use. These are known as epigenetic chemicals. Examples of these types of chemicals include asbestos, which causes a specific and rare form of lung cancer called mesothelioma; estradiol, the natural female hormone referred to as estrogen; saccharin, used as an artificial sweetener in the 1970s until it was reported in 1977 to lead to bladder tumors in mice; and ethanol, contained in all alcoholic beverages.

There is typically a long period of time between exposure and initiation of cancer to development of cancer to a point where it can be diagnosed. This period of time is referred to as a latency period. As an example, skin cancer following arsenic exposure typically takes about Fifteen years to develop. Once a cancer is diagnosed, it can be extremely difficult to trace the origin of the cancer to exposure to specific chemical many years before. This is in part because many different chemicals may affect the same organ (see Table below). Only when many people who share a similar task (e.g., making asbestos, working with benzene) contract similar cancers can a link between cause and effect be made.

We will look at a few examples of these types of effects that we can ascribe directly to chemicals to illustrate these different types of effects. Overall, there are very few chemicals or chemical mixtures that have been proven to cause cancer in humans. These chemicals and the primary affected organs are listed in the Table.

Lung Cancer

Lung cancer is the third leading cause of cancer in the United States (behind prostate and breast cancers).

In spite of decades of focused research, the mortality rate for lung cancer is still higher than for other prevalent forms of cancer.

Chemicals Known to Cause Cancer in Humans

Chemical Name	*Main Tumor Site(s)*
Arsenic	lung, skin
Asbestos	lung, GI tract
Benzene	blood, bone marrow
Benzidine	bladder
Coke oven emissions	lung, kidney, prostrate
Diethylstilbestrol (DES)	breast
Direct black 38	liver
Direct blue	liver
Direct brown 95	liver
Hexavalent chromium	lung
Nickel	lung
Radon	lung
Secondhand smoke	lung
Vinyl chloride	liver, lung

This mortality rate represents an improvement over thirty years ago, in part because we have begun to understand how chemical carcinogenesis works, which aids in early diagnosis and treatment. Although we have reduced our exposure to many carcinogenic chemicals through regulations and education, the incidence of some cancers, including lung cancer, continues to rise (over the last decade, this rise in lung cancer incidence has been mostly among females).

Much of the information regarding how cancer develops and how it can be treated was painfully learned only after humans began getting the same types of cancer from exposure to a given chemical, or mixture of chemicals, over time. Examples of these chemicals are discussed below.

Asbestos manufacturing and use was big business in the years when the space program was on its course to the moon. Asbestos was a great insulator and was used for everything from wrapping pipes and ceiling tiles to hair dryers and potholders. However, after many years of manufacturing, workers began to develop a specific, novel type of lung cancer called mesothelioma. The type of lesion has almost never been seen before, and was only present in workers involved with asbestos handling.

For example, a 1976 epidemiologic study of over 19,000 asbestos insulation workers in the United States, Canada, and Ireland reported 182 deaths from mesothelioma in these workers; none were expected based on the historic incidence of this type of cancer worldwide. This led to other studies of workers in the textile and friction products manufacturing industries, asbestos cement product industry, and mining and milling of naturally occurring asbestos in rock, which showed similar increased incidence of this type of cancer. It was then determined that asbestos fibers were inhaled, lodged in the lung airways, and led to development of cancer at these locations within the lung. Based on this evidence, the USEPA listed asbestos as a Group A chemical, which is defined as a known human carcinogen.

Subsequently, asbestos has been removed from thousands of buildings across the country, including many schools. Asbestos only poses a health threat when the material is flaky or powdery, and small particles can float in the air and be inhaled. In its intact, natural form, it is inert and nontoxic. Although removing asbestos from buildings might make the buildings safer for its occupants (depending on the status of the material), it presents a risk for the workers removing the asbestos. The process of removal makes the asbestos flake, increasing exposure for these people. Therefore, a respirator is required for workers involved with asbestos remediation.

Again, this is an example of a regulation designed to minimize exposure, and therefore toxicity, of a chemical to humans.

Cigarettes have been known for decades to cause lung cancer. Cigarettes contain over 4,000 ingredients. Over 40 of these ingredients are substances that are known to cause cancer in humans or animals; some of these substances are present in tobacco and some are present as additives used by tobacco companies. However, long before we knew which components of cigarettes were responsible, there was substantial evidence across the world that cigarette smokers got lung cancer more often than non-smokers. Filters helped reduce the tar intake from smoking, but the small particulates and vapors, which contain some carcinogenic chemicals, still get absorbed into the lung.

Due to the difficulties involved with identifying chemicals causes of cancer discussed earlier (e.g., latency time), a definite link between second-hand cigarette smoke, also referred to as environmental tobacco smoke (ETS), has only recently been established. Both the USEPA and IARC have recently classified ETS as a known human carcinogen. This should be expected because ETS is chemically similar to the smoke inhaled by smokers, which includes several carcinogenic chemicals.

It is difficult to establish a link between chemical exposure in the environment and cancer because of the latency period and the lack of specific information on the level of exposure (i.e., the dose) someone might receive second-hand. This is more difficult than evaluating risks to the smoker alone, because the amount of exposure is difficult to estimate. For example, we can't ask someone how many packs of cigarettes they inhale from the environment if they don't smoke.

We can, however, identify people with lung cancer that have never smoked, and find out if they grew up with smokers in the house, or worked with smokers. Linking effects to possible causes using this approach is the basis of the science of epidemiology. To illustrate the use of epidemiological research in toxicology, the process used by the USEPA to classify ETS as a known human carcinogen is summarized below.

USEPA first looked at thirty available studies of the lung cancer incidence of the non-smoking women whose husbands were smokers. In twenty-four of these studies, there was in increased risk of lung cancer in the women over those whose husbands did not smoke. Less than half of these studies reported a statistically significant increase. However, the probability that this many studies would find significantly higher risks is less than 1 in 10,000. This first comparison includes those women that might have received only little exposure from their husbands.

This is the problem of quantifying exposure to environmental chemicals discussed earlier.

If these women did not get lung cancer, then this might artificially lower the actual increased risk to ETS. To account for this unknown, USEPA looked only at the seventeen of these twenty-four studies in which the men smoked the most. When incorporating the rate of exposure into the evaluation, all seventeen studies showed as increase in lung cancer risk from ETS. Nine of these seventeen studies reported significantly increased risk. The probability of this many studies finding significantly higher risks is less than one in ten million. This is less likely than winning the state lottery or being struck by lightning. At this point, the evidence becomes pretty strong that the increased risk of lung cancer is directly related to ETS. However, the USEPA went one-step further.

One key feature of toxicology is the dose-response relationship, which describes how increasing does (e.g., exposure) result in increased incidence of response (e.g., cancer).

The USEPA looked for such a relationship between the level of ETS and lung cancer incidence in the wives whose husbands smoked. Fourteen of the twenty-four studies provided dose-response relationship information. All fourteen of these studies showed increasing incidence of lung cancer with increasing levels of ETS. Ten of these fourteen studies reported significantly increased risk.

The probability of this happening by chance is less than one in one billion. This provides very strong evidence of casualty.

As is evident from this example, the process starts with identifying general trends, getting more and more specific as we try to eliminate other sources or causes from consideration. The process usually doesn't work as clearly as shown earlier. As the USEPA reports, it is unprecedented for such consistent results to be seen in epidemiological studies of cancer from environmental levels of a chemical or chemical mixture. In other words, it is rare that epidemiology along can be used to link cause and effect. This is due to the many variables that are typically not consistent across all the people included in the studies.

If cigarettes were dumped into the environment and sprinkled on the ground and regulated as industrial chemicals, the cancer risk from possible exposure to the carcinogenic chemicals contained in cigarettes would require them to be cleaned up and disposed of in a landfill. However, because exposure to chemicals from smoking cigarettes is voluntary, any cancer risks from smoking are accepted by the individual. However, with regard to second-hand smoke, the person exposed is in an involuntary position. When exposures are not voluntary, people usually react by wanting the exposure to be eliminated. This difference between voluntary and involuntary risks lies at the heart of much of the confusion, fear, and emotionalism associated with risk assessment, toxicity, and exposure to chemicals.

Skin Cancer

The lung cancers discussed to this point represent a form of cancer with a high lethality rate.

Some cancers, such as some forms of skin cancer, are not particularly lethal; the death rate from skin cancers is less than most other forms of cancer. Skin cancers are tumors of the skin, including those associated with abnormal growth of moles or discolorations of the skin.

Two examples of causes of skin cancer are exposure to ultraviolet light and ingestion.

Skin melanomas often form in our middle years in response to many years of exposure to ultraviolet light while outdoors. These melanomas do not pose an appreciable risk of dying, and can usually be treated with topical ointments or creams. About 3 percent of all cancers are skin melanomas. The risk of getting skin cancer is measured by the percentage of people that get skin cancer, the same way the risk of getting more lethal cancers (e.g., lung cancer) is measured.

However, the risk of getting these two forms of cancer is not the same as the risk of dying from the cancer. The risk of dying from lung cancer (about 55 percent) is much higher than that for skin melanomas (about 16 percent). Chemicals causing both types of cancers are regulated identically. This makes it especially important to understand the basis of statements about risk to determine how to apply the information.

Ingestion of high enough levels of arsenic, usually from drinking water, can also lead to development of skin cancer. This is different from the skin cancer due to ultraviolet light because this type of skin cancer usually forms in areas not typically exposed to sunlight. Also, while ultraviolet light causes skin cancer from direct exposure, arsenic causes skin cancer only when ingested. Although this form of cancer is also usually not lethal, the amount of arsenic in our drinking water is regulated, so no toxicity should be associated with consumption.

This brings up an interesting observation. Regulations based on cancer chemicals do not differentiate between the types of cancer, for example lung cancer versus skin cancer. Even though lung cancer results in a much higher death rate, chemicals causing skin cancer are regulated to the same level of risk as all other carcinogens. It would be more useful if the regulatory values used for carcinogens reflected the severity of the cancer. In this way, chemicals causing cancers that have high survival rates could be regulated less stringently than those with lower rates of survival. This would allow for our regulations to focus most on those chemicals posing the greatest risk to our survival, while still protecting the public from all regulated chemicals.

Leukemia (Blood system)

Leukemia is cancer of the bone marrow that affects white blood cells; white blood cells help protect us from infection and disease. There are multiple types of leukemia, each differing in its lethality. The incidence of leukemia is about the same as that for skin melanomas. However, the death rate from leukemia (about 45 percent) is much higher than that for skin melanomas (about 16 percent).

One of the first chemicals definitively linked to a specific cancer in humans was benzene.

Benzene was historically used as a solvent, and is a component of gasoline. After many years of exposure, workers in the buildings where benzene was used as a solvent began to develop leukemia. For some of these workers, leukemia didn't develop until years after they left the job.

Using epidemiological evidence, researchers determined that the incidence of this type of leukemia was clustered around the workers at these plants that used benzene. With subsequent studies on animals, this link between benzene exposure and leukemia was confirmed.

Benzene levels are now regulated in most products. The amount of benzene we are exposed to when filling our gas tanks is small; however, exposure over the course of a lifetime does increase our risk of leukemia. Whether or not this increased risk is meaningful depends on one's perception of "acceptable risk".

Breast Cancer

The incidence of breast cancer has risen sharply over the last several years. It is currently the leading cause of cancer in women. As yet, we have not determined many of the causes of breast cancer, but chemical exposure cannot be ruled out. Many chemicals have recently been shown to have endocrine disruption effects; that is, effects that modify the actions of our hormones.

Because breast tissue has receptors for some hormones, chemicals that affect these hormones can affect the breast. It is not yet known if exposure to chemicals in the environment increases our risk for breast cancer. Other explanations for the higher rate of breast cancer recently include that more cancer cases are reported as people live longer and that women are better at detecting the cancer at early stages and are reporting this to their doctors. Endocrine disruption represents a new branch of environmental toxicology, and is in its infancy in terms of our knowledge and understanding.

Prostate Cancer

The incidence of prostate cancer has risen sharply over the last several years. It is currently the leading cause of cancer in men, and is twice as prevalent in men as breast cancer is in women.

However, as with breast cancer, we do not understand the specific causes of prostate cancer.

Chemical exposure might increase the risk of prostate cancer, but as yet we have rarely linked exposure to any specific chemical or chemical mixture with prostate cancer. One exception is emissions from coke ovens. These emissions contain several PAHs. As previously mentioned, several specific chemicals within this group are carcinogenic to the lung. However, there has been evidence in animals linking these emissions with prostate cancer. Other explanations for the increased incidence of this cancer type are the same as those discussed for breast cancer.

Unknowns

The examples of breast and prostate cancer illustrate our current lack of knowledge related to chemical impacts on hormones (the endocrine system) and on mechanisms of specific cancers.

We are only now beginning to understand some types of chemical effects on the immune system.

One example is dioxin, which has been shown to compromise the immune function in many rodent species. This increases the chance for an individual to get ill, and decreases the speed and effectiveness of recovery. These are often subtle effects, and directly ascribing them to a specific chemical is very difficult. That is one reason why animals are used in toxicology research.

We can control their environments well enough so that the only difference between different animals is the amount of a chemical they receive. Then it is easier to see small differences caused by the chemical.

Other major organ systems targeted by chemicals (examples include chloroform and dioxins) include the liver and kidney. As we discussed earlier, these organs have special functions that increase their exposure to chemicals compared with most other organs.

The metabolism that occurs in the liver can activate some chemicals, such as chloroform, to become toxic.

Cancer Mechanisms: Currently in the United States, one in three people develop some form of cancer, or uncontrolled cell growth, in their lifetimes. Some of these cancers are typically fatal (e.g., lung cancer from cigarette smoking), while some are treatable and not usually fatal (e.g., skin cancer from exposure to ultraviolet light). This high incidence rate indicates that there are a myriad of cancer agents, some of which are chemicals.

Sir Percival Pott first reported cancer in the late eighteenth century, which noted that chimney sweeps were developing cancer of the scrotum. It wasn't until 150 years later that the chemical cause and mechanism was understood. One of the chemicals in ash, benzo (a) pyrene, was found to be responsible for the cancer. (This same chemical is also present in diesel fuel, and it and other related chemicals are formed when we burn meats on a barbecue. Yet the number of scrotal cancer cases is very small relative to the number of men that eat barbecued meats, implying that a certain dose is needed before such cancers develop.)

The large time lag between identifying cancer and learning the cause underscores the complexity of cancer. One of the problems in identifying the causes of cancer is that cancer usually only develops many years after exposure to a chemical or set of chemicals.

We are learning more about various cancers, as well as their causes and potential cures, on a daily basis. Based on carefully controlled studies with lab animals and epidemiological (i.e., human) information (e.g., chronic workplace exposures), chemicals have been classified into those that are known human carcinogens, probable carcinogens, possible carcinogens, and those that are not carcinogenic. Very few chemicals are known human carcinogens, but many are considered probable carcinogens. This is because it is very difficult to be sure that a cancer that develops in humans is due only to chemical exposure. We all have different behaviors (e.g., smoking, drinking) that may contribute to cancer development. However, for certain chemicals, the type of cancer that results is very specific (e.g., mesothelioma of the lung from asbestos) or consistent (leukemia from benzene exposure). In these situations, we can feel more confident in directly linking exposure and toxicity.

Although there are many types of cancers and some types do not conform with the typical development of cancer, in general, cancer is the result of a series of events that results in uncontrolled cell growth. This process consists of four basic steps:

- Initiation
- Promotion
- Progression
- Cancer

Initiation is the mutation of a gene. When the initiator is a chemical, this typically occurs when the chemical interacts with and alters DNA. DNA is deoxyribonucleic acid, which contains the genetic code for all organisms. This genetic code is comprised of a series of genes, each of which governs specific actions (e.g., protein synthesis) that define and distinguish each organism.

The altered DNA is then replicated, leading to the mutation.

These mutations are within the cell and usually impact how cell processes work.

Mutations that cause changes to our appearance (e.g., cleft palate) are different than those that lead to cancer. Mutations at the cellular level occur constantly in our bodies. The vast majority of these mutations either result in death of the cell or are repaired through our metabolic processes.

It is only when the mutation allows the cell to survive, escapes repair processes, and successfully replicates during cell division that initiation is considered to have occurred. This step is irreversible. This does not mean the cancer will then develop; it means that if other events occur that allow these replicated, mutated cells to further multiply, cancer may develop.

Promotion is the process whereby the mutant cells formed during initiation are transformed into cancerous cells. This can occur by stimulation of cell division or other processes. Chemicals can cause this stimulation, or by specific genes within our cells that mistake the mutated cell for a normal cell. Cell processes can reverse this promotion up to a certain point. The end process of promotion is the presence of numerous cancerous cells that are stimulated to divide and grow.

Progression involves multiple events over time that result in development of a tumor.

It is at this point that a diagnosis of cancer may first be identified. This can take up to thirty years after initial exposure to a cancer-causing agent. Given this process and the fact that multiple events are necessary for cancer to develop, it is not surprising that we still do not fully understand all of its causes and find it difficult to ascribe a specific type of cancer to a single chemical. However, some chemicals are know to directly cause cancer, indicating that they are able to cause all steps in the progression of cancer from a normal cell (e.g., benzo(a)pyrene).

Because of this lack of knowledge about the majority of chemicals and their ability to directly cause cancer, regulatory programs such as those within USEPA assume that one molecule can lead to cancer. This is a non-threshold approach to cancer. That is, exposure by one cell to one molecule of a chemical can cause initiation, which can then lead to promotion, progression, and tumor development. As we have seen from the above discussion, our cells have repair mechanisms that decrease the chances that one molecule can directly lead to cancer.

Nonetheless, this assumption that there is no threshold for development of cancer has driven many regulatory programs for many years.

Research to find a cure for cancer, all forms of cancer, is on-going. Based on our non-medical experience in studying cancer and its manifestations over the years, it seems obvious that a cure for cancer is out there—every problem has a solution—but the cure for cancer will probably not be a serum like the polio vaccine. Instead, some approach at the cellular level will be found, probably something analogous to realigning domains within a ferrous metal to magnetize it. Of course, in regards to cancer, the realignment is targeted at the cells to get them under control and healthy.

Cancer Risk: A theoretical risk for getting caner if exposed to a substance every day for seventy years (a lifetime exposure). The true risk might be lower.

Candida: Genus of yeast-like fungi that are commonly part of the normal flora of the mouth, skin, intestinal tract, and vagina and can cause a variety of infections.

Candidate Measure (CM): A practice that has the potential to reduce pollutant loading, and thereby, the potential to improve water quality.

Candlepower: Unit of intensity or brightness of a standard candle at its source.

Canopy: In *forestry science*, the more or less continuous cover of branches and foliage formed by the crowns of adjacent trees in a forest.

Cap: A layer of clay, or other impermeable material installed over the top of a closed landfill to prevent entry of rainwater and minimize leachate.

Cap Rocks: Rocks of low permeability that overlie a geothermal reservoir.

Capable of Being Locked Out: In lockout/tagout procedure, an energy isolating device is capable of being locked out if it has a hasp or other means of attachment to which (or through which) a lock can be affixed, or it has a locking mechanism built into it. Other energy isolating devices are capable of being locked out if lockout can be achieved without the need to dismantle, rebuild, or replace the energy isolating device or permanently alter its energy control capability.

NOTE: After January 2, 1990, whenever replacement or major repair, renovation, or modification of a machine or equipment is performed, and whenever new machines or equipment are installed, energy isolating devices for such machines or equipment shall be designed to accept a lockout device.

Capacity Assurance Plan: A statewide plan which supports a state's ability to manage the hazardous waste generated within its boundaries over a twenty year period.

Capillaries: The smallest blood vessels.

Capillary Action: The means by which liquid moves through the porous spaces in a solid, such as soil, plant roots, and the capillary blood vessels in our bodies due to the forces of adhesion, cohesion, and surface tension. Capillary action is essential in carrying substances and nutrients from one place to another in plants and animals.

Capillary Fringe: The zone at the bottom of the vadose zone where ground water is drawn upward by capillary force. The capillary fringe is the zone immediately above the water table in which all or some of the interstices are filled with water that is under less than atmospheric pressure and that is continou7ous with the water below the water table (Meinzer, 1923, p. 26). The water is held above the water table by interfacial forces (for example, surface tension). The capillary fringe is typically saturated to some distance above its base at the water table; upward from the saturated part only progressively smaller pores are filled and the upper limit is indistinct. In some quantitative studies it is convenient to define the upper limit more or less arbitrarily. For instance, this limit may be defined as the level at which 50 percent of the pore space is filled with water (R.W. Stallman, 1969).

Some lateral flow generally occurs throughout the capillary fringe, but because the effective hydraulic conductivity decreases rapidly with moisture content, the lateral flow in the capillary fringe generally is negligible compared with that in the saturated zone, except where the capillary fringe and the saturated zone are of comparable thickness.

Caprock: 1)an impermeable rock layer that forms the seal on top of an oil or gas reservoir (seal) or 2) the insoluble rock on the top of a salt plug.

Capsule, Bacterial: Organized accumulations of gelatinous material on cell walls.

Capture: Water withdrawn artificially from an aquifer is derived from a decrease in storage in the aquifer, a reduction in the previous discharge from the aquifer, an increase in the recharge, or a combination of these changes (Theis, 1940). The decrease in discharge plus the increase in recharge is termed *capture.* Capture may occur in the form of decreases in the groundwater discharge into streams, lakes, and the ocean, or from decreases in that component of evapotranspiration derived from the saturated zone. After a new artificial withdrawal from the aquifer has begun, the head in the aquifer will continue to decline until the new withdrawal is balanced by capture.

Capture Efficiency: The fraction of organic vapors generated by a process that are directed to an abatement or recovery device.

Capture Velocity: The velocity of air induced by a hood to capture emitted contaminants external to the hood.

Capture Zone: The potion of an aquifer that contributes water to a particular pumping well.

Capturing Hood: These hoods are located next to an emission source without surrounding (enclosing it) it.

Carbon: In *chemistry*, a very common non-metallic element having the symbol C, the atomic number 6, anatomic weight of 12.01115, and a melting point about 360ºC.

Carbon Absorber: An add-on control device that uses activated carbon to absorb volatile organic compounds from a gas stream.

Carbon Absorption: Process whereby activated carbon, known as the sorbent, is used to remove certain wastes from water by preferentially holding them to the carbon surface.

Carbon Bonds: In *chemistry*, carbon forms strong bonds with a variety of non-metals:

- C-H bond energy = 99 kcal/mol
- C-O bond energy = 84 kcal/mol
- C-Cl bond energy = 79 kcal/mol
- C-N bond energy = 70 kcal/mol

Carbon also forms single and multiple bonds with itself, allowing carbons to be linked together in chains of varying lengths.

- C-C bond energy = 83 kcal/mol
- C-C bond energy = 143 kcal/mol
- C-C bond energy = 196 kcal/mol

✔ **Key Point:** Carbon likes to form bonds so well with itself that it can form multiple bonds to satisfy its valence of four.

In contrast, Si-Si and Ge-Ge bonds are relatively weak.

- Si-Si bond energy = 42 kcal/mol
- Ge-Ge bond energy = 65.4 kcal/mol

Organic compounds primarily contain ***covalent bonds*** (i.e., equally shared electrons) between carbon and atoms of hydrogen, oxygen, the halogens, nitrogen, sulfur, and other carbon atoms.

The **chemical and physical properties** of carbon compounds are related to three factors:

1. The **number of C atoms** in the molecule

2. The **type of bonding** in the molecule
3. The kind(s) of **functional groups** in the molecule

Carbon Budget: In *environmental science*, the carbon budget is the balance of the exchanges of carbon between carbon reservoirs (atmosphere, oceans, biota, fossil fuel deposits, soils, and society) in the carbon cycle.

Carbon Cycle: The atmosphere is a reservoir of gaseous carbon dioxide, but to be of use to life, this carbon dioxide must be converted into suitable organic compounds—“fixed”—as in the production of plant stems by the process of photosynthesis. The productivity of an area of vegetation is measured by the rate of carbon fixation. The carbon fixed by photosynthesis is eventually returned to the atmosphere as plants and animals die and the dead organic matter is consumed by the decomposer organisms.

Carbon Dioxide (CO_2): A colorless, odorless inert gas—a byproduct of combustion; the most common greenhouse gas.

Carbon Footprint: In *environmental science*, the total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide.

Carbon Monoxide (CO): A colorless, odorless gas produced by incomplete combustion. Carbon monoxide is poisonous inhaled.

Carbon-Nitrogen Ratio (C/N): The weight ratio of carbon to nitrogen.

Carbon Sequestration: The absorption and storage of carbon dioxide from the atmosphere by naturally occurring plants.

Carbon Sink: A place of carbon accumulation such as in large forests or ocean sediments.

Carbon Tetrachloride (CCl4): Compound consisting of one carbon atom and four chlorine atoms, once widely used as an industrial raw material, as a solvent, and in the production of CFCs. Use as a solvent ended when it was discovered be carcinogenic.

Carbonate: A sediment formed by the organic or inorganic precipitation from aqueous solution of carbonates of calcium, magnesium, or iron.

Carbonate Hardness: Temporary hard water caused by the presence of bicarbonates; when water is boiled, the bicarbonates are converted to insoluble carbonates that precipitate as scale.

Carbonic Acid: An unstable acid formed by dissolving carbon dioxide in water.

Carboxyhemoglobin: Hemoglobin in which the iron is bound to carbon monoxide (CO) instead of oxygen.

Carboy: A rigid 5-15 lb container primarily used to transport liquids.

Carcinogen: Any substance or chemical that can cause or aggravate cancer. Chemicals known to cause cancer are listed in the Table.

Carcinogenic: Causing or producing cancer.

Carcinogenicity: Cancer-causing potential (of an agent or substance).

Carpal Tunnel Syndrome: An injury to the median nerve inside the wrist, frequently caused by ergonomically incorrect repetitive motion.

Carrier: 1. An entity engaged in the transportation of passengers or property by land or water as a common, contract, or private carrier, or by civil aircraft (49 CFR 171.8). A common carrier is a for-hire carrier that holds itself out to serve the general public at published rates. A contract carrier offers transportation services to certain shipper under contracts that specify charges to be applied, the character of the service, and the time of performance. 2. A bearer and transmitter of a agent capable of causing infectious disease. An asymptomatic carrier shows no symptoms of carrying an infectious agent.

Carrying Capacity: 1. In recreation management, the amount of use a recreation area can sustain without loss of quality. 2. In wildlife management, the maximum number of animals an area can supported during a given period.

CAS Registration Number: A number assigned by the Chemical Abstract Service to identify a chemical.

Cascade Aeration: In *renewable energy* and *wastewater engineering*, the aeration of an effluent stream through the action of falling water.

Cascading Heat: A process that uses a stream of geothermal hot water or steam to perform successive tasks requiring low and lower temperatures.

Case Study: A brief fact sheet providing risk, cost, and performance information on alternative methods and other pollution prevention ideas, compliance initiatives, voluntary efforts, etc.

Cask: A thick-walled container (usually lead) used to transport radioactive material.

Cassava: In biomass, a shrubby tropical plant native to South American and widely grown there an in other regions as a food crop for its large, tuberous, starchy roots. Now also grown for its potential value as a fuel crop.

Cast Silicon: Crystalline silicon obtained by pouring pure molten silicon into a vertical mold and adjusting the temperature gradient along the mold volume during cooling to obtain slow, vertically-advancing crystallization of the silicon. The polycrystalline ingot thus formed is composed of large, relatively parallel, interlocking crystals. The cast ingots are sawed into wafers for further fabrication into photovoltaic cells. Cast-silicon wafers and ribbon-silicon sheets fabricated into cells are usually referred to as polycrystalline photovoltaic cells.

Casual Factor: A person, thing, or condition that contributes significantly to an accident or to a project outcome. Causal factors fall into three categories: direct cause, contribution cause, and root cause.

Catabolism: In biology, the destructive part of metabolism where living tissue is changed into energy and waste products.

Catalysis: The acceleration (or retardation) of chemical or biochemical reactions by a relatively small amount of a substance (the catalyst), which itself undergoes no permanent chemical change, and which may be recovered when the reaction has finished.

Catalyst: A substance that alters the speed of, or makes possible, a chemical or biochemical reaction, but remains unchanged at the end of the reaction.

Catastrophe: A loss of extraordinary large dimensions in terms of injury, death, damage, and destruction.

Catchment: The natural drainage area for precipitation, the collection area for water supplies or a river system. The notional line, or watershed, on surrounding high land defines the area.

Categorical Exclusion: A class of actions which either individually or cumulatively would not have a significant effect on the human environment and therefore would not require preparation of an environmental assessment or environmental impact statement under the National Environment Policy Act (NEPA).

Categorical Pretreatment Standard: A technology-based effluent limitation of an industrial facility discharging into a municipal sewer system. Analogous I stringency to Best Availability Technology (BAT) for direct dischargers.

Cathode: The electrode at which reduction (a gain of electrons) occurs. For fuel cells and other galvanic cells, the cathode is the positive terminal; for electrolytic bells (where electrolysis occurs), the cathode is the negative terminal.

Cathodic Protection: A technique to prevent corrosion of a metal surface by making it the cathode of an electrochemical cell.

Cation: Positively charged ion; can adsorb to soil particle.

Cation Exchange: Ion exchange process in which cations in solution are exchanged for other cations on the surface of a surface-active (ion exchanger) material, such as a clay colloid or organic colloid.

Cation-Exchange Capacity: The total amount of exchangeable cations that can be adsorbed by a soil, or a soil constituent expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value.

Caustic: Capable of burning, corroding, and dissolving, or eating away by chemical action.

Caution: A safety signal word denoting a precaution.

Cavitation: The formation and collapse of gas pockets or bubbles on the blade of an impeller or the gate of a valve; collapse of these pockets or bubbles drive water with such force that it can cause pitting of the gate or valve surface.

CBRN: Chemical, Biological, Radiological, Nuclear.

CDC: Centers for Disease Control and Prevention, the U.S. government agency at the forefront of public health efforts to prevent and control infectious and chronic diseases, injuries, workplace hazards, disabilities, and environmental health threats.

Ceiling Limit: The concentration in the employee's breathing zone that shall not be exceeded at any time during any part of the working day. For airborne contaminants, if instantaneous monitoring is not feasible, then the ceiling shall be assessed as a 15-minute time-weighted average exposure that shall not be exceeded at any time during the working day (DOE 0 548.10A).

Cells: 1. Are the fundamental units of life. The cell retains a dual existence as distinct entity and a building block in the construction of organisms. These conclusions about cells were observed and published by Schleiden (1838). Later, Rudolph Virchow added the powerful dictum, "Omnis cellula e cellula" . . . "All cells only arise from pre-existing cells". This important tenet, along with others, formed the basis of what we call Cell Theory. The modern tenets of the Cell Theory include:

- all known living things are made up of cells
- the cell is structural and functional unit of all living things
- all cells come from pre-existing cells by division
- cells contain hereditary information which is passed from cell to cell during cell division
- all cells are basically the same in chemical composition
- all energy flow of life occurs within cells.

The modern tenets, of course, post-dated Robert Hooke's 1663 discovery of cells in a piece of cork, which he examined under his primitive microscope. Hooke drew the cell (actually it was the cell wall he observed) and coined the word CELL. The word cell is derived from the Latin word 'cellula' which means small compartment.

Thus, since the 19th century, we have known that all living things, whether animal or plant, are made up of cells. Again, the fundamental unit of all living things, no matter how complex, is the cell. A typical cell is an entity isolated from other cells by a membrane or cell wall. The cell membrane contains protoplasm (the living material found within them) and the nucleus.

In a typical mature plant cell, the cell wall is rigid and is composed of nonliving material, while in the typical animal cell the wall is an elastic living membrane. Cells exist in a very great variety of sizes and shapes, as well as functions. The cell is the smallest functioning unit of a living thing that still as the characteristics of the whole organism. Size ranges from bacteria too small to be seen with the light microscope to the largest single cell known, the ostrich egg. Microbial cells also have an extensive size range, some being larger than human cells.

✔ **Interesting Point**: The small size of a cell is limited by the volume capable of holding genetic material, proteins, etc., which are necessary to carry out the basic cell functions and reproduction. The large size of a cell is limited by metabolism. A cell must take in adequate amounts of oxygen and nutrients and get rid of wastes.

Cells are of two fundamental types, prokaryotic and eukaryotic. ***Prokaryotic*** (meaning before nucleus) cells are simpler in design from eukaryotic cells, possessing neither a nucleus nor the organelles (i.e., internal cell structures, each of which has a specific function within the cells) found in the cytoplasm of eukaryotic (meaning true nucleus) cells. Because prokaryotes do not have a nucleus, DNA is in a "nucleoid" region. With the exception of archaebacteria, proteins are not associated with bacterial DNA. Bacteria are the best known and most studied form of prokaryotic organisms.

✔ **Important Point**: Cells may exist as independent units, e.g., the Protozoa, or as parts of multicellular organisms which the cells may develop specializations and form tissues and organs with specific purposes.

Prokaryotes are unicellular organisms that do not develop or differentiate into multicellular forms. Some bacteria grow in filaments, or masses of cells, but each cell in the colony is identical and capable of independent existence. Prokaryotes are capable of inhabiting almost every place on the earth, from the deep ocean, to the edges of hot springs, to just about every surface of our bodies.

✔ **Important Point**: It is often state that prokaryotic cells are among the most primitive forms of life on earth. However, it is important to point out that primitive does not mean they are outdated in the evolutionary sense, since primitive bacteria seem little changed, and thus may be viewed as well adapted.

As mentioned, prokaryotes are distinguished from eukaryotes on the basis of nuclear organization, specifically their lack of a nuclear membrane. Also, prokaryotes are smaller and simpler than eukaryotic cells. Again, prokaryotes also lack any of the intracellular organelles (i.e., internal cell structures, each of which has a specific function within the cell) and structures that are characteristic of eukaryotic cells. Most of the functions of organelles, such as mitochondria, chloroplasts, and the Golgi apparatus, are taken over by the prokaryotic plasma membrane. Prokaryotic cells have three architectural regions: appendages called **flagella** and **pili**—proteins attached to the cell surface; a **cell envelope** consisting of a **capsule,** a **cell wall**, and a **plasma membrane**; and a **cytoplasmic region** that contains the **cell genome** (DNA) and ribosomes and various sorts of inclusions.

Eukaryotic cells evolved about 1.5 billion years ago. Protists, fungi, plants, and animals have eukaryotic cells—all plants and animals are eukaryotes. They are larger, as much as 10 times the size of prokaryotic cells and most of their genetic material is found within a membrane-bound nucleus (a true nucleus), which is generally surrounded by several membrane-bound organelles. The presence of these membrane-bound organelles points to the significant difference between prokaryotes and eukaryotes. Although eukaryotes use the same genetic code and metabolic processes as prokaryotes, their higher level of organizational complexity has permitted the development of truly multicellular organisms.

✔ **Important Point**: An enormous gap exists between prokaryote cells and eukaryote type cells: ". . . prokaryotes and eukaryotes are profoundly different from each other and clearly represent a marked dichotomy in the evolution of life. . . .The organizational complexity of the eukaryotes is so much greater than that of prokaryotes that it is difficult to visualize how a eukaryote could have arisen from any known prokaryote" (Hickman et al., 1997).

Prokaryotic and eukaryotic cells also have their similarities. All cell types are bounded by a plasma membrane that encloses proteins and usually nucleic acids such as DNA and RNA. The Table shows a comparison of key features of both cell types.

Comparison of typical Prokaryotic and Eukaryotic Cells

Characteristic	*Prokaryotic*	*Eukaryotic*
Size	1-10 μm	10–100 μm
Nuclear envelope	Absent	Present
Cell wall	Usually	Present (Plants)/ Absent (animals)
Plasma membrane	Present	Present
Nucleolus	Absent	Present
DNA	Present (single loop)	Present
Mitochondria	Absent	Present
Chloroplasts	Absent	Present (Plants only)
Endoplasmic reticulum	Absent	Present
Ribosomes	Present	Present
Vacuoles	Absent	Present
Golgi apparatus	Absent	Present
Lysosomes	Absent	Often Present
Cytoskeleton	Absent	Present

✔ **Interesting Point**: Plant cells can *generally* be distinguished from animal cells by: (1) the *presence* of cell walls, chloroplasts, and central vacuoles in *plants* and their absence in animals, and (2) the *presence* of lysosomes and centrioles in *animals* and their absence in plants.

2. In *electricity*, a primary galvanic unit that converts chemical energy directly into electrical energy. 3. A unit designed to convert radiant energy into electrical energy.

Cellulose: The main carbohydrate in living plants. Cellulose forms the skeletal structure of the plant cell wall.

Celsius Scale: In *measurement*, a unit of temperature where 1ºC = 5/9 × (ºFahrenheit – 32).

Central Collection Point: Location where a generator of regulated medical waste consolidates wastes originally generated at various locations in his facility. The wastes are gathered together for treatment on-site or for transportation elsewhere for treatment and /or disposal. This term could also apply in community hazardous waste collections, industrial and other waste management systems.

Centralized Wastewater Treatment System: A wastewater collection and treatment system that consists of collection sewers and a centralized treatment facility. Centralized system are used to collect and treat wastewater from entire communities.

Centrifugal and Centripetal Forces: Two terms environmental professionals should be familiar with are centrifugal and centripetal forces. Centrifugal force is a concept based on an apparent (but not real) force. It may be regarded as a force that acts radially outwards from a spinning or orbiting object (a ball tied to a string whirling about), thus balancing a real force, the centripetal force (the force that acts radially inwards).

This concept is important in engineering, because many of the machines encountered on the job may involve rapidly revolving wheels or flywheels. If the wheel is revolving fast enough, and if the molecular structure of the wheel is not strong enough to overcome the centrifugal force, it may fracture. Pieces (shrapnel) of the wheel would fly off tangent to the arc described by the wheel. The safety implications are obvious. Any worker using such a device, or near it may be severely injured when the rotating member ruptures. This is what happens when a grinding wheel on a pedestal grinder "bursts." Rim speed determines the centrifugal force, and rim speed involves both the speed (rpm) of the wheel and the diameter of the wheel.

Centrifugal Collector: A mechanical system using centrifugal force to remove aerosols from a gas stream or to remove water from sludge.

Centrifugal Pump: The volute-cased centrifugal pump provides the pumping action necessary to transfer liquids from one point to another. First, the drive unit (usually an electric motor) supplies energy to the pump impeller to make it spin. This energy is then transferred to the water by the impeller. The vanes of the impeller spin the liquid toward the outer edge of the impeller at a high rate of speed or velocity. This action is very similar to that which would occur when a bucket full of water with a small hole in the bottom is attached to a rope and spun. When sitting still, the water in the bucket will drain out slowly. However, when the bucket is spinning, the water will be forced through the hole at a much higher rate of speed.

Centrifugal pumps may be single stage, having a single impeller, or they may be multiple stage, having several impellers through which the fluid flows in series. Each impeller in the series increases the pressure of the fluid at the pump discharge. Pumps may have thirty or more stages in extreme cases. In centrifugal pumps, a correlation of pump capacity, head, and speed at optimum efficiency is used to classify the pump impellers with respect their specific geometry. This correlation is called **specific speed**, and is an important parameter for analyzing pump performance (Garay 1990).

The volute of the pump is designed to convert velocity energy to pressure energy. As a given volume of water moves from one cross-sectional area to another with the volute casing, the velocity or speed of the water changes proportionately. The volute casing has a cross-sectional area, which is extremely small at the point in the case that is farthest from the discharge. This area increases continuously to the discharge. As this area increases, the velocity of the water passing through it decreases as it moves around the volute casing to the discharge point.

As the velocity of the water decreases, the velocity head decreases and the energy is converted to pressure head. There is a direct relationship between the velocity of the water and the pressure it exerts. Therefore, as the velocity of the water decreases, the excess energy is converted to additional pressure (pressure head). This pressure head supplies the energy to move the water through the discharge piping.

The centrifugal pump operates on the principle of an energy transfer and, therefore, has certain definite characteristics that make it unique. The type and size of the impeller limit the amount of energy that can be transferred to the water, the characteristics of the material being pumped, and the total head of the system through which the water is moving. For any one centrifugal pump, there is a definite relationship between these factors along with head (capacity), efficiency, and brake horsepower.

Head (Capacity)

As might be expected, the capacity of a centrifugal pump is directly related to the total head of the system. If the total head on the system is increased, the volume of the discharge will be reduced proportionately. As the head of the system increases, the capacity of the pump will decrease proportionately until the discharge stops. The head at which the discharge no longer occurs is known as the **Cut-Off Head**.

The total head includes a certain amount of energy to overcome the friction of the system. This friction head can be greatly affected by the size and configuration of the piping and the condition of the system's valving. If the control valves on the system are closed partially, the friction head can increase dramatically. When this happens, the total head increases and the capacity or volume discharged by the pump decreases. In many cases, this method is employed to reduce the discharge of a centrifugal pump. It should be noted, however, that this does increase the load on the pump and drive system causing additional energy requirements and additional wear.

The total closure of the discharge control valve increases the friction head to the point where all the energy supplied by the pump is consumed in the friction head and is not converted to pressure head. Consequently, the pump exceeds its cut-off head and the pump discharge is reduced to zero. Again, it is important to note that although the operation of a centrifugal pump against a closed discharge may not be hazardous (as with other types of pumps), it should be avoided because of the excessive load placed on the drive unit and pump. Our experience has shown that on occasion the pump can produce pressure higher than the pump discharge piping can withstand. Whenever this occurs, the discharge piping may be severely damaged by the operation of the pump against a closed or plugged discharge.

Efficiency

Every centrifugal pump will operate with varying degrees of efficiency over its entire capacity and head ranges. The important factor in selecting a centrifugal pump is to select a unit that will perform near its maximum efficiency in the expected application.

Brake Horsepower Requirements

In addition to the head capacity and efficiency factors, most pump literature includes a graph showing the amount of energy in horsepower that must be supplied to the pump to obtain optimal performance.

Centrifugal Pump: Advantages & Disadvantages

The primary reason centrifugal pumps have become one of the most widely used types of pumps are the several advantages it offers. These advantages include:

- **Construction**—The pump consists of a single rotating element and simple casing, which can be constructed using a wide assortment of materials. If the fluids to be pumped are highly corrosive, the pump parts that are exposed to the fluid can be constructed of lead or other material that is not likely to corrode. If the fluid being pumped is highly abrasive, the internal parts can be made of abrasion resistant material or coated with a protective material.

  Also, the simple design of a centrifugal pump allows the pump to be constructed in a variety of sizes and configurations. No other pump currently available has the range of capacities or applications available through the use of the centrifugal pump.

- **Operation**—simple and quiet best describes the operation of a centrifugal pump. An operator-in-training with a minimum amount of experience may be capable of operating facilities that use centrifugal-type pumps. Even when improperly operated, the centrifugal pump's rugged construction allows it to operate (in most cases) without major damage.
- **Maintenance**—the amount of wear on a centrifugal pump's moving part is reduced and its operating life is extended because its moving parts are not required to be constructed to very close tolerances.
- **Pressure Is Self-Limited**—because of the nature of its pumping action, the centrifugal pump will not exceed a predetermined maximum pressure. Thus, if the discharge valve is suddenly closed, the pump cannot generate additional pressure that might result in damage to the system or could potentially result in a hazardous working condition. The power supplied to the impeller will only generate a specified amount of head (pressure). If a major portion of this head or pressure is consumed in overcoming friction or is lost as heat energy, the pump will have a decreased capacity.
- **Adaptable to High Speed Drive Systems**—allows the use of high speed, high efficiency motors. In situations where the pump is selected to match a specific operating condition, which remains relatively constant, the pump drive unit can be used without the need for expensive speed reducers.
- **Small Space Requirements**—for most pumping capacities, the amount of space required for installation of the centrifugal-type pump is much less than that of any other type of pump.
- **Fewer Moving Parts**—rotary rather than reciprocating motion employed in centrifugal pumps reduces space and maintenance requirements due to the fewer number of moving parts required.

Although the centrifugal pump is one of the most widely used pumps, it does have a few disadvantages.

- **Additional Equipment Needed for Priming**—the centrifugal pump can be installed in a manner that will make it self-priming, but it is not capable of drawing water to the pump impeller unless the pump casing and impeller are filled with water. This can cause problems, because if the water in the casing drains out, the pump would cease pumping until it is refilled.

  Therefore, it is normally necessary to start a centrifugal pump with the discharge valve closed. The valve is then gradually opened to its proper operating level. Starting the pump against a closed discharge valve is not hazardous provided the valve is not left closed for extended periods.
- **Air Leaks Affect Pump Performance**—air leaks on the suction side of the pump can cause reduced pumping capacity in several ways. If the leak is not serious enough to result in a total loss of prime, the pump may operate at a reduced head or capacity due to air mixing with the water. This causes the water to be lighter than normal and reduces the efficiency of the energy transfer process.
- **Narrow Range of Efficiency**—centrifugal pump efficiency is directly related to the head capacity of the pump. The highest performance efficiency is available for only a very small section of the head-capacity range. When the pump is operated outside of this optimum range, the efficiency may be greatly reduced.
- **Pump May Run Backwards**—if a centrifugal pump is stopped without closing the discharge line, it may run backwards, because the pump does not have any built-in mechanism to prevent flow from moving through the pump in the opposite direction (i.e., from discharge side to suction). If the discharge valve is not closed or the system does not contain the proper check valves, the flow that was pumped from the supply tank to the discharge point will immediately flow back to the supply tank when the pump shuts off. This results in increased power consumption due to the frequent startup of the pump to transfer the same liquid from supply to discharge.

Note: It is sometimes difficult to tell whether a centrifugal pump is running forward or backwards because it appears and sounds like it is operating normally when operating in reverse.

- **Pump Speed Is Difficult to Adjust**—centrifugal pump speed cannot usually be adjusted without the use of additional equipment, such as speed reducing or speed increasing gears or special drive units.

  Because the speed of the pump is directly related to the discharge capacity of the pump, the primary method available to adjust the output of the pump other than a valve on the discharge line is to adjust the speed of the impeller. Unlike some other types of pumps, the delivery of the centrifugal pump cannot be adjusted by changing some operating parameter of the pump.

Centrifugal Pump Applications

The centrifugal pump is probably the most widely used pump available at this time because of its simplicity of design and wide ranging diversity (it can be adjusted to suit a multitude of applications). Proper selection of the pump components (impeller, casing, etc.) and construction materials can produce a centrifugal pump capable of transporting not only water but also other materials ranging from material/chemical slurries to air (centrifugal blowers). To attempt to list all of the various applications for the centrifugal pump would exceed the limitations of this guidebook.

- *Large Volume Pumping*—In water/wastewater operations, the primary use of centrifugal pumps is large volume pumping. In large volume pumping, generally low speed, moderate head, vertically shafted pumps are used. Centrifugal pumps are well suited for water/wastewater system operations because they can be used in conditions where high volumes are required and a change in flow is not a problem. As the discharge pressure on a centrifugal pump is increased, the quantity of water/wastewater pumped is reduced. Also, centrifugal pumps can be operated for short periods with the discharge valve closed.
- *Non-Clog Pumping*—specifically designed centrifugal pumps using closed impellers with, at most, two to three vanes. It is usually designed to pass solids or trash up to 3” in diameter.
- *Dry Pit Pump*—depending on the application, may be either a large volume pump or a non-clog pump. It is located in a dry pit that shares a common wall with the wet well. This pump is normally placed in such a position to ensure that the liquid level in the wet well is sufficient to maintain the pump’s prime.
- *Wet Pit or Submersible Pump*—usually a non-clog type pump that can be submerged, with its motor, directly in the wet well. In a few instances, the pump may be submerged in the wet well while the motor remains above the water level. In these cases, the pump is connected to the motor by an extended shaft.
- *Underground Pump Stations*—using the wet well-dry well design, the pumps are located in an underground facility. Wastes are collected in a separate wet well, then pumped upward and discharged into another collector line or manhole. This system normally uses a non-clog type pump and is designed to add sufficient head to water/waste flow to allow gravity to move the flow to the plant or the next pump station.
- *Recycle or Recirculation Pumps*—since the liquids being transferred by the recycle or recirculation pump normally do not contain any large solids, the use of the non-clog type centrifugal pump is not always required. A standard centrifugal pump may be used to recycle trickling filter effluent, return activated sludge, or digester supernatant.
- *Service Water Pumps*—the wastewater plant effluent may be used for many purposes, such as, to clean tanks, water lawns, provide the water to operate the chlorination system, and to backwash filters. Since the plant effluent used for these purposes is normally clean, the centrifugal pumps used closely parallel the units used for potable water. In many cases, the double suction, closed impeller or turbine type pump will be used.

Centrifuge: A device used to separate solid or liquid particles of different density by spinning them at high speed.

CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act of 1980; Superfund): Provides for cleanup and compensation, and assigns liability for the release of hazardous substances into the air, land, or water.

CFR: Code of Federal Regulations.

Chain of Custody: The process of documenting, controlling, securing, and accounting for physical possession of evidence, from initial collection through final disposition.

Chains and Chain Slings: Steel and alloys (stainless steel, monel, bronze and other metals) are commonly used for lifting slings made of chain. The safety engineer needs to know a number of facts related to chain slings, and the type of chain that is authorized for use in slings. For example, rated capacity (working load limit) for welded alloy steel chain slings must conform with the values in the appropriate tables in 1926.251. Whenever wear at any point of any chain link exceeds that specified in the 1926.251 Table, the assembly must be removed from service. All such slings have permanently affixed durable identification, stating size, grad, rated capacity, and sling manufacturer. Finally, regular hardware chain or other chain not specifically designed for use in slings should not be used for load lifting.

Character Descriptors: Terms used by trained odor panelists to describe an odor’s character (e.g., mint, citrus, or earthy).

Characteristic: Any one of the four categories used in defining hazardous waste: ignitability, corrosivity, reactivity, and toxicity.

Characteristic Waste: Waste that is considered hazardous under RCRA because it exhibits any our different properties: ignitability, corrosivity, reactivity, and toxicity.

Characterization of Ecological Effects: Part of ecological risk assessment that evaluates ability of a stressor to cause adverse effects under given circumstances.

Characterization of Exposure: Portion of an ecological risk assessment that evaluates interaction of a stressor with one or more ecological entities.

Charcoal Filter: In *materials*, a filtering device made of activated carbon capable of eliminating certain materials, especially those organic in nature.

Charcoal Test: A test used to measure the amount of condensate in natural gas. Activated charcoal is used to absorb the condensate from a volume of natural gas.

Charges: In electricity, like charges in an electric field always repel; unlike charges always attract.

Charles's Law: The volume of a given mass of gas at constant pressure is directly proportional to its absolute temperature (temperature in kelvin).

Check-Valve Tubing Pump: Water sampling tool also referred to as a water pump.

Chelating Agent (aka sequestering agents): Chemical that combine with metal ions and remove them from their sphere of action.

Chemical: A substance with a distinct molecular composition that is produced by or used in a chemical process.

Chemical Agent: A chemical substance that is intended for use in military operations to kill, seriously injure, or incapacitate people through its physiological effects.

Chemical Bond: The tendency of elements to link together to form compounds through a shift of electronic structure is known as **valence.** This linking process is accomplished through **valence electrons**. These electrons occupy the last energy level of an atom. It is here where atoms come in contact with each other. It stands to reason that chemical bonds will occur here in any chemical reaction. The maximum number of valence electrons any atom can contain is 8. Any number less than 8 will allow that atom to act as a donor or recipient of electrons to become stable. Atoms that give electrons will become + ions and have a positive (+) charge, while atoms that receive electrons will become a negative ion with a negative (–) charge.

Atoms are linked or joined by **chemical bonds.** Only electrons are involved in the formation of chemical bonds between atoms. Only the *outermost electrons (*i.e., the *outer shell electrons*) are typically involved in bonding. Each bond consists of two electrons, one from each atom in the bond.

There are different "types" of chemical bonds—depending on the type of atoms that are bonded together—**covalent** and **ionic bonds.**

A **covalent bond** results from the sharing of a pair of electrons between two covalent bonds:

- **Nonpolar:** Here the valence electrons are shared equally, thus eliminating a positive and negative end on the molecule. An example of a non-polar bond is $CHCl_4$. It is nonpolar, because although the 4 C-Cl bonds are all polar, the symmetry of their arrangement around the central C atom makes the overall molecule non-polar.
- **Polar covalent bond:** Here the valence electrons are shared unequally, causing the molecule to develop a positive end (where the electrons spend less time) and a negative end (where the electrons spend more time). This has to do with the electronegativity of the atom. The more electronegative the atom the more it will hold on to the electrons. Oxygen is very electronegative. Hydrogen is not. If the difference in electronegativity between two atoms is sufficiently large, the shared electron pair will spend all of its time on the more electronegative atom, resulting in ionic bonding rather than covalent bonding. An example of a polar covalent bond is $CHCL_3$, because of the polar C-Cl bond (Cl is an electronegative atom).

✔ **Key Point:** A polar covalent bond has a positively charged end and a negatively charged end.

In covalent bonding, the sharing of one pair of electrons is called a **single bond;** the sharing of two pairs of electrons is called a **double bond** (e.g., carbon dioxide) and the sharing of three pairs of electrons is called a **triple bond** (e.g., acetylene). Double bonds are more reactive than single bonds and compounds containing double bonds are somewhat more volatile than corresponding single-bonded molecules. Triple bonds are even more reactive than double bonds, and volatility in triple-bonded compounds is still greater.

An **ionic bond** results from the transfer of electrons from one atom to another. In an ionic bond, one atom donates one or more of its outermost electrons to another atom or atoms.

- The atom that gains the electrons becomes a negative ion, or **anion.**

✔ **Key Point:** Remember the mnemonic "a negative ion."

- The atom that loses the electron becomes a positive ion, or **cation.**

✔ **Key Point:** Covalent bonding is a process similar to ionic bonding, but the electrons are shared rather than transferred.

Electronegativity and Polarity

Electronegativity is a measure of the ability of an atom to attract its outermost electrons. The higher the electronegativity, the greater the atom's ability to attract other electrons.

Highly electronegative atoms tend to form ***ionic*** or ***polar covalent*** bonds. In **polar covalent bonds,** the more electronegative atom "keeps" the electron pair more (i.e., takes a larger share of the electron density). In **nonpolar covalent bonds** (e.g., C-C or C-H), the electrons are shared equality.

✔ **Key Point:** Think of chemical bonding as a continuum from nonpolar covalent bonds to ionic bonds. **Bond polarity** depends on the *electronegativity* of the atoms involved, but **overall molecular polarity** depends on *symmetry*.

Bond Strengths and Bond Angles

Chemists measure the *strength* of a bond by determining how much energy is needed to break the bond.

Other examples of Carbon (C) bond strengths are shown below.

Type of Bond	**Strength (kcal/mol)**
C-N	70
C-Cl	79
C-O	84
C-H	99

In addition to measuring bond strengths, chemists can also measure **bond angles** between atoms.

Bond angles depend on the type of atoms bonded together. Chemists predict ***bond angles*** and other 3D structure using computer programs.

Structural Formulas

The overall 3D shape of a molecule is represented by its ***structural formulas,*** which shows how the atoms are attached.

Isomers

Isomers are defined as one of several organic compounds with the same chemical formula but different structural formulas and therefore different properties.

✔ **Key Point:** Structural formulas give us the same information as the chemical formulas but they also tell us how the atoms are bonded together.

As mentioned, isomers are **different** compounds that have different properties, although these differences are often slight.

✔ **Key Point:** Structure makes the difference!

✔ **Interesting Point:** Compounds with the same formula but different molecular structure are called **isomers**. "Iso-" is a Greek word that means same or equal. "Mer" means unit or formula. Isomers are different compounds, even though they have the same formula.

Compound Point	Boiling
n-propanol	97.2°C
Isopropanol	82.5°C

Xylene Isomers

Compound	BP	MP
o-xylene	144C	–25C
m-xylene	139.3C	–47.4C
p-xylene	138C	14C

Hydrogen Bonding

Hydrogen bonds are bonds formed when hydrogen that is covalently bonded to an electronegative atom is attracted to another electronegative atom on another molecule. Hydrogen bonds are *weak* attractions between molecules, whereas ionic and covalent bonds are much stronger attractions between atoms. An everyday example of a hydrogen bond is in water.

✔ **Key Point:** In water, the oxygen-hydrogen bond is polar, oxygen being the more electronegative element. The molecule is therefore polar. The two lone pairs of electrons on the oxygen atom extenuate this. One end of the molecule is partially negative while the two hydrogen atoms become partially positive. The molecules of water are attracted to one another, with the slightly positive hydrogens attracted to the negative "ends" (the oxygens) of the other water molecules. This intermolecular attraction is termed "hydrogen bonding", and acts almost like a glue holding the molecules of water together. In the case of water the effect on the physical properties of water are quite amazing, the boiling point of water, for example, is very much greater than would be the case if such bonding did not exist. Otherwise, water would be a gas at room temperature.

When H is bonded to O or N, its lone electron is pulled away from its single proton nucleus. A broken line represents hydrogen bonds because they are much weaker than covalent bonds.

✔ **Key Point:** Hydrogen bonds are like "glue" between molecules.

Although a single **hydrogen bond** is very weak, the cumulative effect of an enormous number of **hydrogen**

bonds can significantly affect the properties of the compound.

Short Review
When an atom combines chemically with another atom, it will either:

1. Gain electrons (become a negatively charged ion or anion)
2. Lose electrons (become a positively charged ion or cation)
3. Share electrons

Chemical Case: For purposes of review and regulation, the grouping of chemically similar pesticide active ingredients (e.g., slats and esters of the same chemical) into chemical cases.

Chemical Change: A transfer that results from making or breaking chemical bonds. Change that occurs when two or more substances (reactants) interact with each other, resulting in the production of different substances (products) with different chemical compositions. A simple example of chemical change is the burning of carbon in oxygen to produce carbon dioxide.

Chemical Compound: A distinct and pure substance forced by the union or two or more elements in definite proportion by weight.

Chemical Diversion and Trafficking Act (CDTA): 1988 amendment to the Controlled Substances Act to regulate precursor chemicals, essential chemicals, tableting machines, and encapsulating machines by imposing record keeping and import/export reporting requirements on transactions involving these materials .

Chemical Element: A fundamental substance comprising one kind of atom; the simplest form of matter.

Chemical Equation: A shorthand method for expressing a reaction in terms of written chemical formulas.

Chemical Exposure: When a person comes in contact with a chemical, either knowingly or accidentally, several health consequences can arise as a result.

Chemical Extraction: Process in which excavated contaminated soils are washed to remove contaminants of concern.

Chemical Family: A group of elements or, more commonly, compounds that share certain chemical characteristics and have a common name.

Chemical Formula: A **chemical formula** tells us how many atoms of each element are in the molecule of any substance. A chemical formula uses atomic symbols (from the periodic table) and numerical subscripts to show the relative proportions of the atoms of different elements in a compound.

The chemical formula for water is H_2O. The "H" is the symbol for hydrogen. Hydrogen is a part of the water molecule. The "O" means that oxygen is also part of the water molecule. The "$_2$" after the H means that two atoms of hydrogen are combined with one atom of oxygen in each water molecule. There is no number after the O. When no number appears after a symbol, it means that there is only one atom of that element. The water molecule is made of two atoms of hydrogen combined with one atom of oxygen.

To show the number of molecules, a full-sized number is located *in front* of the molecule. For example 4 molecules of carbon dioxide is designated as:

$$4CO_2$$

This means there are a total of 4 C atoms and 8 O atoms in the combination.

Just as in mathematics, we can use parentheses to separate parts in a complex formula. One example is the formula for nitroglycerin, a highly explosive substance. This formula shows that nitroglycerin consists of 3 atoms of C, 5 atoms of H and the 3 molecules of NO_3. If the parentheses were not used, the formula would not describe the true structure of the nitroglycerin molecule.

$$C_3H_5\ (NO_3)\ 3$$

✔ **Key Point:** Formulas identify the elements, and the number of atoms, that compose the molecule. The formula is a shorthand way of writing *what* elements are present in each molecule of a compound, and *how many* atoms of each element are present in each molecule.

As mentioned, subscripts are important part of chemical formulas. The subscripts in a chemical formula identify the compound. They also tell us the ratios of atoms and molecules in a substance.

✔ **Key Point:** Changing a subscript in the chemical formula changes the identity of the substance. For example, H_2O (water) becomes H_2O_2 (hydrogen peroxide) when we place a subscript 2 on the O atom. On the other hand, placing a number (coefficient) in front of a chemical formula only changes the amount of the substance and not its identity. For example, placing a 2 in front of $2H_2O$ means 2 molecules of H_2O.

Writing Formulas

Determining chemical formulas from diagrams is inconvenient. It is easier to apply the rules shown in the Table to determine formulas for aluminum oxide.

Rule	*Application*	
1. Write the symbol of the elements	Al	O
2. Always write the metal first, the nonmetal second.		
3. Write the valence of each element above each symbol	Al^3	O^2
4. Crisscross the valences as shown.	Al^3	O^2
5. Reduce the subscripts to their lowest terms	Al_2O_3	

Radicals

Some covalently bonded groups of atoms act like single atoms. Though the atoms within a radical are held together by covalent bonds, in each case, they contain either excess or a deficiency of electrons. Most radicals, however, are negative ions. The Table gives the names, formulas, and valence numbers of a few of the common radicals.

Table of Valences

Metals		
+1	*+2*	*+3*
Hydrogen (H)	Magnesium (Mg)	Aluminum (Al)
Sodium (Na)	Strontium (Sr)	Boron (B)
Ammonium (NH_4)	Calcium (Ca)	
Nonmetals		
−1	*−2*	*−3*
Fluoride (F)	Oxide (O)	Phosphate (PO_4)
Chloride (Cl)	Sulfide(S)	
Iodide (I)		Carbonate (CO_3)
Nitrate (NO_3)		

Formula Weights

The **formula weight** is the sum of the weights of all the atoms in a formula. The formula weight for sodium chloride, NaCl, is found as follows:

Atomic weight of Na	23
Atomic weight of Cl	35
Formula weight	58

The formula weight of aluminum sulfate, $Al_2\ (SO_4)\ _3$ is found as follows:

Atomic weight of Al (x 2)	27 =	54
Atomic weight of S (x 3)	32 =	96
Atomic weight of O (x 12)	16 =	192
Formula weight	=	342

Moles

Formula or molecular weight in grams is called a **mole.** The number of moles of a compound is found by using the following expression:

$$\frac{\text{Actual weight}}{\text{Formula weight}} = \text{Number of moles}$$

Chemical Hazards: Includes hazardous chemicals conveyed in various forms: mists, vapors, gases, dusts, and fumes. Any chemical that has the capacity to produce injury or illness when taken into the body.

Chemical Industry and Federal Regulations: For workers in the chemical industry, it is important to recognize that many safety and health regulations are affected by federal laws. The federal statutes listed in the Table affect the manner by which manufacturers identify the contents of products sold to consumers. However, it is important to point out that these statutes not only apply to manufacturers in warning the consumer of potential hazards but also serve (indirectly in many cases) to warn workers of hazards. It is also important to remember that if a manufactured product is potentially hazardous to the consumer it can/could doubly affect the safety and health of workers on the front lines; that is, manufacturing production workers.

The chemical industry is one of the nation's most regulated industries. It is subject to numerous environmental regulations as well as the voluntary obligations imposed by the chemical industries environmental, health, and safety improvement initiatives. Including Federal/State OSHA statutes, fifteen major federal statutes, as well as numerous state laws, impose significant compliance and reporting requirements on the industry. A summary of chemical industry regulations is provided in the Table.

Chemical Inventory: Experience has shown that when OSHA conducts a compliance audit of a plant, facility and/or other workplace, the auditors routinely seek out and document any container containing hazardous materials. When they find one (and more), they usually write down the brand name of the product and later ask to see an MSDS for each product found. Again, based on personal experience, it is at this point in the audit process that the property owner or manager (if not already there) gets into trouble with OSHA compliance. We have found that it is not unusual for the in-house facility compliance manager to forget the Hazard Communication Standard requirement for the facility to produce and maintain a current inventory of all chemical products within the workplace.

An initial inventory of all chemicals should be made of all new work areas and facilities. A routine audit, the

Federal Laws That Affect Workers Who Produce Household Chemical Products

Federal Statute	*Responsible Agency*	*Authorization*
Federal Hazardous Substances Act	Consumer Product Safety Commission (CPSC)	Requires that certain hazardous household products bear cautionary labeling to alert consumers to the potential hazards that those products present and to inform them of the measures they need to protect themselves from those hazards.
Federal Food, Drug and Cosmetic Act	U.S. Food and Drug Administration (FDA)	Ensures that foods are safe to eat, drugs are safe and effective, and packaging and labeling of foods, drugs, and cosmetics are truthful and informative
Feral Insecticide, Fungicide, and Rodenticide Act	U.S. Environmental Protection Agency (EPA)	Regulates the manufacture, use, and disposal of pesticides
Toxic Substances Control Act	U.S. Environmental Protection Agency (EPA)	Requires pre-market evaluation of all new chemical products other than food additives, drugs, pesticides, alcohol, and tobacco; regulates existing hazards not covered by other federal laws dealing with toxic substances
Federal Alcohol Administration Act	Bureau of Alcohol, Tobacco, and Firearms (ATF)	Includes ensuring that distilled spirits (beverage alcohols), wines, and malt beverages intended for non-industrial use are safe for consumption, and their packaging and labeling are truthful and informative

Major Health, Safety, and Environmental Legislation (USDC 1996)

1. **Toxic Substances Control Act (TSCA) of 1976** gives the Environmental Protection Agency (EPA) comprehensive authority to regulate any chemical substance whose manufacture, processing, distribution in commerce, use, or disposal may present an unreasonable risk of injury health or the environment.
2. **Clean Air Act (CAA)** was first passed in 1955 as the Air Pollution Control, Research and Technical Assistance Act and amended in 1963 to become the CAA. A more significant statute was passed in 1970 and amended in 1977 and 1990. It provides EPA authority to regulate air pollutants from a wide variety of sources including automobiles, electric power plants, chemical plants, and other industrial sources.
3. **Clean Water Act (CWA)** was first enacted in 1948 as the Federal Water Pollution Control Act. Subsequent extensive amendments defined the statue to be known as the CWA in 1972; it was further amended in 1977 and 987. The CWA provides EPA authority to regulate effluents from sewage treatment works, chemical plants, and other industry sources into U.S. waterways. EPS has recently undertaken control efforts in on-point source pollution as well.
4. **Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA)** provide the basic legal framework for the Federal “Superfund” program to clean up abandoned hazardous waste sites.
5. **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** provides EPA authority to register and assess the risks of agricultural pesticides. It was first enacted in 1947 and last amended in 1988.
6. **Federal Food, Drug and Cosmetics Act (FDCA)** provides the Food and Drug Administration (FDA) authority to regulate the manufacturing of drugs and pharmaceuticals and the use of packaging and additives in food and cosmetics.
7. **Emergency Planning and Community Right-to-Know Act of 1986**, also known as SARA Title III, mandates state and community development of emergency preparedness plans and also establishes an annual manufacturing-sector emissions reporting program.
8. **Resource Conservation and Recovery Act (RCRA) of 1976**, provides EPA with authority to establish standards and regulations for handling and disposing of solid and hazardous wastes.
9. **Occupational Safety and Health Act (OSH Act) of 1970,** provides the Department of Labor authority to set comprehensive workplace safety and health standards, including permissible exposures to chemicals in the workplace, and authority to conduct inspections and issue citations for violations of safety and health regulations.
10. **Safe Drinking Water Act**, enacted in 1974 and amended in 1977 and again in 1986, establishes standards for public drinking water supplies.
11. **Hazardous Materials Transportation Act (HMTA)** provides the Department of Transportation the authority to regulate the packaging and movement of hazardous materials.
12. **Chemical Diversion and Trafficking Act (CDTA) of 1988** is designed to prevent the diversion of chemicals to illegal drug producers.
13. **Pollution Prevention of Act of 1990** makes it the national policy of the United States to reduce or eliminate the generation of waste at the source whenever feasible and directs the EPA to undertake a multimedia program of information collection, technology transfer, and financial assistance to the states to implement this policy and to promote the use of source reduction techniques.
14. **Flammable Fabrics Act**, enacted in 1970 and last amended in 1983, gives the Consumer Product Safety Commission the authority to set flammability standards for fabrics that protect against an unreasonable risk of the occurrence of a fire.
15. **Poison Packaging Prevention Act of 1953**, and last amended in 1990, provides the Consumer Product Safety Commission authority to set stands for the special packaging of any household product to protect children from a hazard.
16. **Consumer Product Safety Act**, enabled in 1972 created the Consumer Product Safety Commission, and gives the Commission authority to issue mandatory safety standards, ban hazardous products, investigate safety of products, and use other forms of corrective action.
17. **State Regulations**. State governments are increasingly active in the environmental and safety areas.

HazCom Inventory, should be conducted thereafter. We have found that this should be done on a quarterly basis (during a regularly scheduled in-house audit, for example). Additionally, someone should be designated (for example, shipping and receiving personnel) to identify new chemicals and ensure they are accompanied by MSDS. After identification and listing on the HazCom Inventory, employees who may come into contact with the new chemical must be notified and made aware of the product's potential hazards. A copy of the HazCom Inventory for each work area should be kept with the MSDS for that area and the updated inventory lists provided to the EH&S office.

Each listing should note at least the following information:

1. Name & contact information for persons responsible for the area or chemicals
2. Date the list was compiled or updated
3. Building & room/area location of the work or storage area
4. Name and hazard(s) of the chemical or product
5. Typical maximum quantity of the chemical or material
6. General location within the work area where material is kept
7. Name of the manufacturer or supplier (to prevent OSHA citation must match the MSDS)

Again, the importance of incorporating a system to add any newly introduced hazardous chemicals or materials to the inventory can't be overstressed. Typically the person responsible for material will update the list for the specific work are and ensure that the master list is updated.

Chemical Name: The primary purpose of naming chemicals is to ensure that the person who hears or reads a chemical name is under no ambiguity as to which chemical compound it refers to.

Chemical Oxygen Demand (COD): An indirect measure of the biochemical load exerted on the oxygen content of a body of water when organic wastes are introduced into the water. If the wastes contain only readily available organic bacterial food and no toxic matter, the COD values can be correlated with BOD values obtained from the wastes.

Chemical Precipitation: Process by which inorganic contaminants (heavy metals from groundwater) are removed by addition of carbonate, hydroxide, or sulfide chemicals.

Chemical Process Audit/Survey: A procedure used to gather information on the type, composition, and quantity of waste produced.

Chemical Processing: Those activities or operations that involve the production, use, storage, processing, and/or disposal of caustic, toxic, or volatile chemicals in liquid, gaseous, particulate, powder, or solids states.

Chemical Protective Clothing and Equipment: Any item of clothing (e.g., gloves, boots, suits) used to isolate parts of the body from direct contact with potentially hazardous substances. Safe use of this type of protective clothing and equipment requires specific skills developed through training and experience. This type of special clothing may protect against one chemical, yet be readily permeated by chemicals for which it was not designed. Therefore, protective clothing should not be used unless it is compatible with the released material. This type of special clothing offers little or no protection against heat and/or cold.

Chemical Reaction: Process that occurs when atoms of certain elements are brought together and combine to form molecules, or when molecules are broken down into individual atoms.

Chemical Reactivity: The ability of a material to undergo a chemical change.

Chemical Spill: An accidental dumping, leakage, or splashing of a harmful or potentially harmful substance.

Chemical Spill Emergency Response: Having an emergency plan will not mean that a disaster will not happen, but with a plan in place, the chances of an accident becoming a disaster are greatly diminished. An emergency plan should be constantly reevaluated and updated to ensure that changing conditions and personnel are taken into account. An obsolete plan is little better than no plan at all (Newton, 1987).

The very nature of working in a workplace with hazardous chemicals makes emergencies very real possibilities. These emergencies strike immediately and unexpectedly and require immediate response. Although it is the accidents with hazardous materials that are most likely to lead to emergency response situations in the workplace, other possible emergency situations must also be taken into account. For example, fires, storms (hurricanes ans tornadoes), earthquakes, electrical shock, power failure, and medical emergencies are real possibilities [these events may be related to (in the case of fire and medical problems) or compounded by hazardous materials but not in every situation].

This entry addresses emergency response procedures used to control and contain losses of property and prevent injury to workers in the chemical industry workplace due to fire, explosion, toxic chemical spill, and/or accidents. Moreover, an emergency response procedure, currently used in a chemical industry workplace, is presented as an example of the type of procedure that is required. Along with standard emergency response procedures for use in the workplace, several work practices related to specific workplace equipment is included. Finally, emergency medical response procedures for the chemical industry workplace are discussed.

When a hazardous materials (hazmat) incident occurs, decisive action is immediately required. Decisive action, however, cannot be taken in a safe and sound manner unless those reacting follow a plan, a routine, and a protocol that will allow them to mitigate the situation with the least degree of danger to themselves, others, and the environment. Because of the need for decisive action and a written plan of action for hazardous materials incidents that may occur in the workplace, OSHA has mandated two basic but far-reaching requirements:

1. Every workplace where hazardous materials are used or produced is responsible for having a comprehensive emergency action plan that complies with OSHA's Standard on Emergency Plans and Fire Prevention Plans (29 CFR 1910.38). This emergency action plan must be readily available for implementation during emergency events.
2. OSHA also has a special regulation dealing specifically with spills of hazardous chemicals. This regulation, called the Hazardous Waste Operations and Emergency Response (HAZWOPER) standard, is found at 29 CFR 1910.120 and has direct applicability to the chemical industry workplaces where hazardous chemicals are used.

At the heart of safe work practices with hazardous materials handling is good emergency planning. Hazardous materials mishaps are always characterized by their potential for complexity (Hall, 1994). This is why OSHA specifically mandates emergency planning. The chemical industry workplace's emergency plan should address actions to be taken in case of fire and/or explosion and should include, at a minimum, the following:

- a list of emergency numbers to be used to alert workplace personnel, local police, fire, emergency rescue, and medical personnel
- the preferred means of reporting fire and emergencies
- names and phone numbers of personnel to be contact in an emergency
- rescue and medical duties for those who are designated to perform them
- emergency escape procedures and emergency escape route assignments
- procedures to account for all employees after an emergency evacuation
- procedures to be followed by employees who remain to operate or shut down operations before they evacuate
- Safety Data Sheets (SDSs) detailing the chemical and physical properties of hazardous materials stored or handled in the workplace, and specific emergency response measures to be implemented to contain these materials in the event of an emergency

Even with a written plan it is important to keep in mind that under no circumstances should untrained personnel respond to a hazardous materials incident.

Chemical Stressors: Chemicals released to the environment through industrial waste, auto emissions, pesticides, and other human activity that can cause illnesses and even death in plants and animals.

Chemical Treatment: Any one of a variety of technologies that use chemicals or a variety of chemical processes to treat waste.

Chemnet: Mutual aid network of chemical shippers and contractors that assigns a contracted emergency response company to provide technical support if a representative of the firm whose chemicals are involved in an incident is not readily available.

CHEMTREC: The industry-sponsored Chemical Transportation Emergency Center; provides information and/or emergency assistance to emergency responders. Located in Washington D.C. Available 24 hours a day. (1-800-424-9300).

Chiller: A device that generates a cold liquid that is circulated through an air-handling unit's cooling coil to cool the air supplied to the building.

Chilling Effect: The lowering of the Earth's temperature because of increased particles in the air blocking the sun's rays.

Chisel Plowing: Preparing croplands by using a special implement that avoids complete inversion of the soil as in conventional plowing. Chisel plowing can leave protective cover or crops residues on the soil surface to help prevent erosion and improve filtration.

Chloinesterase: Family of enzymes that catalyze the hydrolysis of the neurotransmitters acetylcholine into choline and acetic acid, a reaction necessary to allow a cholinergic neuron to return to its resting state after activation.

Chlorinated Hydrocarbons: A class of synthetic organic compounds used by industry, farms, and households for a variety of purposes including pest control. These organic compounds can also be produced by chlorinating sewage effluent, which is done to aid oxidation and kill pathogens contained in the untreated effluent.

Chlorinated Solvent: An organic solvent containing chlorine atoms (e.g., methylene chloride and 1.1.1-tricholormethane). Uses of chlorinated solvents include aerosol spray containers, in highway paint, and dry cleaning fluids.

Chlorination: The application of chlorine to drinking water, sewage, or industrial waste to disinfect or to oxidize undesirable compounds.

Chlorination Terminology: Several terms used in discussion of disinfection by chlorination.

- Chlorine—a strong oxidizing agent which has strong disinfecting capability. A yellow-green gas which is extremely corrosive, and is toxic to humans in extremely low concentrations in air.
- Chlorine-Contact Chamber—that part of a wastewater treatment plant where effluent is disinfected by chlorine before being outfalled to receiving water body.
- Contact Time—the length of time the time the disinfecting agent and the wastewater remain in contact.
- Demand—the chemical reactions, which must be satisfied before a residual or excess chemical will appear.
- Disinfection—refers to the selective destruction of disease-causing organisms. All the organisms are not destroyed during the process. This differentiates disinfection from sterilization, which is the destruction of all organisms.
- Dose—the amount of chemical being added in milligrams/liter.
- Feed Rate—the amount of chemical being added in pounds per day.
- Residual—the amount of disinfecting chemical remaining after the demand has been satisfied.
- Sterilization—the removal of all living organisms.

Chlorinator: A device that adds chlorine, in gas or liquid form, so water or sewage to kill infectious bacteria.

Chlorine (Wastewater Treatment): Chlorine Facts:

- Elemental chlorine (Cl_2—gaseous) is a yellow-green gas, 2.5 times heavier than air.
- The most common use of chlorine in wastewater treatment is for disinfection. Other uses include odor control and activated sludge bulking control. chlorination takes place prior to the discharge of the final effluent to the receiving waters.
- Chlorine may also be used for nitrogen removal, through a process called *breakpoint chlorination.* For nitrogen removal, enough chlorine is added to the wastewater to convert all the ammonium nitrogen gas. To do this, approximately 10 mg/l of chlorine must be added for every 1 mg/l of ammonium nitrogen in the wastewater.
- For disinfection, chlorine is fed manually or automatically into a chlorine contact tank or basin, where it contacts flowing wastewater for at least 30 minutes to destroy disease-causing microorganisms (pathogens) found in treated wastewater.
- Chlorine may be applied as a gas, a solid, or in liquid hypochlorite form.
- Chlorine is a very reactive substance. It has the potential to react with many different chemicals (including ammonia), as well as with organic matter. When chlorine is added to wastewater, several reactions occur:
  1. Chlorine will react with any reducing agent (i.e., sulfide, nitrite, iron, and thiosulfate) present in wastewater. These reactions are known as *chlorine demand.* The chlorine used for these reactions is not available for disinfection.
  2. Chlorine also reacts with organic compounds and ammonia compounds to form chlor-organics and chloramines. Chloramines are part of the group of chlorine compounds that have disinfecting properties and show up as part of the chlorine residual test.
  3. After all of the chlorine demands are met, addition of more chlorine will produce free residual chlorine. Producing free residual chlorine in wastewater requires very large additions of chlorine.

Chlorine-Contact Chamber: That part of a water treatment plant where effluent is disinfected by chlorine.

Chlorine Residual: The total amount of chlorine (combined and free available chlorine) remaining in water, sewage, or industrial wastes at the end of a specified contact period following disinfection.

Chlorofluorocarbons (CFCs): A family of synthetic chemicals that are odorless, nontoxic, nonflammable, and chemically inert. Chlorofluorocarbons (CFCs) have been blamed and targeted for air pollution problems. Most scientists identify the family of chlorine-based compounds, most notably these chlorofluorocarbons (CFCs) and chlorinated solvents (carbon tetrachloride and methyl chloroform) as the primary culprits involved in ozone depletion. In 1974, Molina and Rowland hypothesized the CFCs, containing chlorine, were responsible for ozone depletion. They pointed out that chlorine molecules are highly active and readily and continually break apart the three-atom ozone into the two atom form of oxygen generally found close to earth, in the lower atmosphere.

The Interdepartmental Committee for Atmospheric Sciences (1975) estimates that a 5 percent reduction in ozone could result in nearly a 10 percent increase in cancer. This already frightening scenario was made even more frightening by 1987 when evidence showed that CFCs destroy ozone in the stratosphere above Antarctica every spring. The ozone hole had become larger, with more than half of the total ozone column wiped out and essentially all ozone disappeared from some regions of the stratosphere (Davis & Cornwell, 1991).

In 1988, Zurer reported that on a worldwide basis, the ozone layer shrunk approximately 2.5 percent in the preceding decade. This obvious thinning of the ozone layer, with its increased chances of skin cancer and cataracts, is also implicated in suppression of the human immune system, and damage to other animals and plants, especially aquatic life and soybean crops. The urgency of the problem spurred the 1987 signing of the Montreal Protocol by twenty-four countries, which required signatory countries to reduce their consumption of CFCs by 20 percent by 1993, and by 50 percent by 1998, marking a significant achievement in solving a global environmental problem.

The Clean Air Act of 1990 borrowed from EPA requirements already on the books in other regulations and mandated phase-out of the production of substances that deplete the ozone layer. Under these provisions, the EPA was required to list all regulated substances along with their ozone-depletion potential, atmospheric lifetime, and global warming potentials.

Chlorophenoxy: A class of herbicides that may be found in domestic water supplies and cause adverse health effects.

Chlorophyll: A combination of green and yellow pigments, present in all “green” plants, which captures light energy and enables the plants to form carbohydrate material from carbon dioxide and water in the process known as photosynthesis. Found in all algae, phytoplankton, and almost all higher plants.

Chlorosis: Discoloration of normally green plant parts caused by disease, lack of nutrients, or various air pollutants.

CHRIS: An acronym for the Chemical Hazard Response information System. Written and maintained by the United States Coast Guard.

Chromium: Chemical element which is steely-gray, lustrous, hard metal that takes a high polish and have a high melting point.

Chronic: Persistent, prolonged, repeated. Chronic exposure occurs when repeated exposure to or contact with a toxic substance occurs over a period of time, the effects of which become evident only after multiple exposures.

Chronic Effect: An adverse effect on a human or animal in which symptoms recur frequently or develop slowly over a long period of time.

Chronic Exposure: Multiple exposures occurring over an extended period of time or over a significant fraction of an animal’s or human’s lifetime (usually seven years to a lifetime).

Chronic Toxicity: The capacity of a substance to cause long-term poisonous health effects in humans, animals, fish, and other organisms.

Cilia: Small threadlike organs on the surface of some cells, composed of contractile fibers that produce rhythmic waving movements. Some single-celled organisms move by means of cilia. In multicellular animals, they keep lubricated surfaces clear of debris. They also move food in the digestive tracts of some invertebrates.

Circle of Influence: The circular outer edge of a depression produced in the water table by the pumping of water form a well.

Cistern: Small tank or storage facility used to store water for a home or farm; often used to store rain water.

Clade: A group of organisms, such as a species, whose members share homologous features derived from a common ancestor. The avian virus H5N1 clade 1 includes human and bird isolates from Vietnam, Thailand, Cambodia, Laos, and Malaysia. Clade 2 viruses have been identified in bird isolates for Chain, Indonesia, Japan, and South Korea.

Clarification: The process of removing solids from water. This is often aided by centrifugal action and chemically induced coagulation in wastewater.

Clarifier: A tank in which solids settle to the bottom and are subsequently removed as sludge.

Clarifiers: Settling tanks that typically remove settleable solids by gravity.

Class I Area: Under the Clean Air Act a Class I area is one in which visibility is protected more stringently than under the national ambient air quality standards; includes national parks, wilderness areas, monuments, and other areas of special national and cultural significance.

Class I Asbestos Work: Activities involving the removal of thermal system insulation (TSI) and surfacing asbestos-containing material (ACM) and presumed asbestos-containing material (PACM).

Class II Asbestos Work: Activities involving the removal of ACM which is not thermal system insulation or surfacing material. This includes, but is not limited to, the removal of asbestos-containing wallboard, floor tile and sheeting, roofing and siding shingles, and construction mastics.

Class III Asbestos Work: Involves repair and maintenance operations, where ACMP, including TSI and surfacing ACM and PACM, is likely to be disturbed.

Class IV Asbestos Work: Involves maintenance and custodial activities during which employees contact but not disturb ACM and PACM and activities to clean up dust, waste and debris resulting from Class I, II, III activities.

Class I Substance: One of several groups of chemicals with an ozone depletion potential of 0.2 or higher, including CFCs, Halon, Carbon Tetrachloride, and Methyl Chloroform.

Class II Substance: A substance with an ozone depletion potential of less than 0.2. All hydrochlorofluorocarbons (HCFCs) are currently included in this classification.

Classification of Fires: Most fires that occur will fall into one or more of the following categories:

Class A: Fires involving ordinary combustible materials, such as paper, wood, and textile fibers, where a cooling, blanketing, or wetting extinguishing agent is needed.

Class B: Fires involving flammable liquid such as gasoline, thinner, oil-based paints and greases. Extinguishers for this type of fire include carbon dioxide, dry chemical and halogenated (Halon) agent types.

Class C: Fries involving energize electrical equipment, where a nonconducting gaseous clean agent is needed. The most common type of extinguisher for this class is a carbon dioxide extinguisher.

Class D: Fires involving combustible metal such as magnesium sodium, potassium, titanium, and aluminum. Special dry powder extinguishing agents are required for this type of fire, and must be tailored to the specific hazardous material.

Class K:
Fires involving commercial cooking appliances with vegetable oils, animal oils, or fats a high temperatures. A wet potassium acetate, low pH-based agent issued for this class of fire.

Classification of Hazardous Materials: Hazmat shippers can ensure the safe transportation of hazardous materials by following the six steps listed below.

- Classification—shipping description
- Packaging—selection and assembly
- Marking of packages
- Labeling of packages
- Shipping papers and emergency response information
- Placarding and marking of vehicles

DOT divides hazardous materials into nine main hazard classes. Classification involves determining whether the material meets any of the DOT hazard classes specified in the HM Regulations (49 CFR Parts 171-180), and, if it does, selecting the Proper Shipping Name (PSN). The MHT (Section 172.101) is used to select the PSN and determine the Basic Shipping Description. Sections 172.200 through 172.205 explain how the Basic Shipping Description must appear on the shipping paper, and under what circumstances it is necessary to supplement the basic description.

Hazardous materials are typically classified in two ways: traditional approach and DOT approach. In the following both approaches are discussed for comparative purpose.

Classification of Hazmats: Traditional Approach
For classification purposes, we regard hazardous materials in several different ways. From the perspective of fire science, a hazardous material is often regarded as any substance or mixture that, if improperly handled, may be damaging to our health and well-being or to the environment. While our concern in this text is with the way the U.S. Department of Transportation classifies hazardous materials (which is much more inclusive than the approach usually followed in fire science), we set the stage with the traditional approach, which is a useful introduction to the characteristics likely to cause a substance to be regarded as a hazardous material.

The following are the seven classes of hazardous materials conventionally noted in fire science (Meyer, 1989):

1. *Flammable materials*. Any solid, liquid, vapor, or gaseous materials that ignite easily and burn rapidly when exposed to an ignition source. Examples of flammable materials within this broad definition include certain solvents like benzene and ethanol, dusts like flour and certain finely dispersed powders like aluminum, and gases like hydrogen and methane.

2. *Spontaneously ignitable materials*. Solid or liquid materials that ignite spontaneously without an ignition source, usually (but not necessarily) due to the dangerous buildup of heat during storage caused by oxidation or microbiological action. An example of a substance that ignites spontaneously without an ignition source is white phosphorus; examples of substances that spontaneously ignite due to the buildup of heat are fishmeal and grass.
3. *Explosives*. These chemical substances detonate, usually as the result of shock, heat, or some other initiating mechanism. Examples are dynamite and trinitrotoluene (TNT).
4. *Oxidizers*. Substances that evolve or generate oxygen, either at ambient conditions or when exposed to heat. Examples are ammonium nitrate and benzoyl peroxide.
5. *Corrosive materials*. Solids or liquid materials, like battery acid, that burn or otherwise damage skin tissue at the site of contact.
6. *Toxic materials*. Broadly, poisons that, in small doses, either kill or cause adverse health effects. Examples of toxic materials of primary concern to firefighters are carbon monoxide and hydrogen cyanide.
7. *Radioactive materials*. These materials are characterized by transformations occurring in their atomic nuclei. Uranium hexafluoride is an example of a radioactive material.

✔ **Important Point:** Not only are these materials individually hazardous, they pose an even more severe hazard when mixed—or when they interact to produce new substances that are likely to be hazardous materials.

Classification of Hazardous Materials: DOT Approach

DOT's 49 CFR requires shippers to properly classify materials according to the criteria established by DOT. This means that anyone involved in/with hazmat transportation must understand the Classification Process.

The properties of the material are compared to the hazardous material definitions. After assessing the specific hazard class, packing group, and subsidiary risk, the appropriate **proper shipping name** is chosen from the Hazardous Materials Table. Also, it must be determined whether the material is a hazardous substance or a marine pollutant.

✔ **Important Point:** The DOT Hazardous Materials Table designates hazardous materials for transportation. For each listed material, it identifies the hazard class or specifies that the material is forbidden to transport. The Table lists the proper shipping name, identification number and packing group, if any. It also specifies or references requirements pertaining to labeling, packaging, quantity limits aboard aircraft, and stowage of hazardous materials aboard vessels. If the material is not identified by name in the Hazardous Materials Table, then the shipper must assign a generic **N.O.S. (Not Otherwise Specified)** name that best describes the material.

✔ **Important Point:** A material may meet the definition of more than one hazard class. In this case, the material will be described in accordance with the precedence table established by the DOT in 49 CFR 173.2a.

DOT Hazard Classes (Listing)

The hazard class of a hazardous material is indicated either by its class (or division) number, its class name, or by the letters "ORM-D". Nine hazard classes are used to identify hazardous materials. The Table lists class numbers, division numbers, and class or division names.

DOT HAZARD CLASSES

Class #	*Division #*	*Name of Class or Division*
None	—	Forbidden Materials
None	—	Forbidden Explosives
1	1.1	Explosives (with a mass explosion hazard)
1	1.2	Explosives (with a projection hazard)
1	1.3	Explosives (with predominantly a fire hazard)
1	1.4	Explosives (with no significant blast hazard)
1	1.5	Very insensitive explosives; blasting agents
1	1.6	Extremely insensitive detonating substances
2	2.1	Flammable gas
2	2.2	Non-flammable compressed gas
2	2.3	Poisonous gas
3	—	Flammable and combustible liquid
4	4.1	Flammable solid
4	4.2	Spontaneously combustible material
4	4.3	Dangerous when wet material
5	5.1	Oxidizer
5	5.2	Organic peroxide
6	6.1	Poisonous materials
6	6.2	Infectious substance (Etiologic agent)
7	—	Radioactive material
8	—	Corrosive material
9	—	Miscellaneous hazardous material
None	—	Other regulated material: ORM-D

DOT Hazard Classes (Defined)

DOT specifically defines its nine Hazard Classes.

Class 1 (§173.50)

This class includes explosive substances—materials that can detonate or are subject to very rapid combustion. Specifically, an **explosive** is defined as any substance or article, including a device, which is designed to function by explosion (i.e., an extremely rapid release of gas and heat) or which, by chemical reaction within itself, is able to function in a similar manner even if not designed to function by explosion, unless the substance or article is otherwise classed.

Class 1 is divided into six divisions: 1.1, 1.2, 1.3, 1.4, 1.5, and 1.6.

1. **Division 1.1** consists of explosives that have a mass explosion hazard. A mass explosion is one that affects almost the entire load instantaneously. Division 1.1 includes dynamite, TNT, black powder, and some types of military ammunition.
2. **Division 1.2** consists of explosives that have a projection hazard but not a mass explosion hazard.
3. **Division 1.3** consists of explosives that have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard.
4. **Division 1.4** consists of explosives that present a minor explosion hazard. The explosive effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire must not cause virtually instantaneous explosion of almost the entire contents of the package.
5. **Division 1.5** consists of very insensitive explosives. This division is comprised of substances that have a mass explosion hazard but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of transport. [**Note:** the probability of transition from burning to detonation is greater when large quantities are transported in a vessel].
6. **Division 1.6** consists of extremely insensitive articles that do not have a mass explosive hazard. This division is comprised of articles that contain only extremely insensitive detonating substances, and which demonstrate a negligible probability of accidental initiation. [**Note**: the risk from articles of Division 1.6 is limited to the explosion of a single article].

✔ **Important Point**: Unless otherwise provided, no person may offer for transportation or transport an explosive, unless it has been tested, classed, and approved by the Associate Administrator for Hazardous Materials Safety.

Class 2 (49 CFR 173.115)

Class 2 materials include compressed and liquid gases, in three divisions.

1. **Division 2.1—***Flammable Gases* (examples are propane and hydrogen). A Division 2.1 flammable gas means any material that is a gas at 20°C (68°F) or less and 101.3 Kpa (14.7 psi) of pressure (a material which has a boiling point of 20°C (68°F) or less at 101.3 Kpa (14.7 psi).
2. **Division 2.2—***Nonflammable, Nonpoisonous Compressed Gases*—including compressed gas, liquefied gas, pressurized cryogenic gas, compressed gas in solution, asphyxiant gas and oxidizing gas (an example is nitrogen). A Division 2.2 nonflammable, nonpoisonous compressed gas means any material (or mixture) that exerts in the packaging an absolute pressure of 280 Kpa (40.6 psia) or greater at 20°C (68°F), and does not meet the definition of Division 2.1 or 2.3.
3. **Division 2.3—***Poisonous Gases by Inhalation* (an example is chlorine) is a material that is a gas at 20°C (68°F) or less and a pressure of 101.3 Kpa (14.7 psi) (a material with a boiling point of 20°C (68°F) or less at 101.3 Kpa (14.7 psi) and which is known to be so toxic to humans as to pose a hazard to health during transportation, or in the absence of adequate data on human toxicity, is presumed to be toxic to humans because when tested on laboratory animals it has an LC50 (Lethal Concentration) value of not more than 5000 ml/m^3.

✔ **Important Point:** When the hazard zone is to be determined based on the grouping criteria for Division 2.3, the hazard zones are determined by applying the following criteria:

Hazard Zone	Inhalation Toxicity
A	LC$_{50}$ less than or equal to 200 ppm.
B	LC$_{50}$ greater than 200 ppm and less than or equal to 1000 ppm.
C	LC$_{50}$ greater than 1000 ppm and less than or equal to 3000 ppm.
D	LC$_{50}$ greater than 3000 ppm or less than or equal to 5000 ppm.

Class 3 (49 CFR 173.120)

This class includes both flammable and combustible liquids.

1. **Flammable liquid—**a liquid having a flash point of not more than 141°F, or any material in a liquid phase with a flash point at or above 100°F that is intentionally heated and offered for transportation or transported at or above its flash point in a bulk packaging (an example is gasoline).
2. **Combustible liquid—**any liquid that does not meet the definition of any other hazard class specified, and has a flash point above 141°F and below 200°F (an example is fuel oil).

✔ **Important Point:** Certain flammable liquids with a flashpoint of 100°F or more may be reclassified as combustible liquids, and certain combustible liquids in non-bulk packaging are not subject to the Hazardous Materials Regulations.

Class 4 (49 CFR 173.124)
This class is comprised of three divisions:
Division 4.1—*Flammable Solids* (such as nitrocellulose)- any of three types of materials:

1. Desensitized explosives that when dry are explosives of Class 1 (other than those of compatibility group A), which are wetted with sufficient water, alcohol, or plasticizer to suppress explosive properties; and are specifically authorized.
2. Self-reactive materials are thermally unstable materials that can undergo a strongly exothermic decomposition even without participation of oxygen (air).
3. Readily combustible solids are solids that may cause a fire through friction (such as matches); show a burning rate faster than 2.2 mm per second when tested in accordance with UN Manual of Tests and Criteria; or any metal powders that can be ignited and react over the whole length of a sample in 10 minutes or less, when tested in accordance with UN Manual of Tests and Criteria.

Division 4.2—*Spontaneously Combustible* (such as phosphorus):

1. A **pyrophoric material**: a liquid or solid that, even in small quantities and without an external ignition source, can ignite within five (5) minutes after coming in contact with air when tested according to the UN Manual of Tests and Criteria.
2. A **self-heating material**: a material that, when in contact with air and without an energy supply, is liable to self-heat. A material of this type which exhibits spontaneous ignition or if the temperature of the sample exceeds 200°C during the 24-hour test period when tested in accordance with UN Manual of Tests and Criteria.

Division 4.3—*Dangerous When Wet* (such as sodium and calcium carbide or magnesium) - a material that, by contact with water, is liable to become spontaneously flammable or to give off flammable or toxic gas at a rate greater than 1 liter per kilogram of the material per hour, when tested in accordance with UN Manual of Tests and Criteria.

Class 5 (49 CFR 173.127 & 173.128)
This class includes materials that cause or enhance the combustion of other materials. This class has two divisions.

1. **Division 5.1** *Oxidizer* (example—hydrogen peroxide)—a material that may, generally by yielding oxygen, cause or enhance the combustion of other materials.
2. **Division 5.2** *Organic peroxide* (example—benzoyl peroxide)—any organic compound containing oxygen (O) in the bivalent -O-O- structure, and which may be considered a derivative of hydrogen peroxide, where one or more of the hydrogen atoms have been replaced by organic radicals.

Class 6 (49 CFR 173.132 & 173.134)
Class 6 is comprised of two divisions:

1. **Division 6.1**—*Poisonous Materials* are liquids or solids known to be as toxic to humans as to afford a hazard to health during transportation. The skull and crossbones *Poison* label is required for materials in Packing Groups I and II (see *Packing Groups*). A *Harmful, Keep Away From Foodstuffs* label is used for Packing Group III materials.
2. **Division 6.2**—*Infectious Substances* are materials that may cause disease in humans or animals (for example, medical waste).

Class 7 (49 CFR 173.403)
This class includes radioactive materials that can cause burns and other injuries. Examples are radioisotopes such as uranium and cobalt.

Class 8 (49 CFR 173.136)
This class consists of corrosive liquids and solids that cause visible full thickness destruction or irreversible alterations in human skin tissue at the site of contact, and liquids that have a severe corrosion rate on steel or aluminum. Examples are sulfuric acid, nitric acid, and sodium hydroxide.
Class 9 (49 CFR 173.140)
This class includes *Miscellaneous Hazardous Materials*. Specifically, miscellaneous hazardous material means a material that presents a hazard during transportation but that does not meet the definition of any other hazard class. This class includes:

- Any material that has an anesthetic, noxious or other similar property that could cause extreme annoyance or discomfort to a flight crew member so as to prevent the correct performance of assigned duties; or
- material that meets the definition for an elevated temperature material, a hazardous substance, a hazardous waste, or marine pollutant.

Other Regulated Materials (ORM)—(49 CFR 173.144)
ORM-D materials are materials such as any consumer commodity, which, although otherwise subject to the

regulations of this sub-chapter, presents a limited hazard during transportation due to its form, quantity and packaging.

Clean Air Act (CAA): Act passed by the U.S. Government. Originally passed in 1963, it dealt with the control of smoke from industrial and domestic sources. It was extended by the Act of 1968, particularly to control gas cleaning and heights of stacks of installations in which fuels are burned to deal with smoke from industrial open bonfires. The 1990 Clean Air Act brought wide-ranging reforms for all kinds of pollution from large or small mobile or stationary sources, and including routine and toxic emissions ranging from power plants to consumer products.

Clean Coal Technology: Any technology not in widespread use prior to the Clean Air Act Amendments in 1990. This Act will achieve significant reductions in pollutants associated with the burning of coal.

Clean Fuels: Blends or substitutes for gasoline fuels, including compressed natural gas, methanol, ethanol, and liquefied petroleum gas.

Clean Room: An uncontaminated room having facilities for the storage of employees' street clothing and uncontaminated materials and equipment.

Clean Water Act (CWA): A keystone environmental law credited with significantly cutting the amount of municipal and industrial pollution fed into the nation's waterways. More formally known as the Federal Water Pollution Control Act Amendments, passed in 1972, it stems originally from a much-amended 1948 law aiding communities in building sewage treatment plants and has itself been much amended, most notably in 1977 and 1987.

Clean Zone: That point in a river or stream upstream before a single point of pollution discharge.

Cleaner Technologies Substitutes Assessment: A document that systematically evaluates the relative risk, performance, and cost trade-offs of technological alternatives; serves as a repository for all the technical data (including methodology and results) developed by a DfE or other pollution prevention or education project.

Cleaning Respirators: Cleaning respirators involves washing with mild detergent and rinsing with potable water.

Cleanup: Actions taken to deal with a release or threat of release of a hazardous substance that could affect humans and/or the environment. The term "cleanup" is sometimes used interchangeably with the terms remedial action, removal action, response action, or corrective action.

Clear Well: A reservoir for string filtered water of sufficient quantity to prevent the need to vary the filtration rate with variations in demand. Also used to provide chlorine contact time for disinfection.

Climate: 1. The long-term weather pattern of a particular region. 2. The composite pattern of weather conditions that can be expected in a given region. Climate refers to yearly cycles of temperature, wind, rainfall, and so on, not to daily variations.

Climate Change: A change to the statistical distribution of weather over periods of time that range from decades to millions of year.

Cloning: In biotechnology, obtaining a group of genetically identical cells from a single cell; making identical copies of a gene.

Closed-Loop Biomass: Crops grown, in a sustainable manner for the purpose of optimizing their value for bioenergy and bioproduct uses. This includes annual crops such as maize and wheat, and perennial crops such as trees, shrubs, and grasses such as switchgrass.

Closed-Loop Recycling: Reclaiming or reusing wastewater for non-potable purposes in an enclosed process.

Closely Resemble: In asbestos abatement, mean that the major workplace conditions which have contributed to the levels of historic asbestos exposure, are no more protective than the conditions of the current workplace.

Closure: The procedure a landfill operator must follow when a landfill reaches it legal capacity for solid waste: ceasing acceptance of solid waste and placing a cap on the landfill site.

Cluster Investigation: A review of an unusual number, real or perceived, or health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether thy represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Cluster System: A wastewater collection and treatment system under some form of common ownership and management that provides treatment an dispersal/discharge of wastewater from two or more homes or buildings but less than an entire community.

CNMP: Comprehensive nutrient management plan. A CNMP is a conservation plan that is unique to animal feeding operations. It is a grouping of conservation practices and management activities which, when implemented as part of a conservation system, will help to ensure that both production and natural resource protection goals are achieve. A CNMP incorporates practices to utilize animal manure and organic by-products as a beneficial resource. A CNMP addresses nature resource concerns dealing with soil erosion, manure, and organic by-products and their potential impacts on water quality, which may derive from a CAFO. A CNMP is developed to assist a CAFO owner/operator in meeting all applicable local, tribal, State, and Federal water quality goals or regulations. For nutrient impaired stream segments or water bodies, additional management activities or conservation practices may be required to meet local, tribal, State, or Federal Water quality goals or regulations.

CNMP must meet NRCS technical standards. For those elements included by Owner and/or operator in a CNMP for which NRCS currently does not maintain technical standards (i.e., feed management, vector control, air quality, etc.), producers should meet criteria established by Land Grant Universities, industry, or other technically qualified entities. Within each state, the NRCS State Conservationist has the authority to approve non-NRCS criteria established for use in the planning and implementation of CNMP elements.

CO_2 equivalent: The mass of carbon dioxide with the same climate change potential as the mass of the greenhouse gas in question.

Coagulation: The term coagulation refers to the series of chemical and mechanical operations by which coagulants are applied and made effective. These operations are comprised of two distinct phases: (1) rapid mixing to disperse coagulant chemicals by violent agitation into the water being treated and (2) flocculation to agglomerate small particles into well-defined floc by gentle agitation for a much longer time.

The coagulant must be added to the raw water and perfectly distributed into the liquid; such uniformity of chemical treatment is reached through rapid agitation or mixing.

Coagulation results from adding salts of iron or aluminum to the water. Common coagulants (salts) are as follows:

- alum—aluminum sulfate
- sodium aluminate
- ferric sulfate
- ferrous sulfate
- ferric chloride
- polymers

Coagulation is the reaction between one of these salts and water. The simplest coagulation process occurs between alum and water. Alum or aluminum sulfate is made by a chemical reaction of bauxite ore and sulfuric acid. The normal strength of liquid alum is adjusted to 8.3 percent, while the strength of dry alum is 17 percent.

When alum is placed in water, a chemical reaction occurs that produces positively charged aluminum ions. The overall result is the reduction of electrical charges and the formation of a sticky substance—the formation of floc, which when properly formed, will settle. These two destabilizing factors are the major contributions that coagulation makes to the removal of turbidity, color, and microorganisms.

Liquid alum is preferred in water treatment because it has several advantages over other coagulants, including the following:

1. Ease of handling
2. Lower costs
3. Less labor required to unload, store and convey
4. Elimination of dissolving operations
5. Less storage space required
6. Greater accuracy in measurement and control provided
7. Elimination of the nuisance and unpleasantness of handling dry alum
8. Easier maintenance

Use of polymers

The formation of floc is the first step of coagulation; for greatest efficiency, rapid, intimate mixing of the raw water and the coagulant must occur. After mixing, the water should be slowly stirred so that the very small, newly formed particles can attract and enmesh colloidal particles, holding them together to form larger floc. This slow mixing is the second stage of the process (flocculation), covered later.

A number of factors influence the coagulation process—pH, turbidity, temperature, alkalinity, and the use of polymers. The degree to which these factors influence coagulation depends upon the coagulant use.

The raw water conditions, optimum pH for coagulation and other factors must be considered before deciding which chemical is to be fed and at what levels.

To determine the correct chemical dosage, a Jar Test or Coagulation Test is performed. Jar tests (widely used for many years by the water treatment industry) simulate full-scale coagulation and flocculation processes to determine optimum chemical dosages. It is important to note that jar testing is only an attempt to achieve a ballpark approximation of correct chemical dosage for the treatment process. The test conditions are intended to reflect the normal operation of a chemical treatment facility.

The test can be used to:

- select the most effective chemical
- select the optimum dosage
- determine the value of a flocculant aid and the proper dose

The testing procedure requires a series of samples to be placed in testing jars and mixed at 100 ppm. Varying amounts of the process chemical or specified amounts of several flocculants are added (one volume/sample container). The mix is continued for one minute. Next, the mixing is slowed to 30 rpms to provide gentle agitation, and then the floc is allowed to settle. The flocculation period and settling process is observed carefully to determine the floc strength, settleability, and clarity of the supernatant liquor (defined: the water that remains above the settled floc). Additionally, the supernatant can be tested to determine the efficiency of the chemical addition for removal of TSS, BOD_5, and phosphorus.

The equipment required for the jar test includes a six-position variable speed paddle mixer, six two-quart wide-mouthed jars, an interval timer, and assorted glassware, pipettes, graduates, and so forth.

Coal Gasification: Involves the conversion of coal to a gaseous product by one of several available technologies. According to DOE (2009), coal gasification offers one of the most versatile and clean ways to covert coal into electricity, hydrogen, and other valuable energy products.

Coal gasification electric power plants are now operating commercially in the U.S. and in other nations, and many experts predict that coal gasification will be at the heart of future generations of clean coal technology plants.

Rather than burning coal directly, gasification (a thermo-chemical process) breaks down coal-or virtually any carbon-based feedstock—into its basic chemical constitutes. In a modern gasifier, coal is typically exposed to steam and carefully controlled amounts of air or oxygen under higher temperatures and pressures. Under these conditions, molecules in coal break apart, initiating chemical reactions that typically produce a mixture of carbon monoxide, hydrogen and other gaseous compounds.

Coarse Materials: Wood residues suitable for chipping, such as slabs, edgings, and trimmings.

Coarse Textured Soil: Sand or loamy soil.

Coastal Zone: Lands and waters adjacent to the coast that exert an influence on the uses of the sea and its ecology, or whose uses and ecology are affected by the sea.

Cocci (pl.), **coccus** (sing.): Member of group of globular bacteria, some of which are harmful to humans.

Code of Federal Regulations (CFR): Document that codifies all rules of the executive departments and agencies of the federal government. It is divided into fifty volumes, know as title. Title 40 of the CRF lists all environmental regulations.

Codominant: In forestry science, trees in an even-aged stand, somewhat smaller than the dominants, that occupy a secondary position in the upper canopy.

Coefficient of Coupling: In *electricity*, a numerical rating between 0 and 1 that specifies the degree of magnetic coupling between two circuits.

Coefficient of Entry (C_e): A measure of the efficiency of a hood's ability to convert static pressure to velocity pressure; the ratio of actual flow to ideal flow.

Coefficient Of Friction: A numerical correlation of the resistance of one surface against another surface.

Coefficient of Haze (COH): A measurement of visibility interference in the atmosphere.

Coefficient of Storage: A group of bacteria predominately found in the soil. The fecal coliform species inhabits the intestines of man or animal. Coliform bacteria includes all aerobic and facultative anaerobic, gram negative, non-spore-forming bacilli that ferment lactose with production of gas. This group of "total" coliforms includes *Escherichia coli (E. coli)*, which is considered to be a typical coliform of fecal origin.

Cofactor: Nonprotein activator that forms a functional part of an enzyme.

Cogeneration: The consecutive generation of useful thermal and electric energy from the same fuel source.

Cold Front: The leading portion of a cold atmospheric air mass moving against and eventually replacing a warm air mass.

Cold Temperature CO: A standard for automobile-emissions of carbon monoxide (CO) emissions to be met at a low temperature (i.e., 20 degrees Fahrenheit).

Conventional automobile catalytic converters are not efficient in cold weather until they warm up.

Coliform Bacteria: A group of bacteria predominantly inhabiting the intestines of humans or other warm-blooded animals, but also occasionally fond elsewhere. Used as an indicator of human fecal contamination.

Coliform Index: A rating of the purity of water based on a count of fecal bacteria. The coliform index is used because it is difficult to test for pathogenic bacteria directly. However, the coliform index is far from perfect because they do not give a good indication of how many pathogenic bacteria are present in the water, and hey give no idea at all of whether there are pathogenic viruses or protozoa which also cause diseases and are rarely test for. Therefore, it does not always give accurate or useful results regarding the purity of water.

Coliform Organism: Microorganisms found in the intestinal tract of humans and animals. Their presence in water indicates fecal pollution and potentially adverse contamination by pathogens.

Collective Dose: The sum of the total effective dose equivalent values for all individuals in a specified population. Collective dose is expressed in units of person-rem (or person-sievert).

Collector: 1. Public or private hauler that collects nonhazardous waste and recyclable material from residential, commercial, institutions and industrial sources. 2. In *energy*, any device that absorbs solar radiation and transforms it to thermal energy that can then be used for heating or power generation.

Colloidal Material: A constituent of total solids in wastewater; consists of particulate matter with an approximate diameter range of from 1 millimicron to 1 micron.

Colloids: Very small, finely divided solids (that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.

Color: A physical characteristic of water often used to judge water quality; pure water is colorless.

Columns: Engineers are not only concerned with structural members (beams and flooring support members, for example), but also with columns. Columns are structural members with an unsupported length 10 times greater than the smallest lateral dimension, and are loaded in compression. When a column is subjected to small compressive loads, the column axially shortens. If continually larger loads are applied, a load is reached at which the column suddenly bows out sideways. This load is referred to as the column's critical or buckling load. These sideways deformations are normally too large to be acceptable; consequently, the column is considered to have failed. For slender columns, the axial stress corresponding to the critical load is generally below the yield strength of the material. Since the stresses in the column just prior to buckling are within the elastic range, the failure referred to as elastic buckling. The term elastic stability is commonly used to designate the study of elastic buckling problems. For short columns, yielding or rupture of the column may govern failure while it is still axially straight. Failure of short columns may also be caused by inelastic buckling; that is, large sideways deformation that occur when the nominal axial stress is greater than the yield strength.

Beams, floors and columns are all critical elements for safe loading. As an example, in late October of 2003, the top five floors of a parking garage under construction in Atlantic City, NJ, collapsed while workmen were pouring concrete on the structure's top floor, killing four workers, and critically injuring six others. OSHA's investigation of the collapse will involve close examination of the blueprints for the garage, and evaluation of the cure rate for the concrete. No matter who or what element of construction, design, or engineering was ultimately to blame in this collapse, obviously the load limits were exceeded for that moment. Perhaps a longer concrete curing interval would have prevented the collapse. Regardless of the cause, the cost in lives and dollars both is too high.

Combined Cycle: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. Such designs increase the efficiency of the electric generating unit.

Combined Heat and Power (CHP) Plant: A plant designed to produce both heat and electricity from a single heat source. Note: This term is being used in place of the term "cogenerator" that was used by EIA in the past. CHP better describes the facilities because some of the plants included to not produce heat and power in a sequential fashion and, as a result, do not meet the legal definition of cogeneration specified in the Public Utility Regulatory Polices Act (PURPA).

Combined Sewer Overflows: Discharge of a mixture of storm water and domestic waste when the flow capacity of a sewer system is exceeded during rainstorms.

Combined Sewers: A sewer system that carries both sewage and stormwater runoff. Normally, its entire flow goes to a waste treatment plant, but during a heavy storm, the volume of water may be so great as to cause overflows of untreated mixtures of storm water and sewage into receiving waters. Stormwater runoff may also carry toxic chemicals from industrial areas or streets into the sewer system.

Combined Wastewater: The combination of sanitary wastewater and storm water runoff.

Combustible: Will ignite, burn, or support combustion.

Combustible Liquid: Liquids having a flash point at or above 37.8°C (100°F).

Combustible Material: Any material that will ignite and burn. Any material that does not comply with the definition of "noncombustible" as contained in DOE-STD-1066-99 is considered combustible. The term combustible is not related to any specific ignition temperature or flame spread rating.

Combustion: Burning, defined in chemical terms as the rapid combination of a substance with oxygen, accompanied by the evolution of heat and usually light. In air pollution control, combustion or incineration is a beneficial pollution control process in which the objective is to convert certain contaminants to innocuous substance such as carbon dioxide and water.

Combustion Chamber: The actual compartment where waste is burned in an incinerator.

Combustion Product: Substance produced during the burning or oxidation of a material.

Command Post: Facility located at a safe distance upwind from an accident site. Where the on-scene coordinator, responders, and technical representatives make response decisions, deploy manpower and equipment, maintain liaison with news media, and handle communications.

Comment Period: Time provided for the public to review and comment on a proposed EPA action or rulemaking after publication in the Federal Register.

Commercial Chemical Products: USEPA category listing of hazardous wastes (also called *P* or *U* listed wastes because their code numbers begin with these letters); includes specific commercial chemical products or manufacturing chemical intermediates.

Commercial Sources of MSW: Solids generated in restaurants, hotels, stores, motels, service stations, repair shops, markets, office buildings, and print shops.

Commercial Species: Tree species suitable for industrial wood products.

Commercial Waste: All solid waste emanating from business establishments such as stores, markets, office buildings, restaurants, shopping centers, and theatres.

Commercial Waste Management Facility: A treatment storage, disposal, or transfer facility which accepts waste from a variety of sources, as compared to a private facility which normally manages a limited waste stream generated by its own operations.

Commercial Water Use: Water used for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. Water for commercial uses comes both from public-supplied sources, such as a county water department, and self-supplied sources, such as local wells.

Commingled Recycles: Mixed recyclables that are collected together.

Comminution: Mechanical shredding or pulverizing of waste. Used in both solid waste management and wastewater treatment.

Comminutor: The most common shredding device used in wastewater treatment. In this device all the wastewater flow passes through the grinder assembly. The grinder consists of a screen or slotted basket, a rotating or oscillating cutter, and a stationary cutter. Solids ass through the screen and are chopped or shredded between the two cutters. The comminutor will not remove solids that are too large to fit through the slots, and it will not remove floating objects. These materials must be removed manually.

Common Sense Initiative: Voluntary program to simplify environmental regulation to achieve clearer, cheaper, smarter results, starting with six major industry sectors.

Community: In ecology, an assemblage of populations of different species within a specified location in space and time. Sometimes, a particular subgroup may be specified, such as the fish community in a lake or the soil arthropod community in a forest.

Community Assistance Panel (CAP): A group of people from a community and from health and environmental agencies who work with the Agency for Toxic Substances and Disease Registry (ATSDR) to resolve issues and problems related to hazardous substance in the community. CAP members work with ATSDR to gather and review community health concerns, provide information o how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

Community Relations: The EPA effort to establish two-way communication with the public to create understanding of EPA programs and related actions, to ensure public input into decision-making processes related to affected communities, and to make certain that the Agency is aware of and responsive to public concerns. Specific community relations activities are required in relation to Superfund remedial acts.

Community Right-To-Know-Act: A part of SARA Title III under CERCLA. Stipulates that a community located near a facility storing, producing, or using hazardous materials has a right-to-know about the potential consequences of a catastrophic chemical spill or release of chemicals from the site.

Community Water System: A public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

Compaction: In solid waste: Reduction of the bulk of solid waste by rolling and tamping. In soil science: compaction is used in its geologic sense and refers to the inelastic compression of the aquifer system. Compaction of the aquifer system reflects the rearrangement of the mineral grain pore structure and largely nonrecoverable reduction of the porosity under stress greater than the preconsolidation stress. Compaction, as used here, is synonymous with the term “virgin consolidation” used by soils engineers. The term refers to both the process and the measured change in thickness. As a practical matter, a very small amount (1 to 5 percent) of the compaction is recoverable as a slight elastic rebound of the compacted material if stresses are reduced.

Compaction, Residual: Compaction that would ultimately occur if a given increase in applied stress were maintained until steady-state pore pressures were achieved. Residual compaction may also be defined as the difference between (1) the amount of compaction that will occur ultimately for a given increase in applied stress, and (2) that which has occurred at a specified time.

Comparative Risk Analysis: Process that generally uses the judgment of experts to predict effects and set priorities among a wide range of environmental problems.

Comparison Value (CV): Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Competent Person: As defined by OSHA, one who is capable of recognizing and evaluating employee exposure to hazardous substances or to unsafe conditions, and who is capable of specifying protective and precautionary measures to be taken to ensure the safety of employees as required by particular OSHA regulations under the conditions to which such regulations apply.

Competent Person Training Requirements—Asbestos: In addition to the definition in 29 CFR 1926.32 (f), one who is capable of identifying existing asbestos hazards in the workplace and selecting the appropriate control strategy for asbestos exposure, who has the authority to take prompt correction measures to eliminate them, as specified in 29 CFR 1926..32(f): in addition for Class I and Class II work who is specially trained in a training course which meets the criteria of EPA’s Model Accreditation Plan (40 CFR 763) for supervisor, or its equivalent and, for Class III and Class IV work, who is trained in a manner consistent with EPA requirements for training of local education agency maintenance and custodial staff as set forth at 50 CFR763.92 (a)(20).

Complete Treatment: A method of treating water that consists of the addition of coagulant chemicals, flash mixing, coagulation-flocculation, sedimentation, and filtration.

Complexation (chelation): The reaction between a metallic ion and a complexing organic agent that form a complex chemical ring structure and the effective removal of the metallic ion from the system.

Compliance Boundary: A performance boundary with enforceable performance limits (through an operating permit).

Compliance Coating: A coating whose volatile organic compound content does not exceed that allowed by regulation.

Compliance Cycle: The nine-year calendar year cycle, beginning January 1, 1993, during which public water systems must monitor. Each cycle consists of three three-year compliance periods.

Compliance Monitoring: Collection and evaluation of data, including self-monitoring reports, and verification to show whether pollutant concentrations and loads contained in permitted discharge are in compliance with the limits and conditions specified in the permit.

Compliance Schedule: A negotiated agreement between a pollution source and a government agency that specifies dates and procedures by which a source will reduce emissions and, thereby, comply with a regulation.

Composite: In *materials engineering*, a material or material system composed of a combination of two or more smaller constituents that differ in form and chemical composition and that are essentially insoluble in each other.

Composite Sample: A sample formed by mixing discrete samples taken at periodic points in time or a continuous proportion of the flow. The number of discrete samples that make up the composite depends upon the variability of pollutant concentration and flow.

Compost (Biosolids): In *wastewater treatment*, the purpose of composting biosolids (sewage sludge) is to stabilize the organic matter, reduce volume, eliminate pathogenic organisms, and produce a product that can be used as a soil amendment or conditioner. Composting is a biological process. In a composting operation, dewatered solids are usually mixed with a bulking agent (i.e., hardwood chips) and stored until biological stabilization occurs. The composting mixture is ventilated during storage to provide sufficient oxygen for oxidation and to prevent odors. After the solids are stabilized, they are separated from the bulking agent. The composted solids are then stored for curing and are applied to farm lands or other beneficial uses. Expected performance of the composting operation for both percent volatile matter reduction and percent moisture reduction ranges from 40 to 60 percent.

Performance factors related to biosolids composting include moisture content, temperature, pH, nutrient availability, and aeration.

The biosolids must contain sufficient moisture to support the biological activity. If the moisture level is too low (40 percent less), biological activity will be reduced or stopped. At the same time, if the moisture level exceeds approximately 60 percent, it will prevent sufficient airflow through the mixture.

The composting process operates best when the temperature is maintained within an operating range of 130 to 140°F—biological activities provide enough heat to increase the temperature well above this range. Forced air ventilation or mixing is used to remove heat and maintain the desired operating temperature range.

The temperature of the composting solids when maintained at the required levels will be sufficient to remove pathogenic organisms.

The influent pH can affect the performance of the process if extreme (less than 6.0 or greater than 11.0). The pH during composting may have some impact on the biological activity but does not appear to be a major factor. Composted biosolids generally have a pH in the range of 6.8 to 7.5.

The critical nutrient in the composting process is nitrogen. The process works best when the ratio of nitrogen to carbon is in the range of 26 to 30 carbon to one nitrogen. Above this ratio, composting is slowed. Below this ratio, the nitrogen content of the final product may be less attractive as compost.

Aeration is essential to provide oxygen to the process and to control the temperature. In force air processes, some means of odor control should be included in the design of the aeration system.

Composting Facilities: 1. An offsite facility where the organic component of municipal solid waste is decomposed under controlled conditions. 2. An aerobic process in which organic materials are ground or shredded and then decomposed to hum in windrow piles or in mechanic digesters, drums, or similar enclosures.

Compound: A substance composed of two or more elements, chemically combined in a definite proportion.

Comprehensive Environmental Response Compensation and Liabilities Act (CERCLA): The mission of the *Comprehensive Environmental Response, Compensation, and Liabilities Act of 1980* (Superfund or SARA) is to clean up hazardous waste disposal mistakes of the past, and 8to cope with emergencies of the present. More often referred to as the *Superfund Law***,** as a result of its key provisions a large trust fund (about $1.6 billion) was created. Later, in 1986, when the law was revised, this fund was increased to almost $9 billion. The revised law is designated as the *Superfund Amendments and Reauthorization Act of 1986 (SARA)*. The key requirements under CERCLA include:

1. CERCLA authorizes the EPA to deal with both short-term (emergency situations triggered by a spill or release of hazardous substances), as well as long-term problems involving abandoned or uncontrolled hazardous waste sites for which more permanent solutions are required.

2. CERCLA has set up a remedial scheme for analyzing the impact of contamination on sites under a hazard ranking system. From this hazard ranking system, a list of prioritized disposal and contaminated sites is compiled. This list becomes the National Priorities List (NPL) when promulgated. The NPL identifies the worst sites in the nation, based on such factors as the quantities and toxicity of wastes involved, the exposure pathways, the number of people potentially exposed, and the importance and vulnerability of the underlying groundwater.
3. CERCLA also forces those parties who are responsible for hazardous waste problems to pay the entire cost of cleanup.
4. Title III of SARA requires federal, state, and local governments and industry to work together in developing emergency response plans and reporting on hazardous chemicals. This requirement is commonly known as the Community Right-To-Know Act, which allows the public to obtain information about the presence of hazardous chemicals in their communities and releases of these chemicals into the environment.

Compressed Gas: One or more gases in a container having an absolute pressure that exceeds 40 psi at 37.8ºC (100ºF) as determined by ASTM D-322-72 test methods.

Compressed Gas Safety: The very properties that make compressed gases, liquefied compressed gases, and cryogenic liquids useful in almost every area of modern life can also make them dangerous when mishandled (Compressed Gas Association, 1990).

"Dangerous when mishandled" is the key phrase. Fortunately, years of experience with compressed gas has resulted in safe work practices and equipment which, if properly used, results in complete safety.

Compressed gases are usually stored in cylinders or other containers at high pressures and must always be handled with care. While compressed gas containers are designed to meet rigid regulatory specifications and are safe for their intended use, they can be extremely hazardous if abused or misused. Thus, care and caution is always advised when working with or around compressed gases.

A compressed gas cylinder may have a series of numbers stamped into it. For instance, the designation "DOT 3AA 2300" refers to Department of Transportation (DOT) specification of tank for 2,300 psi at 70°F. Directly under this designation may be a serial number such as "Z48976" to identify the specific tank. Other identifiers, such as "10 PB 89+", indicate the most recent inspection date or date of manufacture. In this case, an inspector with initials PB inspected the cylinder in October, 1989. The plus sign reveals that this tank may be filled to 10 percent over the 2,300 psi service pressure. In addition, the tank must be clearly marked as to the contents and whether or not the gas is hazardous.

All compressed gas cylinders are equipped with a safety device that permit gas to escape from the cylinder in the event that excessive pressures develop inside the tank. A hand wheel is used to open or close the valve, but not to adjust the pressure of the escaping gas. An outlet connection is provided for attaching a pressure regulator valve to the main cylinder valve. The threads of these connections are designed to accommodate special regulators or attachments and to prevent the connection of improper accessories to the tank (e.g., the wrong type of regulator). A two-stage pressure regulator valve is normally used with the standard compressed gas cylinder. The gauge nearest the cylinder indicates the pressure inside of the main tank, while the second gauge indicates the discharge pressure of the gas. The discharge pressure is regulated by the handle on the large portion of the regulator. In most of these valves, the discharge pressure may be increased by turning the valve clockwise, rather than counterclockwise as one might expect. A final delivery valve may be present to turn the flow of gas from the regulator on or off. It has no effect on the dispensing pressure, but only on the rate of discharge. All tanks have a cylinder cap that is screwed over the cylinder valve to protect it when the tank is not in use or during shipping. This cap must be securely screwed in place on all tanks that do not have a regulator or on tanks that are not in use.

When received, a cylinder must be checked for damage and for proper contents. An in-house "necklace" label should be placed over the cap of the tank to indicate its contents, that it is full, the date received, and the initials of the person receiving the tank.

Caution: The Compressed Gas Association warns that color should never be used as the sole means of identifying the contents of a compressed gas container.

Do not attempt to open the main tank valve until the tank has been attached to a pressure regulator or other piece of equipment. Otherwise, the tank may give off a high pressure discharge of gas that cuts like a knife.

Caution: The Compressed Gas Association warns that the release of high pressure gas from cylinders can be hazardous unless adequate means are provided for reducing the gas pressure to usable levels and for controlling the gas flow. Accordingly, pressure-reducing regulators should always be used when withdrawing the contents of a cylinder, as such devices deliver a constant safe working pressure.

Transport the cylinder in a specially designed gas tank transport cart with the cap in place and with the tank secured to the cart with chains or ties. Never attempt to move the cylinder by rolling it or sliding it along the floor as it may drop to the floor and damage the main cylinder valve.

Store gas cylinders in a dry, well-ventilated area that does not get excessively hot or cold (-29 to 52°C). Do not store incompatible gases in close proximity.

Cylinders must be securely chained or held in place to prevent their falling over. When removing tanks, use the special cart to transport them to the location and immediately chain or secure the tank into position rather than leaving it on the cart.

When attaching the cylinder to the apparatus or pressure regulator, use the proper tool, (wrench) rather than a makeshift device such as pliers. Keep the proper tool chained near the area where the cylinder is used. The apparatus should be securely attached to the main valve so that it will not shift position when lateral pressure is applied to the device. After attaching the device to the main cylinder valve and before opening it, verify that the attached device or pressure regulator is closed off. Then, partially open the main cylinder valve and check for any leaks between the main valve and the attached device. If any leaks are found, close the main valve immediately and seek assistance from the workplace supervisor. If no leaks are found, check the tank pressure (it should be neither too high nor too low for the particular gas) and verify that the discharge pressure valve is closed or that the final dispensing valve is closed.

Adjust the flow of gas using the pressure adjustment valve (if present) and open the final valve. If any problems are encountered during the use of the compressed gas, turn off the main tank valve first before attempting to resolve the problem. Wear appropriate eye, hand, and body protection when working with the cylinders and use no lubricants on the cylinder or the pressure regulators. It is best to discontinue using the tank before it is completely empty to prevent contaminants from entering the tank during the refilling step at the suppliers. Remove the original necklace label and replace it with another label indicating that the cylinder is *empty***.** Have the empty tank removed as soon as possible to prevent others from using it and to remove clutter from the laboratory. The tank must be transported back to storage on the cylinder cart with the cylinder cap in place.

Caution: The Compressed Gas Association warns: do not attempt to force connections that do not fit.

The Compressed Gas Association advises or cautions about a number of practices (in addition to those already pointed out above) that should be followed or avoided when handling compressed gas cylinders. These advisories are listed in the following:

1. **Caution:** Compressed gases must never be transferred from one container to another except by the gas manufacturer or distributor.
2. **Caution:** o not smoke or permit smoking or open flames in any area where flammable liquids or gases or liquid oxygen are stored, handled, or used, or where they are loaded or unloaded.
3. **Caution:** Keep all combustible materials, especially oil or grease, away from oxygen.
4. **Caution:** Liquid oxygen, if spilled on clothing or another combustible substance, can pose a serious hazard of fire or explosion due to the rapid chemical reaction between the two substances.
5. **Caution:** A flame must never be used for detection of flammable gas leaks.
6. **Caution:** Never permit oil, grease, or other combustible materials to come in contact with cylinders, valves, regulators, gases, hose, and fittings used for oxidizing gases such as oxygen and nitrous oxide, which may combine with these substances with explosive violence.
7. **Caution:** Poison gases pose serious potential hazards to personnel and therefore require special handling.
8. **Caution:** Corrosive gases attack human tissue and other materials, and special protective clothing and self-contained breathing apparatus must be used by personnel handling these substances.

Compressed Natural Gas (CNG): An alternative fuel for motor vehicles; mixtures of hydrocarbon gases and vapors, consisting principally of methane in gaseous form that has been compressed. Considered one of the cleanest because of low hydrocarbon emissions and its vapors are relatively non-ozone producing. However, vehicles fueled with CNG do emit a significant quantity of nitrogen oxides.

Compressive strength: The ability of a material to resist being crushed.

Computer Security: “Society is growing increasingly dependent upon large-scale, highly distributed systems that operate in unbounded network environments. Unbounded networks, such as the Internet, have no central administrative control and no unified security policy. Furthermore, the number and nature of the nodes connected to such networks cannot be fully known. Despite the best efforts of security practitioners, no amount of system hardening can assure that a system that is connected to an unbounded network will be invulnerable to attack. The discipline of survivability can help ensure that such systems can deliver essential services and maintain essential properties such as integrity, confidentiality, and performance, despite the presence of intrusion.”

An Approach to Survivable Systems. R J. Ellison, et al. CERT[1]® Coordination Center, Software Engineering Institute, Carnegie Mellon University Pittsburgh, PA

The safety and security of a facility's computer system has elements that demand the safety engineer's attention. Familiarity with important issues in computer system and data security is critical. While safety engineers shouldn't be expected to know as much about computers as a systems engineer, ensuring that the IT (Information Technology) staff has the tools they need to provide reasonable levels of system security, ensuring that security measures are in place to limit access to data and equipment, and keeping up with current issues in computer and data security is a growing part of the safety professional's job. Facility administration, IT, and the safety engineer should work together on formulating company policy on computer access, security, auditing, and back-up systems. Current best practice for information security is a layered, defense-in-depth program that involves policy, procedures and tools.

According to Larry McCreary of IT Security, as networks become increasingly more complex, security has become much more than off-the-shelf software. Today firewalls, authentication, intrusion detection/prevention and web filtering are all part of an effective data security program.

Best practices include:

- A regularly updated and reviewed security policy as a formal condition of employment.
- A general security approach that allows access only to authenticated users.
- Encryption of sensitive data accessible by public connections.
- Well configured and enforced access rules across physical, logical, and social boundaries.
- Traffic control across physical, logical, and social boundaries.
- Role-based authentication/authorization (as needed) including dynamic passwords (generated by hardware or software tokens or sent to mobile devices, etc.) for network administrators, remote users, and employees accessing mission-critical information.
- Filtering content that could cause:
  - ○ Network vulnerabilities (email attachments, hacker tools, viruses, etc.);
  - ○ Legal liability (pornography, criminal skills, anonymizers, cults, etc.);
  - ○ Poor network availability (MP3, streaming content, etc).
  - ○ Regular third-party audits and assessments.

Computer Security Auditing: Issues and actions for computer and data systems security include many different elements to consider. Using a Computer Security Audit checklist provides steps to securing computer and information systems. Just like any other safety area, computer and data security is not static—no once-and-done solution is possible. The equipment to protect, the risks, and the threats change rapidly. This section addresses common audit items and the audit questions to help determine system needs.

- Who within the organization should have access to what information? Ensure that people do not unnecessarily have full access to the systems.
- What information is most important to protect in terms of confidentiality?
- Does the Acceptable Use Policy explain what everyone in the organization should and should not do with the information systems?
- Is a current equipment and configuration list maintained for the organization?
- Is a current software installation list available for all computers and equipment in the organization?
- Are all passwords used in the IT systems changed from the default?
- Are log-on passwords effectively maintained as confidential, changed regularly, and in a format that cannot easily be guessed?
- Do any workers take laptops and other portable devices off the network and outside of standard security procedures?
- Will any remote workers need to connect to the network?
- What is the organization plan for security requirement evaluation?
- Is someone responsible for network and information security? Does that person have the authority to take action to respond to security breaches and vulnerabilities?
- Can abnormal network activity on your network be identified?
- How is company physical waste disposed? Secure computer data revealed through print-out paper waste instead of system intrusion is just as disruptive (Colin Rose).

Computer Security Needs: Computer system risks mean that any complete security program pays attention to all risk areas. That means that developing ways to protect:

- The physical equipment itself, including desktop computers (whether office based or home computers supplied by the company) and the associated peripherals (output devices like printers, input devices

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[1] ® CERT and CERT Coordination Center are registered in the U.S. Patent and Trademark Office.

like scanners, and data transfer, back-up and storage devices, like zip drives, CD or DVD drives, whether external or internal); laptop computers and their associated gear; and an ever-widening body of hand-held devices, including PDAs, bar code readers, and many different types of data readers.

- Logical assets, including IP and other network configuration information.
- Application and data integrity
- Password integrity

Different types of equipment present different security needs. Laptops are easier to physically steal than desktop units, but are more apt to be the targets of incidental theft, not a deliberate to steal a particular unit because of the data it contains. More important is the protection of the computer system and the information held within the system, which may have value, or may simply be vulnerable to hackers.

Computer Security Threats: Risks to computer systems data include physical theft, logical usurpation, application damage through viral attack, and "social engineering" attacks. For example, the possibility is very high that any organization with more than twenty workers will have lost laptops or handhelds in the last year. The associated costs for such losses are usually determined only for replacement costs—which doesn't include the value of the lost data. Count up all of the replacement costs, including equipment, software, and restoring or replacing data, and the reasoning behind why staff should be taught clear policies, procedures, and the importance of computer security becomes clear.

Concentrated Solution: Solute in concentration present in large quantities.

Concentration: The relative amount of a substance mixed with another substance; expressed as pounds per gallon, milliliters per liter, parts per million, etc. An example is five ppm of carbon monoxide in air or 1 mg/L of iron in water.

Concentrator: A reflective or refractive device that focuses incident insolation onto an area smaller than the reflective or refractive surface, resulting in increased insolation at the point of focus.

Condensate: 1. Liquid formed when warm landfill gas cools as it travels through a collection system. 2. Water created by cooling steam or water vapor.

Condensation: Air pollution control technology used to remove gaseous pollutants from waste stream; a process in which the volatile gases are removed from the contaminant stream and changed into a liquid.

Condenser: 1. Air pollution control device used in a condensation method to condense vapors to a liquid phase by either increasing the system pressure without a change in temperature or by decreasing the system temperature to its saturation temperature without a pressure change. 2. Equipment that condenses turbine exhaust steam into condensate.

Conditionally Exempt Generators (CE): Persons or enterprises which produce less than 220 pounds of hazardous waste per month. Exempt from most regulations, they are required merely to determine whether their waste is hazardous, notify appropriate state or local agencies, and ship it by an authorized transporter to a permitted facility for proper disposal.

Conductance: A rapid method of estimating the dissolved solids content of water supply by determining the capacity of a water sample to carry an electrical current. Conductivity is a measure of the ability of a solution to carry an electrical current.

Conduction: The transfer of heat between two bodies that are touching, or from one location to another within a body. For example, if an employee touches a workpiece that has just been welded and is still hot, heat will be conducted from the workpiece to the hand. Of course, the result of this heat transfer is a burn.

Conductivity: A measure of the ability of a solution to carry an electrical current.

Conductivity, Effective Hydraulic, K_e [LT^{-1}]: The effective hydraulic conductivity is the rate of flow of water through a pours medium that contains more than one fluid, such as wad and air in the unsaturated zone, and should be specified in terms of both the fluid type and content and the existing pressure. Effective hydraulic conductivity has been called capillary conductivity by many soil physicists and effective permeability by many petroleum engineers.

Conductivity, Hydraulic, K: Replaces the term "field coefficient of permeability," P_f, introduced by Meinzer and Wenzel, 1942), which embodies the inconsistent units gallon, foot, and mile. If a porous medium is isotropic and the fluid is homogenous, the hydraulic conductivity of the medium is the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

Darcy's law can be expressed as

$$q = \frac{Q}{A} = -K\,\frac{dh}{dl} \tag{1}$$

K, the constant of proportionality in equation 1, is the hydraulic conductivity and may be expressed as

$$K = -\,\frac{q}{dh/dl} \tag{2}$$

Hydraulic conductivity can have any units of LT^{-1} suitable to the problem involved. In data tabulations of the Geological Survey, hydraulic conductivity may be expressed in feet per day and, so that the work of the Geological Survey may be readily interpreted in other countries, also in meters per day, Thus,

$$K = -\,\frac{\text{ft}^3}{\text{day ft}^2\,(-\text{ ft ft}^{-1})} = \text{ft day}^{-1} \tag{3}$$

$$K = -\,\frac{\text{m}^3}{\text{day ft}^2\,\text{m}^2\,(-\text{m m}^{-1})} = \text{ft day}^{-1} \tag{4}$$

Hydraulic conductivity is dependent primarily on the nature of the pore space, the type of liquid occupying it, and the strength of the gravitational field. For comparing the hydraulic conductivities of aquifers at different locations that contain water of appreciably different kinematic viscosity, it is only necessary to relate them by the dimensionless ratio of the kinematic viscosities and values of the acceleration due to gravity; thus, for the same intrinsic permeability,

$$K_1 = \frac{v_2 g_1}{v_1 g_2} K_2 \tag{5}$$

Ordinarily, differences in the acceleration due to gravity are negligible; hence, equation 5 is closely approximated by

$$\mathrm{K}_1 = \frac{\mathrm{v}_2}{\mathrm{v}_1}\,\mathrm{K}_2 \tag{6}$$

In anisotrophic media (not isotropic) the direction of the specific discharge q is not generally parallel to that of the gradient (dh/dl) of the head. In such media the cartesian components of the specific discharge are related to those of the gradient by

$$-q_x = K_{xx}\frac{\partial h}{\partial x} + Kxy\frac{\partial h}{\partial y} + K_{xz}\frac{\partial h}{\partial z}$$

$$-q_y = K_{yx}\frac{\partial h}{\partial x} + K_{yy}\frac{\partial h}{\partial y} + K_{yz}\frac{\partial h}{\partial z}$$

$$-q_z = K_{zx}\frac{\partial h}{\partial x} + K_{zy}\frac{\partial h}{\partial y} + K_{zz}\frac{\partial h}{\partial z}$$

The quantities in the form K_{xx}, K_{xy}, K_{xz} and so forth, called *conductivity coefficients*, are the second-order tensor, generally symmetric.

Confined Animal Feeding Operation (CAFO): CAFOs are farming operations where large numbers (often in the thousands of animals) of livestock or poultry are housed inside buildings or in confined feedlots. How many animals? The USEPA defines a CAFO or industrial operation as a concentrated animal feeding operation where animals are confined for more than 45 days per year. To classify as a CAFO, such an operation must also have over 1000 animal units—a standardized number based on the amount of waste each species produces, basically 1000 pounds of animal weight. Thus dairy cattle count as 1.4 animal units each. A CAFO could house more than 750 mature dairy cattle (milking and or dry cows) or 500 horses, and discharge into navigable water through a man-made ditch or a similarly man-made device. CAFO classification sets numbers for various species per 1000 animal units:

- 2500 Hogs
- 700 Dairy Cattle
- 1000 Beef Cattle
- 100,000 Broiler Chickens
- 82,000 Laying Hens

Unless you've seen such an operation, getting a grasp on the scope of the problem can be difficult. By using comparison, we quantify the issue: How do the amounts of CAFO-generated animal manure compare to human waste production? Let's take a look at it.

Here's a small-scale number: One hog, per day, excretes 2.5 times more waste than an adult human—nearly three gallons (Cantrell, Perry, & Sturtz, 2004).

Here's a medium-scale number: A 10,000-hog operation produces as much waste in a single day as a town of 25,000 people (Sierra Club, 2004)—but the town has a treatment plant.

Here's a big picture approach: The USEPA estimates that human uses generate about 150 million tons (wet weight) of human sanitary waste annually in the United States, assuming a U.S. population of 285 million and an average waste generation of about 0.518 tons per person per year. The USDA estimates that operations that confine livestock and poultry animals generate about 500 million tons of excreted manure annually. The USEPA estimates over 450,000 CAFOs in the United States, producing 575 billion pounds of manure annually in the United States today (USEPA, 2003).

Here's the bottom line: By these estimates, all confined animals generate well over **3 times** more raw waste than is generated by humans in the United States Much of this waste undergoes no—or very little—waste treatment. Waste-handling for any CAFO is a major business concern and expense. Unless regulation and legislation supports sound environmental practices for these operations, CAFO owners have little incentive to improve their waste handling practices.

Confined Aquifer: Sandwiched between two impermeable layers that block the flow of water. The water in a confined aquifer is under hydrostatic pressure. It does not have a free water table. Confined aquifers are referred to as artesian aquifers. Wells drilled into artesian aquifers are artesian wells and commonly yield large quantities of high-quality water. An artesian well is any well where the water in the well casing would rise above the saturated strata. Wells in configured aquifers are normally referred to as deep wells and are not generally affected by local hydrological events.

A confined aquifer is recharged by rain or snow in the mountains where the aquifer lies close to the surface of the Earth. Because the recharge area is some distance from areas of possible contamination, the possibility of contamination is usually very low; however, once contaminated, confined aquifers may take centuries to recover.

Confined Space: A vessel, compartment, or any area having limited access and (usually) no alternate escape route, having severely limited natural ventilation or an atmosphere containing less that 19.5 percent oxygen, and having the capability of accumulating a toxic, flammable, or explosive atmosphere, or of being flooded (engulfing a victim).

OSHA has a confined space entry standard, 29 CFR 1910.146 Confined Space Entry, 1995. Under the standard, OSHA's Confined Space Entry Program (CSEP) is a proven vital guideline to protect workers and others. CSEP was issued to protect workers who must enter confined spaces. It is designed and intended to protect workers from toxic, explosive, or asphyxiating atmospheres, and from possible engulfment from small particles such as sawdust and grain (e.g., wheat, corn, and soybean normally contained in silos). It focuses on areas with immediate health or safety risk—areas with hazards that could potentially cause death or injury—areas or spaces classified as permit-required confined spaces. Under the standard, employers are required to identify all permit-required spaces in their workplaces, prevent unauthorized entry into them, and protect authorized workers from hazards through a entry by permit only program.

CSEP covers all of general industry, 29 CFR 1910, including agricultural services (the keyword here is "services" and not agriculture), manufacturing, chemical plants, refineries, transportation, utilities, wholesale and retail trade, and miscellaneous services. It applies to manholes, vaults, digesters, contact tanks, basins, clarifiers, boilers, storage vessels, furnaces, railroad tank cars, cooking and processing vessels, tanks, pipelines, silos, among other spaces.

Confined space entry operations are extremely dangerous undertakings. We stated earlier that confined spaces are very unforgiving—even for those workers who have been well trained. However, training helps to reduce the severity of any incident. When something goes wrong (as if often the case) it is better to have fully trained personnel standing by than to have people standing by who are not trained—who do not know how to properly rescue an entrant, let alone how to rescue themselves. When you get right down to it, having fully trained workers for any job just makes good common sense.

Confirmed Positive Test: For drugs, a finding based on a positive initial or screening test result, confirmed by another positive test on the same sample. The confirmatory test must be by the gas chromatography/mass spectrometry method.

Confluence: Point at which the two streams merge.

Confluent Growth: A continuous bacterial growth covering all or part of the filtration area of a membrane filter in which the bacteria colonies are not discrete.

Conformality: A map projection is conformal when at any point the scale is the same in every direction. Therefore, meridians and parallels intersect at right angles and the shapes of very small areas and angles with very short sides are preserved. The size of most areas, however, is distorted.

Conidia: The asexual spores borne on aerial mycelia (actinomycetes bacteria).

Conifers: In forestry science, conifers are gymnosperms in division Pinophyta within the Kingdom Plantae. They are needle- and cone-bearing seed plants with vascular tissue; they are woody plants, the great majority being trees with just a few being shrubs. Typical examples of conifers include Douglas-firs, cypress, firs, cedars, pines, larch, hemlocks, redwoods, spruces, and yews.

Connate Water: In *geology*, highly mineralized water that has been trapped in igneous rock formations at the time the rocks were formed.

Consent Decree: A legal document, approved by a judge, that formalizes an agreement reached *between* EPA and potentially responsible parties (PRPs) through which PRPs will conduct all or part of a cleanup actin at a Superfund site; cease or correct actions or processes that are polluting the environment; or otherwise comply with EPA initiated regulatory enforcement actions to resolve the contaminant the Superfund site involved. The consent decree describes the actions PRPs will take and may be subject to a public comment period.

Conservation: Preserving and renewing, when possible, human and natural resources. The use, protection, and improvement of natural resource according to principles that will ensure their highest economic or social benefits.

Conservation Cropping Sequence: An adapted sequence of crops designed to provide adequate organic residue for maintenance or improvement of soil tilth and for other conservation purposes.

Conservation Easement: Easement restricting a landowner to land uses that tare compatible with long-term conservation and environmental values.

Conservation of Energy: In *physics*, the principle that the energy of the universe is constant and cannot be created or destroyed.

Conservation Practice: A specific structure. Managerial or cultural treatment of natural resources commonly used to meet a specific need in planning and carrying out soil and water conservation programs.

Conservation Reserve Program (CRP): CRP provides farm owners or operators with an annual per-acre rental payment and half the cost of established a permanent land cover in exchange for retiring environmentally sensitive cropland from production for ten to fifteen years. In 1996, Congress reauthorized CRP for an additional round of contracts, limiting enrollment to 36.4 million acres at any time. The 2002 Farm Act increased the enrollment limit to 39 million acres. Produces can offer land for competitive bidding based on an Environmental Benefits Index (EBI) during periodic signups, or can automatically enroll more limited acreages in processes such as riparian buffers, field windbreaks, and grass strips on a continuous basis. CRP is funded through the Commodity Credit Corporation (CCC).

Conservative Pollutants: Pollutants that are not altered as they are transported from their source to the receiving water.

Consolidation: In soil mechanics, consolidation is the adjustment of a saturated soil in response to increased load, involving the squeezing of water from the pores and decrease in void ratio or porosity of the soul. In this book, the geologic term "compaction" is used in preference to consolidation.

Constituent(s) of Concern: Specific chemicals that are identified for evaluation in the site assessment process.

Constructed Wetland: An aquatic treatment system consisting of one or more lined or unlined basins, some or all of which may be filled with a treatment medium and wastewater undergoing some combination of physical, chemical, and/or biological treatment and evaporation and evapotranspiration by means of macrophytes planted in the treatment medium.

Construction and Demolition Sources of MSW: Generated at new construction sites, razing of old buildings, road repair/renovation sites and broken pavement.

Construction and Demolition Waste: Waste building materials, dredging materials, tree stumps, and rubble resulting from construction, remodeling, repair, and demolition of homes, commercial buildings and other structures and pavements. May contain lead, asbestos, or other hazardous substances.

Construction Ban: If, under the Clean Air Act, EPA disapproves an areas' planning requirements for correcting nonattainment, EPA can ban the construction or modification of any major stationary source of the pollutant for which the are is in nonattainment.

Construction Permit: A permit issued or authorized by the regulatory authority that allows the installation of a wastewater treatment system in accordance with approved plans and applicable codes.

Construction Safety: OSHA's Construction Standard (29 CFR 1926) includes many elements. Some of the elements and their requirements overlap with general industry requirements. For example, compliance requirements with OSHA's Hazard Communication, Lockout/Tagout, Personal Protective Equipment (PPE), Slips, Trips, and Falls, Lifting Techniques, First Aid and Bloodborne Pathogens, Respiratory Protection, Emergency Response, and Confined Space Entry (to list just a few) apply both to General Industry and the Construction Industry. Other elements generally apply to the Construction Industry only, such as scaffolding, cranes, derricks hoists, elevators, and conveyors, underground construction, blasting and use of explosives, excavations, trenching, and shoring, steel erection, and demolition, for example.

Consumers: In ecology, organisms that cannot produce their own food and eat by engulfing or predigesting the fluids, cells, tissues, or waste products of other organisms.

Consumptive Water Use: That part of water withdrawn that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.

Contact Condenser: Similar to a simple spray scrubber; it cools vapor stream by spraying liquid directly on the vapor stream.

Contact Dermatitis: Inflammation of the skin caused by direct contact with an irritant.

Contact Pesticide: A chemical that kills pests when it touches them, instead of by ingestion. Also, soil that contains the minute skeletons of certain algae that scratch and dehydrate waxy-coated insects.

Contagious: A contagious disease is easily spread from one person to anther by contact with the infectious agent that causes the disease. The agent may be in droplets of liquid particles made by coughing or sneezing, contaminated food utensils, water, or food.

Container: Any vessel with a capacity of 60 U.S. gallons or less that is used for transporting or storing liquids is referred to as a "container."

Containment: In fire terminology, restricting the spread of fire. For chemicals, restricting chemicals to an area that is diked or walled off to protect personnel and the environment.

Containment System: A structurally closed barrier and its associated systems (including ventilation) between areas containing hazardous materials and the environment or other areas in the nuclear facility that are normally expected to have levels of hazardous materials lower han allowable concentration limits. A containment barrier is designed to remain closed and intact during all design basis accidents.

Contaminated: Containing potentially harmful material.

Contamination: 1. The degradation of water quality as a result of natural processes and/or the activities of people. No specific limits are established because the degree of permissible contamination depends upon the intended end use or uses of the water. 2. Deposition of radioactive material in any place where it is not wanted.

Contamination Area: Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in appendix D of 10 CFR 835.

Contamination Source Inventory: An inventory of contaminant sources within delineated State Water-Protection Areas. Targets likely sources for further investigation.

Contingency Plan: Under CFR 40 §260.10, a document that sets forth an organized, planned, and coordinated course of action to be followed in the event of an emergency that could threaten human health or the environment.

Continuous Air Monitor (CAM): An instrument that continuously samples and measures the levels of airborne radioactive materials on a 'real-time" basis and has alarm capabilities at preset levels.

Continuous Discharge: A routine release to the environment that occurs without interruption, except for infrequent shut-downs for maintenance, process changes, etc.

Continuous-Flow Suspended-Growth Aerobic System: A typical activated sludge process. Conventional onsite system: A wastewater treatment system consisting of a septic tank and subsurface wastewater infiltration system.

Continuous Sample: A flow of water, waste or other material from a particular place in a plant to the location, where sample are collected for testing. May be used to obtain grab or composite samples.

Contract Labs: Laboratories under contract to EPA, which analyze samples taken from waste, soil, air, and water or carry out research projects.

Control of Disposal: A system of controls and restrictions governing the disposal of hazardous wastes onto, or into, the land. A key element of RCRA's goal of protecting groundwater supplies.

Control Technique Guideline (CTG): EPA documents designed to assist state and local pollution authorities to achieve and maintain air quality standards for certain sources (e.g., organic emissions from solvent metal cleaning know as degreasing) through reasonably available control technologies (RACT).

Controlled Area: An area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason.

Controlled Reaction: A chemical reaction under temperature and pressure conditions maintained within safe limits to produce a desired product or process.

Controlled Substances (49 CFR PART 382/40): *The U.S. Department of Transportation set out to strengthen the nation's program, subjecting 8.3 million transportation* *workers to drug and alcohol testing, and also to make the rules easier for all parties to understand. By all accounts, the revisions unveiled last December [1999] achieve both goals* (Laws, 2000).

Since their enactment, Part 382 and Part 40 of 49 CFR have received mixed reviews from drivers, from employers required to test drivers, and from drug testing laboratories. From the driver's point of view, many feel the controlled substances and alcohol use and testing requirements mandated for drivers are unnecessary and unwarranted invasions of privacy.

However, experience (backed by many records demonstrating that on-the-road highway accidents related to drug/alcohol abuse are frequent) shows that when drivers use drugs or alcohol to push their bodies beyond the normal limits, the results can be disastrous. Drivers may think they are working faster and/or more efficiently, but the truth is that they are more likely to make mistakes—mistakes of catastrophic proportions. As the drug or alcohol wears off, drivers work slower and more sluggishly. Since driving is both a mental and reflex task, being slow and sluggish can have terrible consequences.

Consider one common example of drug abuse. Illegal use of cocaine may give drivers the idea that "I can do anything," a false belief that could cause them to take unnecessary risks on the highway—risks that could put their life (and the lives of their others on the road) in great danger. Add to that the risk inherent in the action of the drug itself. Cocaine takes a terrible toll on even normal, healthy hearts—just one line can aggravate a hidden heart defect or trigger a reaction to an unknown allergy (both of which can result in death). Until only a few years ago, the popular perception of cocaine was that it was a "safe" drug, and not even physically addictive. In reality, this drug is anything but safe. In fact, doctors consider it three times more lethal than heroin.

When used, those under the influence of these commonly abused substances may exhibit the symptoms as follows:

Alcohol
- slowed reaction time
- poor hand-eye coordination
- impaired judgment
- poor concentration and short-term memory

Marijuana
- impaired coordination
- impaired sense of time and distance
- inability to retain information

Cocaine
- strong mood swings
- false belief that the drug enhances physical ability
- tendency to work too quickly, performing jobs carelessly and superficially

Crack
- confusion
- inability to concentrate
- difficulty making decisions
- distrust
- delusions and hallucinations

Negative reactions to substance abuse testing from drivers range from anger at the invasion of privacy, to irritation at a hassle and inconvenience. However, those drivers who do use drugs or alcohol while driving put us all at risk. From the above list of possible symptoms from various substances used, it should be clear that our highways must be used only drivers that have full control of their faculties.

Negative reactions to substance abuse testing from the employer's point of view are also prevalent. Some see DOT's substance abuse prevention requirements as wasteful, expensive, and a hassle. However, since employers are usually directly or vicariously responsible for their employees' performance on the job (especially when such performance could affect the health and well being of innocent others), they have a very real personal stake in ensuring that the drivers are alcohol/drug free.

Drug testing laboratories are in business to perform certain analytical procedures for profit. To consider or acknowledge that a testing facility—a for-profit business—might have heartburn with testing for alcohol/drug abuse of DOT-sanctioned drivers might seem silly. But this is the case, to a degree. When testing procedures are vague and ambiguous (as many federal requirements are in an attempt to cover as many contingencies as possible), attempting to perform analytical procedures in full compliance with mandated regulations is not always straightforward. In fact, because of vagaries and ambiguities, DOT's 49 CFR Part 40 *Drug Testing*, originally enacted in 1989, was revised (December 1999) to make requirements easier to follow and implement.

Controlled Substances and Alcohol Use/Testing (Part 382)

The following material is largely derived from 49 CFR Part 382. The numbering and lettering of paragraphs and subparagraphs are shown as they appear in this Part.

Subpart A—General

In Subpart A (General), DOT states that the purpose of this part is to establish programs designed to help prevent accidents and injuries resulting from the misuse of alcohol or use of controlled substances by drivers of commercial motor vehicles.

- **§382.103 (a) (Applicability)**—applies to every person and to all employers of such persons who operate a commercial motor vehicle in commerce in any state, and is subject to:
  1. The commercial driver's license requirements of Part 383 of this subchapter;
  2. Licencia Federal de Conductor (Mexico) requirements; or
  3. The commercial driver's license requirements of the Canadian National Safety Code.
- **§382.103 (b)**—an employer who employs himself/herself as a driver must comply with both the requirements in this part that apply to employers and the requirements in this part that apply to drivers. An employer who employs only himself/herself as a driver is required to implement a random alcohol and controlled substances testing program of two or more covered employees in the random testing selection pool.
- **§382.103 (c)**—The exceptions contained in §390.3(f) of this subchapter do not apply to this part. The employers and drivers identified in §390.3(f) must comply with the requirements of this part, unless otherwise specifically provided in Paragraph (d) of this section.
- **§382.103 (d) Exceptions**—This part lists the following exceptions for employers and drivers:
  1. Required to comply with the alcohol and/or controlled substances testing requirements of parts 653 and 654 of this title (Federal Transit Administration alcohol and controlled substances testing regulations); or
  2. Who a State must waive from the requirements of Part 383 of this subchapter. These individuals include active duty military personnel; members of the reserves; and members of the national guard on active duty, including personnel on full-time national guard duty, personnel on part-time national guard training and national guard military technicians (civilians who are required to wear military uniforms), and active duty U.S. Coast Guard personnel; or
  3. Who a State has, at its discretion, exempted from the requirements of Part 383 of this subchapter. These individuals may be:
     - (i) Operators of a farm vehicle which is:
       - (A) Controlled and operated by a farmer;
       - (B) Used to transport either agricultural products, farm machinery, farm supplies, or both to or from a farm;
       - (C) Not used in the operations of a common or contract motor carrier; and
       - (D) Used within 241 kilometers (150 miles) of the farmer's farm.
     - (ii) Firefighters or other persons who operate commercial motor vehicles that are necessary for the preservation of life or property or the execution of emergency governmental functions, are equipped with audible and visual signals, and are not subject to normal traffic regulations.

✔ **Important Point:** A foreign resident driver operating between the U.S. and a foreign country from a U.S. terminal for a U.S.-based employer is subject to the FHWA alcohol and controlled substances testing regulations.

- **§382.105 Testing Procedures**—each employer must ensure that all alcohol or controlled substances testing conducted under this part complies with the procedures set forth in Part 40 of this title. The provisions of Part 40 of this title that address alcohol or controlled substances testing are made applicable to employers by this part.
- **§382.109 Preemption of State and local laws**.
  - (a) Except as provided in Paragraph (b) of this section, this part preempts any State or local law, rule, regulation, or order to the extent that:
    1. Compliance with both the State or local requirement and this part is not possible; or
    2. Compliance with the State or local requirement is an obstacle to the accomplishment and execution of any requirement in this part.
  - (b) This part can not be construed to preempt provisions of State criminal law that impose sanctions for reckless conduct leading to actual loss of life, injury, or damage to property, whether the provisions apply specifically to transportation employees, employers, or the general public.
- **§382.111 Other requirements imposed by employers**—Except as expressly provided in this part, nothing in this part is to be construed to affect the authority of employers, or the rights of drivers, with respect to the use of alcohol, or the use of controlled substances, including authority and rights with respect to testing and rehabilitation.
- **§382.113 Requirement for notice**—Before performing an alcohol or controlled substances test under this part, each employer must notify the driver that the alcohol or controlled substances test is required by this part. No employer is allowed to falsely represent that a test is administered under this part.

✔ **Important Point:** A driver must be notified before submitting to each test required by Part 382. This notification can be provided to the driver either verbally or in writing.

- **§382.115 Starting date for testing programs**.
  - (a) **All domestic employers.** Each domestic-domiciled employer that begins commercial motor vehicle operations is required to implement the requirements of this part on the date the employer begins such operations.
  - (b) **Large foreign employers.** Each foreign-domiciled employer with fifty or more drivers assigned to operate commercial motor vehicles in North America on December 17, 1995, is required to implement the requirements of this part beginning on July 1, 1996.
  - (c) **Small foreign employers.** Each foreign-domiciled employer with less than fifty drivers assigned to operate commercial motor vehicles in North America on December 17, 1995, must implement the requirements of this part beginning on July 1, 1997.
  - (d) **All foreign employers.** Each foreign-domiciled employer that begins commercial motor vehicle operations in the U.S. after December 17, 1995, but before July 1, 1997, must implement the requirements of this part beginning on July 1, 1997. A foreign employer that begins commercial motor vehicle operations in the U.S. on or after July 1, 1997, must implement the requirements of this part on the date the foreign employer begins such operations.

✔ **Important Note:** Any governmental entity, or a subunit of it that controls CMVs and the day-to-day operations of its drivers, may be considered the employer for purposes of Part 382. For example, a city government divided into various departments, such as parks and public works, could consider the departments as separate employers if the CMV operations are separately controlled. The city also has the option of deeming the city as the employer of all of the drivers of the various departments.

Subpart B—Prohibitions

- **§382.201 Alcohol concentration**—Drivers are strictly prohibited from reporting for duty or remaining on duty requiring the performance of safety-sensitive functions while having an alcohol concentration of 0.04 or greater. No employer having actual knowledge that a driver has an alcohol concentration of 0.04 or greater shall permit the driver to perform or continue to perform safety-sensitive functions.
- **§382.205 On-duty use**—No driver is allowed to use alcohol while performing safety-sensitive functions. No employer having actual knowledge [**Note:** The form of "actual knowledge" is not specified, but may result from the employer's direct observation of the employee, the driver's previous employer(s), the employee's admission of alcohol use, or other occurrence] that a driver is using alcohol while performing safety-sensitive functions shall permit the driver to perform or continue to perform safety-sensitive functions.
- **§382.207 Pre-duty use**—No driver is allowed to perform safety-sensitive functions within four (4) hours after using alcohol. No employer having actual knowledge that a driver has used alcohol within four (4) hours shall permit a driver to perform or continue to perform safety-sensitive functions.
- **§382.209 Use following an accident**—No driver required to take a post-accident alcohol test under §382.303 of this part shall use alcohol for eight (8) hours following the accident, or until he/she undergoes a post-accident alcohol test, whichever occurs first.
- **§382.211 Refusal to submit to a required alcohol or controlled substances test**—No driver shall refuse to submit to a post-accident alcohol or controlled substances test required under §382.303, a random alcohol or controlled substances test required under §382.305, a reasonable suspicion alcohol or controlled substances test required under §382.307, or a follow-up alcohol or controlled substances test required under §382.311. No employer shall permit a driver who refuses to such tests to perform or continue to perform safety-sensitive functions.
- **§382.213 Controlled substances use**.
  - (a) No driver shall report for duty or remain on duty requiring the performance of safety-sensitive functions when the driver uses any controlled substance, except when the use is pursuant to the instructions of a licensed medical practitioner, as defined in §382.107 of this part, who has advised the driver that the substance will not adversely affect the driver's ability to safely operate a CMV.
  - (b) No employer having actual knowledge that a driver has used a controlled substance shall permit the driver to perform or continue to perform a safety-sensitive function.
  - (c) An employer may require a driver to inform the employer of any therapeutic drug use.

✔ **Important Point:** A physician, and only a physician—not a pharmacist or anyone else—must specifically advise the driver that the substances in a prescription will not adversely affect the driver's ability to safely operate a CMV.

- **§382.215 Controlled substances testing**—No driver shall report for duty, remain on duty or perform a safety-sensitive function, if the driver tests positive for controlled substances. [**Note:** The Federal Highway Administration considers test results to be complete for the calendar year in which the MRO makes a final determination of the test results, regardless of the date the specimen was collected]. No employer having actual knowledge that a driver has tested positive for controlled substances shall permit the driver to perform or continue to perform safety-sensitive functions.

Subpart C—Tests Required

- **§382.301 Pre-employment Testing**
  - (a) Prior to the first time a driver performs safety-sensitive functions for an employer, the driver shall undergo testing for alcohol and controlled substances as a condition prior to being used, unless the employer uses the exception in paragraphs (c) and (d) of this section. No employer shall allow a driver, who the employer intends to hire or use, to perform safety-sensitive functions unless the driver has been administered an alcohol test with a result indicating an alcohol concentration less than 0.04, and has received a controlled substances test result from the Medical Review Officer (MRO) indicating a verified negative test result. If pre-employment alcohol test result under this section indicates an alcohol content of 0.02 or greater but less than 0.04, the provision of §382.505 shall apply.
  - (b) **Exception for pre-employment alcohol testing**—an employer is not required to administer an alcohol test required by Paragraph (a) of this section if:
    1. The driver has undergone an alcohol test required by this section or the alcohol misuse rule of another DOT agency under Part 40 of this title within the previous six months, with a result indicating an alcohol concentration less than 0.04; and
    2. The employer ensures that no prior employer of the driver of whom the employer has knowledge has records of a violation of this part or the alcohol misuse rule of another DOT agency within the previous six months.
  - (c) **Exception for pre-employment controlled substances testing**—an employer is not required to administer a controlled substances test required by Paragraph (a) of this section if:
    1. The driver has participated in a controlled substances testing program that meets the requirements of this part within the previous 30 days; and
    2. While participating in that program, either
       - (i) Was tested for controlled substances within the past six months (from the date of application with the employer) or
       - (ii) Participated in the random controlled substances testing program for the previous twelve months (from the date of application with the employer); and
    3. The employer ensures that no prior employer of the driver of whom the employer has knowledge has records of a violation of this part or the controlled substances use rule of another DOT agency within the previous six months.
  - (d) 1. An employer who exercises the exception in either Paragraph (b) or (c) of this section shall contact the alcohol and/or controlled substances testing program(s) in which the driver participates or participated and shall obtain and retain from the testing program(s) the following information:
       - (i) Name(s) and address(es) of the program(s).
       - (ii) Verification that the driver participates or participated in the program(s).
       - (iii) Verification that the program(s) conforms to Part 40 of this title.
       - (iv) Verification that the driver is qualified under the rules of this part, including that the driver has not refused to be tested for controlled substances.
       - (v) The date the driver was last tested for alcohol or controlled substances.
       - (vi) The results of any tests taken within the previous six months and any other violations of Subpart B of this part.
    2. An employer who uses, but does not employ [i.e., employs “trip lease” drivers involved in intestate commerce or this statement applies to volunteer organizations that use loaned drivers], a driver more than once a year to operate commercial motor vehicles must obtain the information in Paragraph (d)(1) of this section at least once every six months. The records prepared under this paragraph shall be maintained in accordance with §382.401. If the employer cannot verify that the driver is participating in a controlled substances testing program in accordance with this part and Part 40, the employer shall conduct a pre-employment alcohol and/or controlled substances test.
  - (e) Notwithstanding any other provisions of this subpart, all provisions and requirements in this section pertaining to pre-employment testing for alcohol are vacated as of May 1, 1995.
- **§382.303 Post-accident testing**
  - (a) As soon as practicable following an occurrence involving a commercial motor vehicle operating on a public road in commerce, each employer

shall test for alcohol and controlled substances each surviving driver:

1. Who was performing safety-sensitive functions with respect to the vehicle, if the accident involved the loss of human life; or
2. Who receives a citation under State or local law for a moving traffic violation arising from the accident, if the accident involved:
   - (i) Bodily injury to any person who, as a result of the injury, immediately receives medical treatment away from the scene of the accident; or
   - (ii) One or more motor vehicles incurring disabling damage as a result of the accident, requiring the motor vehicle to be transported away from the scene by a tow truck or other motor vehicle.

The Table notes when a post-accident test is required.

Requirements for a Post-Accident Test

Type of Accident Involved	*Citation issued to the CMV*	*Test must be performed by driver employer*
Human fatality	YES	YES
	NO	YES
Bodily injury with immediate medical treatment away from the scene.	YES	YES
	NO	NO
Disabling damage to any motor vehicle requiring tow away.	YES	YES
	NO	NO

(b) 1. **Alcohol tests**. If a test required by this section is not administered within two hours following the accident, the employer shall prepare and maintain on file a record stating the reasons the test was not promptly administered. If a test required by this section is not administered within eight hours following the accident, the employer shall cease attempts to administer an alcohol test and shall prepare and maintain the same record. Records shall be submitted to the FHWA upon request of the Associate Administer.

2. For the years stated in this paragraph, employers who submit MIS (Management Information System) reports shall submit to the FHWA each record of a test required by this section that is not completed within eight hours. The employer's records of tests that are not completed within eight hours shall be submitted to the FHWA by March 15, 1996; March 15, 1997, and March 15, 1998, for calendar years 1995, 1996, and 1997, respectively. Employers shall append these records to their MIS submissions. Each record shall include the following information:
   - (i) Type of test (reasonable suspicion/post-accident);
   - (ii) Triggering event (including date, time, and location);
   - (iii) Reason(s) test could not be completed within eight hours:
   - (iv) If blood alcohol testing could have been completed within eight hours, the name, address, and telephone number of the testing site where blood testing could have occurred; and

3. Records of alcohol tests that could not be completed in eight hours shall be submitted to the FHWA at the following address: Attn: Alcohol Testing Program, Office of Motor Carrier Research and Standards (HCS-1), Federal Highway Administration, 400 Seventh Street, SW., Washington, DC 20590.

4. **Controlled substances tests.** If a test required by this section is not administered within 32 hours following the accident, the employer shall cease attempts to administer controlled substances test, and prepare and maintain on file a record stating the reasons the test was not promptly administered. Records shall be submitted to the FHWA upon request upon request of the Associate Administrator.

(c) A driver who is subject to post-accident testing shall remain readily available for such testing or may be deemed by the employer to have refused to submit to testing. Nothing in this section shall be construed to require the delay of necessary medical attention for injured people following an accident or to prohibit a driver from leaving the scene of an accident for the period necessary to obtain assistance in responding to the accident, or to obtain necessary emergency medical care.

(d) An employer shall provide drivers with necessary post-accident information, procedures and instructions, prior to the driver operating a commercial motor vehicle, so that drivers will be able to comply with the requirements of this section.

(e) 1. The results of a breath or blood test for the use of alcohol, conducted by Federal, State, or local officials having independent authority for the test, shall be considered to meet the requirements of this section, provided such tests conform to the applicable Federal, State or local alcohol testing requirements, and that the results of the tests are obtained by the employer.

2. The results of a urine test for the use of controlled substances, conducted by Federal, State, or local officials having independent authority for the test, shall be considered to meet the requirements of this section, provided such tests conform to the applicable Federal, State or local controlled substances testing requirements, and that the results of the tests are obtained by the employer.

(f) **Exception**. This section does not apply to:

1. An occurrence involving only boarding or alighting from a stationary vehicle; or
2. An occurrence involving only the loading or unloading of cargo; or
3. An occurrence in the course of the operation of a passenger car or a multipurpose passenger vehicle by an employer unless the motor vehicle is transporting passengers for hire or hazardous materials of a type and quantity that require the motor vehicle to be marked or placarded in accordance with §177.823 of this title.

✔ **Important Note:** An employer may allow a driver, subject to post-accident controlled substances testing, to continue to drive pending receipt of the results of the controlled substances test, so long as no other restrictions are imposed by §382.307 or by law enforcement officials.

✔ **Important Note:** U.S. employers are responsible for ensuring that drivers who have an accident (as defined by §390.5) in a foreign country are post-accident alcohol and drug tested in conformance with the requirements of 49 CFR parts 40 and 382. If the test(s) cannot be administered within the required 8 or 32 hours, the employer shall prepare and maintain a record stating the reasons the test(s) was not administered.

- **§382.305 Random testing**

(a) Every employer shall comply with the requirements of this section. Every driver shall submit to random alcohol and controlled substance testing as required in this section.

(b) 1. Except as provided in paragraphs (c) through (e) of this section, the minimum annual percentage rate for random alcohol testing shall be 25 percent (10 percent for calendar year 1998) of the average number of driver positions.

2. Except as provided in paragraphs (f) through (h) of this section, the minimum annual percentage rate for random controlled substances testing shall be 50 percent of the average number of driver positions.

(c) The FHWA Administrator's decision to increase or decrease the minimum annual percentage rate for alcohol testing is based on the reported violation rate for the entire industry. All information used for this determination is drawn from the alcohol management information system reports required by §382.403 of this part. To ensure reliability of the data, the FHWA Administrator considers the quality and completeness of the reported data, may obtain additional information or reports from employers, and may make appropriate modifications in calculating the industry violation rate. Each year, the FHWA Administrator will publish in the *Federal Register* the minimum annual percentage rate for random alcohol testing of drivers (e.g., as pointed out earlier, the random testing rate was reduced to 10 percent for calendar year 1998). The new minimum annual percentage rate for random alcohol testing will be applicable starting January 1 of the calendar year following publication.

(d) 1. When the minimum annual percentage rate for random alcohol testing is 25 percent or more, the FHWA Administrator may lower this rate to 10 percent of all driver positions if the FHWA Administrator determines that the data received under the reporting requirements of §382.403 for two consecutive calendar years indicates that the violation rate is less than 0.5 percent.

2. When the minimum annual percentage rate for random alcohol testing is 50 percent, the FHWA Administrator may lower this rate to 25 percent of all driving positions if the FHWA Administrator determines that the data received under the reporting requirements of §382.403 for two consecutive calendar years indicate that the violation rate is less than 1.0 percent but equal to or greater than 0.5 percent.

(e) 1. When the minimum annual percentage rate for random alcohol testing is 10 percent, and the data received under the reporting requirements of §382.403 for that calendar year indicate that the violation rate is equal to or greater than 0.5 percent, but less than 1.0 percent, the FHWA Administrator will increase the minimum annual percentage rate for random alcohol testing to 25 percent for all driver positions.

2. When the minimum annual percentage rate for random alcohol testing is 25 percent or less, and the data received under the reporting requirements of §382.403 for that calendar year indicate that the violation rate is equal to or greater than 1.0 percent, the FHWA

Administrator will increase the minimum annual percentage rate for random alcohol testing to 50 percent testing for all driver positions.

(f) The FHWA Administrator's decision to increase or decrease the minimum annual percentage rate for controlled substances testing is based on the reported positive rate for the entire industry. All information used for this determination is drawn from the controlled substances management information system reports required by §382.403 of this part. To ensure reliability of the data, the FHWA Administrator considers the quality and completeness of the reported data, may obtain additional information or reports from employers, and may make appropriate modifications in calculating the industry positive rate. Each year, the FHWA Administrator will publish in the *Federal Register* the minimum annual percentage rate for random controlled substances testing of drivers. The new minimum annual percentage rate for random controlled substances testing will be applicable starting January 1 of the calendar year following publication.

(g) When the minimum annual percentage rate for random controlled substances testing is 50 percent, the FHWA Administrator may lower this rate to 25 percent of all driver positions if the FHWA Administrator determines that the data received under the reporting requirements of §382.403 for two consecutive calendar years indicate that the positive rate is less than 1.0 percent. However, after the initial two years of random testing by large employers and the initial first year of testing by small employers under this section, the FHWA Administrator may lower the rate the following calendar year, if the combined positive testing rate is less than 1.0 percent, and if it would be in the interest of safety.

(h) When the minimum annual percentage rate for random controlled substances testing is 25 percent, and the data received under the reporting requirements of §382.403 for any calendar year indicate that the reported positive rate is equal to or greater than 1.0 percent, the FHWA Administrator will increase the minimum annual percentage rate for random controlled substances testing to 50 percent of all driver positions.

(i) The selection of drivers for random alcohol and controlled substances testing shall be made by a scientifically valid method, such as a random number table or a computer-based random number generator that is matched with drivers' Social Security numbers, payroll identification numbers, or other comparable identifying numbers. Under the selection process used, each driver shall have an equal chance of being tested each time selections are made.

(j) The employer shall randomly select a sufficient number of drivers for testing during each calendar year to equal an annual rate not less than the minimum annual percentage rate for random alcohol and controlled substances testing determined by the FHWA Administrator. If the employer conducts random testing for alcohol and/or controlled substances through a consortium, the number of drivers to be tested may be calculated for each individual employer or may be based on the total number of drivers covered by the consortium who are subject to random alcohol and/or controlled substances testing at the same minimum annual percentage rate under this part or any DOT alcohol or controlled substances random testing rule.

(k) Each employer shall ensure that random alcohol and controlled substances tests conducted under this part are unannounced and that the dates for administering random alcohol and controlled substances tests are spread reasonably throughout the calendar year.

(l) Each employer shall require that each driver who is notified of selection for random alcohol and/or controlled substances testing proceeds to the test site immediately; provided, however, that if the driver is performing a safety-sensitive function other than driving a commercial motor vehicle at the time of notification, the employer shall instead ensure that the driver ceases to perform the safety-sensitive function and proceeds to the testing site as soon as possible.

(m) A driver shall only be tested for alcohol while the driver is performing safety-sensitive functions, or just after the driver has ceased performing such functions.

(n) If a given driver is subject to random alcohol or controlled substances testing under the random alcohol or controlled substances testing rules of more than one DOT agency for the same employer, the drive shall be subject to random alcohol and/or controlled substances testing at the annual percentage rate established for the calendar year by the DOT agency regulating more than 50 percent of the driver's functions.

(o) If an employer is required to conduct random alcohol or controlled substances testing under the alcohol or controlled substances testing rules of more than one DOT agency, the employer may—

1. Establish separate pools for random selection, with each pool containing the DOT-covered employees who are subject to testing at the

same required minimum annual percentage rate; or

2. Randomly select such employees for testing at the highest minimum annual percentage rate established for the calendar year by any DOT agency to which the employer is subject.

A driver must be about to perform, or immediately available to perform, a safety sensitive function to be considered subject to random alcohol testing. A supervisor, mechanic, or clerk, etc., who is on call to perform safety-sensitive functions may be tested at any time they are on call, ready to be dispatched while on-duty. For the employee who does not drive as part of the employee's usual job functions, but who holds a CDL and may be called upon at any time, on an occasional or emergency basis to drive, the employer's obligations, in terms of random testing, must ensure such an employee is included in the random testing pool, like a fulltime driver. A drug test must be administered each time the employee's name is selected from the pool. However, alcohol testing may only be conducted just before, during, or just after the performance of safety-sensitive functions. Once an employee is randomly tested during a calendar year, he or she must be returned to the pool for each new selection. Each driver must be subject to an equal chance of being tested during each selection process.

✔ **Important Point:** Driver positions that are vacant for a testing cycle are not to be included in the determination of how many random tests must be conducted.

✔ **Important Point:** When a driver works for two or more employers, the driver must be in the pool of each employer for which the driver works.

- **§382.307 Reasonable suspicion testing**
  (a) An employer shall require a driver to submit to an alcohol test when the employer has reasonable suspicion to believe that the driver has violated the prohibitions of Subpart B of this part concerning alcohol. The employer's determination that reasonable suspicion exists to require the driver to undergo an alcohol test must be based on specific, contemporaneous observations concerning the appearance, behavior, speech or body odors of the driver.
  (b) An employer shall require a driver to submit to a controlled substances test when the employer has reasonable suspicion to believe that the driver has violated the prohibitions of Subpart B of this part concerning controlled substances. The employer's determination that reasonable suspicion exists to require the driver to undergo a controlled substances test must be based on specific, contemporaneous, articulable observations concerning the appearance, behavior, speech or body odors of the driver. The observations may include indications of the chronic and withdrawal effects of controlled substances.
  (c) The required observations for alcohol and/or controlled substances reasonable suspicion testing shall be made by a supervisor or company official who is trained in accordance with §382.603 of this part. The person who makes the determination that reasonable suspicion exists to conduct an alcohol test shall not conduct the alcohol test of the driver.
  (d) Alcohol testing is authorized by this section only if the observations required by Paragraph (a) of this section are made during, just preceding, or just after the period of the work day that the driver is required to be in compliance with this part. A driver may be directed by the employer to only undergo reasonable suspicion testing while the driver is performing safety-sensitive functions, just before the driver is to perform safety-sensitive functions, or just after the driver has ceased performing such functions.
  (e) 1. If an alcohol test required by this section is not administered within two hours following the determination under Paragraph (a) of this section, the employer shall prepare and maintain on file a record stating the reasons the alcohol test was not promptly administered. If an alcohol test required by this section is not administered within eight hours following the determination under Paragraph (a) of this section, the employer shall cease attempts to administer an alcohol test and shall state in the record the reasons for not administering the test.
    2. For the years stated in this paragraph, employers who submit MIS reports shall submit to the FHWA each record of a test required by this section that is not completed within eight hours. The employer's records of tests that could not be completed within eight hours shall be submitted to the FHWA by March 15, 1996; March 15, 1997; and March 15, 1998; for calendar years 1995, 1996, and 1997, respectively. Employers shall append these records to their MIS submissions. Each record shall include the following information:
      (i) Type of test (reasonable suspicion/post accident);
      (ii) Triggering event (including date, time, and location);
      (iii) Reason(s) test could not be completed within eight hours; and

(iv) If blood alcohol testing could have been completed within eight hours, the name, address, and telephone number of the testing site where blood testing could have occurred.

3.˜Records of tests that could not be completed in eight hours shall be submitted to the FHWA at the following address: Attn.: Alcohol Testing program, Office of Motor carrier Research and Standards (HCS-1), Federal Highway Administration, 400 Seventh Street, SW., Washington, DC 20590.

4. Notwithstanding the absence of a reasonable suspicion alcohol test under this section, no driver shall report for duty or remain on duty requiring the performance of safety-sensitive functions while the driver is under the influence of or impaired by alcohol, as shown by the behavioral, speech, and performance indicators of alcohol misuse, nor shall an employer permit the driver to perform or continue to perform safety-sensitive functions, until:
   (i) An alcohol test is administered and the driver's alcohol concentration measures less than 0.02; or
   (ii) Twenty four hours have elapsed following the determination under Paragraph (a) of this section that there is reasonable suspicion to believe that the driver has violated the prohibitions in this part concerning the use of alcohol.

5. Except as provided in Paragraph (e)(2) of this section, no employer shall take any action under this part against a driver based solely on the driver's behavior and appearance, with respect to alcohol use, in the absence of an alcohol test. This does not prohibit an employer with independent authority of this part from taking any action otherwise consistent with law.

(f) A written record shall be made of the observations leading to a controlled substance reasonable suspicion test, and signed by the supervisor or company official who made the observations, within 24 hours of the observed behavior or before the results of the controlled substances test are released, whichever is earlier.

A reasonable suspicion alcohol test can't be based upon any information or observations of alcohol use or possession, other than a supervisor's actual knowledge. In other words, information conveyed by third parties of a driver's alcohol use may not be the only determining factor used to conduct a reasonable suspicion test. Only a trained supervisor may conduct a reasonable suspicion test based on observed specific, contemporaneous, articulable appearance. Alcohol is generally a legal substance, thus only its use or presence in sufficient concentrations while operating a CMV is a violation of FHWA regulation. Alcohol withdrawal effects, standing alone, do not indicate that a driver has used alcohol in violation of the regulations, and would not constitute reasonable suspicion to believe so.

✔ **Important Point:** The requirements of §§382.307 and 382.603 are not applicable to owner-operators in non-supervisory positions.

- **§382.309 Return-to-duty testing**
  (a) Each employer shall ensure that before a driver returns to duty requiring the performance of a safety-sensitive function after engaging in conduct prohibited by Subpart B of this part concerning alcohol, the driver shall undergo a return-to-duty alcohol test with a result indicating an alcohol concentration of less than 0.02.
  (b) Each employer shall ensure that before a driver returns to duty requiring the performance of a safety-sensitive function after engaging in the conduct prohibited by Subpart B of this part concerning controlled substances, the driver shall undergo a return-to-duty controlled substances test with a result indicating a verified negative result for controlled substances use.
- **§382.311 Follow-up testing**
  (a) Following a determination under §382.605(b) that a driver is in need of assistance in resolving problems associated with alcohol misuse and/or use of controlled substances, each employer shall ensure that the driver is subject to unannounced follow-up alcohol and/or controlled substances testing as directed by a substance abuse professional in accordance with the provisions of §382.605(c)(2)(ii).
  (b) Follow-up alcohol testing shall be conducted only when the driver is performing safety-sensitive functions, just before the driver is to perform safety-sensitive functions, or just after the driver has ceased performing safety-sensitive functions.

Subpart D—Handling of Test Results, Record Retention and Confidentiality

- **§382.401 Retention of Records**
  (a) **General requirements**. Each employer shall maintain records of its alcohol misuse and controlled substances use prevention programs as provided in this section. The records shall be maintained in a secure location with controlled access.

(b) **Period of retention.** Each employer shall maintain the records in accordance with the following schedule:
1. **Five years.** The following records shall be maintained for a minimum of five years:
   - (i) Records of driver alcohol test results indicating an alcohol concentration of 0.02 or greater.
   - (ii) Records of driver verified positive controlled substances test results.
   - (iii) Documentation of refusals to take required alcohol and/or controlled substances tests,
   - (iv) Driver evaluation and referrals,
   - (v) Calibration documentation.
   - (vi) Records related to the administration of the alcohol and controlled substances testing programs, and
   - (vii) A copy of each annual calendar year summary required by §382.403.
2. **Two years.** Records related to the alcohol and controlled substances collection process (except calibration of evidential breath testing devices).
3. **One year.** Records of negative and canceled controlled substances test results (as defined in Part 40 of this title) and alcohol test results with a concentration of less than 0.02 shall be maintained for a minimum of one year.
4. **Indefinite period.** Records related to the education and training of breath alcohol technicians, screening test technicians, supervisors, and drivers shall be maintained by the employer while the individual performs the functions that require the training and for two years after ceasing to perform those functions.

(c) **Types of records.** The following specific types of records shall be maintained. “Documents generated” are documents that may have to be prepared under a requirement of this part. If the record is required to be prepared, it must be maintained.
1. Records related to the collection process:
   - (i) Collection logbooks, if used;
   - (ii) Documents relating to the random selection process;
   - (iii) Calibration documentation for evidential breath testing devices;
   - (iv) Documentation of breath alcohol technician training;
   - (v) Documents generated in connection with decisions to administer reasonable suspicion alcohol or controlled substances tests;
   - (vi) Documents generated in connection with decisions on post-accident tests;
   - (vii) Documents verifying existence of a medical explanation of the inability of a driver to provide adequate breath or to provide a urine specimen for testing; and
   - (viii) Consolidated annual calendar year summaries as required by §382.403.
2. Records related to a driver’s test results:
   - (i) The employer’s copy of the alcohol test form, including the results of the test;
   - (ii) The employer’s copy of the controlled substances test chain of custody and control form;
   - (iii) Documents sent by the MRO to the employer, including those required by §382.407(a).
   - (iv) Documents related to the refusal of any driver to submit to an alcohol or controlled substances test required by this part; and
   - (v) Documents presented by a driver to dispute the result of an alcohol or controlled substances test administered under this part.
   - (vi) Documents generated in connection with verifications of prior employers’ alcohol or controlled substances test results that the employer;
     - (A) Must obtain in connection with the exception contained in §382.301 of this part, and
     - (B) Records related to other violations of this part.
4. Records related to evaluations:
   - (i) Records pertaining to a determination by a substance abuse professional concerning a driver’s need for assistance; and
   - (ii) Records concerning a driver’s compliance with recommendations of the substance abuse professional.
5. Records related to education and training:
   - (i) Materials on alcohol misuse and controlled substance use awareness, including a copy of the employer’s policy on alcohol misuse and controlled substance use;
   - (ii) Documentation of compliance with the requirements of §382.601, including the driver’s signal receipt of education materials;
   - (iii) Documentation of training provided to supervisors for the purpose of qualifying the supervisors to make a determination concerning the need for alcohol and/or controlled substances testing based on reasonable suspicion;

    - (iv) documentation of training for breath alcohol technicians as required by §40.51(a) of this title, and
    - (v) Certification that any training conducted under this part complies with the requirements for such training.
  6. Administrative records related to alcohol and controlled substances testing:
    - (i) Agreements with collection site facilities, laboratories, breath alcohol technicians, screening test technicians, medical review officers, consortia, and third party service providers;
    - (ii) Names and positions of officials and their role in the employer's alcohol and controlled substances testing program(s);
    - (iii) Quarterly laboratory statistical summaries of urinalysis required by §40.29(g)(6) of this title; and
    - (iv) The employer's alcohol and controlled substances testing policy and procedures.
- (d) **Location of records.** All records required by this part shall be maintained as required by §390.31 of this subchapter and shall be made available for inspection at the employer's principal place of business within two business days after a request has been made by an authorized representative of the Federal Highway Administration.

(e) 1. **OMB control number.** The information collection requirements of this part have been reviewed by the Office of Management and Budget pursuant to the Paperwork Reduction Act of 1995 and have been assigned OMB control number 2125-0543.

✔ **Important Point:** Employers may use agents to maintain records, as long as they are in a secure location with controlled access. The employer must also make all records available for inspection at the employer's principal place of business within two business days after an FHWA representative has made a request.

- **§382.403 Reporting of results in a management information system**
  - (a) An employer shall prepare and maintain a summary of the results of its alcohol and controlled substances testing programs performed under this part during the previous calendar year, when requested by the Secretary of Transportation, any DOT agency, or any State or local officials with regulatory authority over the employer or any of its drivers.
  - (b) If an employer is notified, during the month of January, of a request by the Federal Highway Administration to report the employer's annual calendar year summary information, the employer shall prepare and submit the report to the Federal Highway Administration by March 15 of that year. The employer shall ensure that the annual summary report is accurate and received by March 15 at the location that the Federal Highway Administration specifies in its request. The report shall be in the form and manner prescribed by the Federal Highway Administration in its request. When the report is submitted to the Federal Highway Administration by mail or electronic transmission, the information requested shall be typed, except for the signature of the certifying official. Each employer shall ensure the accuracy and timeliness of each report submitted by the employer or a consortium.
  - (c) **Detailed summary**. Each annual calendar year summary that contains information on a verified positive controlled substances test result, an alcohol screening test result of 0.02 or greater, or any other violation of the alcohol misuse provisions of Subpart B of this part shall include the following informational elements:

1. Number of drivers subject to Part 382;
2. Number of drivers subject to testing under the alcohol misuse or controlled substances use rules of more than one DOT agency, identified by each agency;
3. Number of urine specimens collected by type of test (e.g., pre-employment, random, reasonable suspicion, post-accident);
4. Number of positives verified by a MRO by type of test, and type of controlled substance;
5. Number of negative controlled substance tests verified by a MRO by type of test;
6. Number of persons denied a position as a driver following a pre-employment verified positive controlled substances test and/or a pre-employment alcohol test that indicates an alcohol concentration of 0.04 or greater;
7. Number of drivers with tests verified positive by a medical review officer for multiple controlled substances;
8. Number of drivers who refused to submit to an alcohol or controlled substances test required under this subpart;
9. (i) Number of supervisors who have received required alcohol training during the reporting period; and
   (ii) Number of supervisors who have received required controlled substances training during the reporting period;
10. (i) Number of screening alcohol tests by type of test; and
    (ii) Number of confirmation alcohol tests, by type of test;

11. Number of confirmation alcohol tests indicating an alcohol concentration of 0.02 or greater but less than 0.04, by type of test;
12. Number of confirmation alcohol tests indicating an alcohol concentration of 0.04 or greater, by type of test;
13. Number of drivers who were returned to duty (having complied with the recommendations of a substance abuse professional as described in §382.503 and §382.605), in this reporting period, who previously:
    - (i) Had a verified positive controlled substance test result, or
    - (ii) Engaged in prohibited alcohol misuse under the provisions of this part;
14. Number of drivers who were administered alcohol and drug tests at the same time, with both a verified positive drug test result and an alcohol test result indicating an alcohol concentration of 0.04 or greater; and
15. Number of drivers who were found to have violated any non-testing prohibitions of Subpart B of this part, and any action taken in response to the violation.

(d) **Short summary.** Each employer's annual calendar year summary that contains only negative controlled substance test results, alcohol screening test results of less than 0.02, and does not contain any other violations of Subpart B of this part, may prepare and submit, as required by Paragraph (b) of this section, either a standard report form containing all the information elements specified in Paragraph (c) of this section, or an "EZ" report form. The "EZ" report shall include the following information elements:

1. Number of drivers subject to this Part 382;
2. Number of drivers subject to testing under the alcohol misuse or controlled substance use rules of more than one DOT agency, identified by each agency;
3. Number of urine specimens collected by type of test (pre-employment, random, reasonable suspicion, post-accident);
4. Number of negatives verified by a medical review officer by type of test;
5. Number of drivers who refused to submit to an alcohol or controlled substances test required under this subpart;
6. (i) Number of supervisors who have received required alcohol training during the reporting period; and
    - (ii) Number of supervisors who have received required controlled substances training during the reporting period;
7. Number of screen alcohol tests by type of test; and
8. Number of drivers who were returned to duty (having complied with the recommendations of a substance abuse professional as described in §§382.503 and 382.605), in this reporting period, who previously:
    - (i) Had a verified positive controlled substance test result, or
    - (ii) Engaged in prohibited alcohol misuse under the provisions of this part.

(e) Each employer that is subject to more than one DOT agency alcohol or controlled substances rule shall identify each driver covered by the regulations of more than one DOT agency. The identification will be by the total number of covered functions. Prior to conducting any alcohol or controlled substances test on a driver subject to the rules of more than one DOT agency, the employer shall determine which DOT agency rule or rules authorizes or requires the test. The test result information shall be directed to the appropriate DOT agency or agencies.

(f) A consortium may prepare annual calendar year summaries and reports on behalf of individual employers for purposes of compliance with this section. However, each employer shall sign and submit such a report and shall remain responsible for ensuring the accuracy and timeliness of each report prepared on its behalf by a consortium.

- **§382.405 Access to facilities and records**

(a) Except as required by law (i.e., federal statutes or an order of a competent Federal jurisdiction, such as an administrative subpoena) or expressly authorized or required in this section, no employer shall release driver information that is contained in records required to be maintained under §382.401.

(b) A driver is entitled, upon written request, to obtain copies of any records pertaining to the driver's use of alcohol or controlled substances, including any records pertaining to his or her alcohol or controlled substances tests. The employer shall promptly provide the records requested by the driver. Access to a driver's records shall not be contingent upon payment for records other than those specifically requested.

(c) Each employer shall permit access to all facilities utilized in complying with the requirements of this part to the Secretary of transportation, any DOT agency, or any State or local officials with regulatory authority over the employer or any of its drivers.

(d) Each employer shall make available copies of all results for employer alcohol and/or controlled substances testing conducted under this part and any other information pertaining to the employer's alcohol misuse and/or controlled substances use prevention program, when requested by the Secretary of transportation, any DOT agency, or any State or local officials with regularity authority over the employer or any of its drivers.

(e) When requested by the National Transportation Safety Board as part of an accident investigation, employers shall disclose information related to the employer's administration of a post-accident alcohol and/or controlled substance test administered following the accident under investigation.

(f) Records shall be made available to a subsequent employer upon receipt of a written request from a driver. Disclosure by the subsequent employer is permitted only as expressly authorized by the terms of the driver's request.

(g) An employer may disclose information required to be maintained under this part pertaining to a driver, the decision-maker in a lawsuit, grievance, or other proceeding initiated by or on behalf of the individual, and arising from the results of an alcohol and/or controlled substance test administered under this part, or from the employer's determination that the driver engaged in conduct prohibited by Subpart B of this part (including, but not limited to, a worker's compensation, unemployment compensation, or other proceeding relating to a benefit sought by the driver).

(h) An employer shall release information regarding a driver's records as directed by the specific, written consent of the driver authorizing release of the information to an identified person. Release of such information by the person reviewing the information is permitted only in accordance with the terms of the employee's consent.

✔ **Important Point:** Employers who are subject to other Federal agencies' regulations, such as the Nuclear Regulatory Commission, Department of Energy, Department of Defense, etc., may allow those agencies access to view or have access to test records required to be prepared and maintained by parts 40 and/or 382 only when a specific, contemporaneous authorization for release of the test records is allowed by the driver.

A motor carrier must respond to a third-party request (as directed by the specific, written consent of the driver authorizing release of the information on behalf of an entity such as a motor carrier) to release driver information that is contained in records required to be maintained under §382.401. However, the third-party administrator must comply with the conditions established concerning confidentiality, test results, and record keeping as stipulated in the "Notice: Guidance on the role of Consortia and Third-Party Administrators in DOT Drug and Alcohol Testing Programs. An employer (motor carrier) may disclose information required to be maintained under 49 CFR Part 382 (pertaining to the driver) to the driver or the decision maker in a lawsuit, grievance, or other proceeding (including, but not limited to, worker's compensation, unemployment compensation) initiated by or on behalf of the driver concerning prohibited conduct under 49 CFR Part 382.

Also an employer (motor carrier) may be required to provide the test result information pursuant to other Federal statues or an order of a competent federal jurisdiction, such as an administrative subpoena, as allowed by §382.405(a) without the driver's written consent.

- **§382.407 Medical review officer notifications to the employer.**
  (a) The medical review officer may report to the employer using any communications device, but in all instances a signed, written notification must be forwarded within three business days of completion of the medical review officer's review, pursuant to Part 40 of this title. A legible photocopy of the fourth copy of Part 40 Appendix A subtitled COPY 4—SEND DIRECTLY TO MEDICAL REVIEW OFFICER—DO NOT SEND TO LABORATORY of the *Federal Custody and Control Form OMB Number 9999-0023* may be used to make the signed, written notification to the employer for all test results (positive, negative, canceled, etc.), provided that the controlled substance(s) verified as positive, and the MRO's signature, shall be legibly noted in the remarks section of step 8 of the form completed by the medical review officer. The MRO must sign all verified positive test results. An MRO may sign or rubber-stamp negative test results. An MRO's staff may rubber-stamp negative test results under written authorization of the MRO. In no event shall an MRO, or his/her staff, use electronic signature technology to comply with this section. All reports, both oral and in writing, from the medical review officer to an employer shall clearly include:
    1. A statement that the controlled substances test being reported was in accordance with Part 40 of this title and this part, except for legible photocopies of Copy 4 of the Federal Custody and Control Form;
    2. The full name of the driver for whom the test results are being reported;
    3. The type of test indicated on the custody and control form (i.e., random, post-accident, follow-up);
    4. The date and location of the test collection;
    5. The identities of the persons or entities performing the collection, analyzing the

specimens, and serving as the medical review officer for the specific test;

6. The results of the controlled substances test, positive, negative, test canceled, or test not performed, and if positive, the identity of the controlled substance(s) for which the test was verified positive.

(b) A medical review officer shall report to the employer that the medical review officer has made all reasonable efforts to contact the driver as provided in §40.33(c) of this title. The employer shall, as soon as practicable, request that the driver contacts the medical review officer prior to dispatching the driver or within 24 hours, whichever is earlier.

- **§382.409 Medical review officer record retention for controlled substances**

(a) A medical review officer shall maintain all dated records and notifications, identified by individual, for a minimum of five years for verified positive controlled substances test results.

(b) A medical review officer shall maintain all dated records and notifications, identified by individual, for a minimum of one year for negative and canceled controlled substances test results.

(c) No person may obtain the individual controlled substances test results retained by a medical review officer, and no medical review officer shall release the individual controlled substances test results of any driver to any person, without first obtaining a specific, written authorization from the tested driver. Nothing in this authorization shall prohibit a medical review officer from releasing, to the employer or to officials of the Secretary of Transportation, and DOT agency, or any State or local officials with regulatory authority over the controlled substances testing program under this part, the information delineated in §382.407(a) of this subpart.

- **§382.411 Employer notifications**

(a) An employer shall notify a driver of the results of a pre-employment controlled substance test conducted under this part, if the driver requests such results within sixty calendar days of being notified of the disposition of the employment application. An employer shall notify a driver of the results of random, reasonable suspicion and post-accident tests for controlled substances conducted under this part if the test results are verified positive. The employer shall also inform the driver which controlled substance or substances were verified as positive.

(b) The designated management official shall make reasonable efforts to contact and request each driver who submitted a specimen under the employer's program, regardless of the driver's employment status, to contact and discuss the results of the controlled substances test with a medical review officer who has been unable to contact the driver.

(c) The designated management official shall immediately notify the medical review officer that the driver has been notified to contact the medical review officer within 24 hours.

- **§382.413 Inquiries for alcohol and controlled substances information from previous employers**

(a) 1. An Employer shall, pursuant to the driver's written authorization, inquire about the following information on a driver from the driver's previous employers, during the preceding two years from the date of application, which are maintained by the driver's previous employers under §382.401(b)(1)(i) through (iii) of this subpart:

  (i) Alcohol tests with a result of 0.04 alcohol concentration or greater;

  (ii) Verified positive controlled substances test results; and

  (iii) Refusals to be tested.

2. The information obtained from a previous employer may contain any alcohol and drug information the previous employer obtained from other previous employers under Paragraph (a)(1) of this section.

(b) If feasible, the information in Paragraph (a) of this section must be obtained and reviewed by the employer prior to the first time a driver performs safety-sensitive functions for the employer. If not feasible, the information must be obtained and reviewed as soon as possible, but no later than fourteen-calendar days after the first time a driver performs safety-sensitive functions for the employer. An employer may not permit a driver to perform safety-sensitive functions after fourteen days without having made a good faith effort to obtain the information as soon as possible. If a driver hired or used by the employer ceases performing safety-sensitive functions for the employer before expiration of the fourteen-day period or before the employer has obtained the information in Paragraph (a) of this section, the employer must still make a good faith effort to obtain this information.

(c) An employer must maintain a written, confidential record of the information obtained under Paragraph (a) or (f) of this section. If, after making a good faith effort, an employer is unable to obtain the information from a previous employer, a record must be made of the efforts to obtain the information and retained in the driver's qualification file.

(d) The prospective employer must provide to each of the driver's previous employers the driver's specific, written authorization for release of the information in Paragraph (a) of this section.
(e) The release of any information under this section may take the form of personal interviews, telephone interviews, letters, or any other method of transmitting information that ensures confidentiality.
(f) The information in Paragraph (a) of this section may be provided directly to the prospective employer by the driver, provided the employer assures itself that the information is true and accurate.
(g) An employer may not use a driver to perform safety-sensitive functions if the employer obtains information on a violation of the prohibitions in Subpart B of this part by the driver, without obtaining information on subsequent compliance with the referral and rehabilitation requirements of §382.605 of this part.
(h) Employers need not obtain information under Paragraph (a) of this section generated by previous employers prior to the starting dates in §382.115 of this part.

✔ **Important Point:** If a previous employer refuses to make a driver's records available, in violation of §382.405, pursuant to the new employer's and driver's request, the new employer should note the attempt to obtain the information and place the note with the driver's other testing information.

Subpart E—Consequences for Drivers Engaging In Substance Use-Related Conduct

- **§382.501 Removal from safety-sensitive function**
  (a) Except as provided in Subpart F of this part, no driver shall perform safety-sensitive functions, including driving a commercial motor vehicle, if the driver has engaged in conduct prohibited by Subpart B of this part or an alcohol or controlled substances rule of another DOT agency.
  (b) No employer shall permit any driver to perform safety-sensitive functions, including driving a commercial motor vehicle, if the employer has determined that the driver has violated this section.
  (c) For purposes of this subpart, commercial motor vehicle means a commercial motor vehicle in commerce as defined in §382.107, and a commercial motor vehicle in interstate commerce as defined in Part 390 of this subchapter.

✔ **Important Point:** If a driver violates the prohibitions in Subpart B, he/she is prohibited from performing safety-sensitive functions. However, a driver who has violated the prohibitions of Subpart B may perform any duties for an employer that are not considered "safety-sensitive functions."

- **§382.503 Required evaluation and testing**
  No driver who has engaged in conduct prohibited by Subpart B of this part shall perform safety-sensitive functions, including driving a commercial motor vehicle, unless the driver has met the requirements of §382.605. No employer shall permit a driver who has engaged in conduct prohibited by Subpart B of this part to perform safety-sensitive functions, including driving a commercial motor vehicle, unless the driver has met the requirements of §382.605.
- **§382.505 Other alcohol-related conduct**
  (a) No driver tested under the provisions of Subpart C of this part who is found of have an alcohol concentration of 0.02 or greater but less than 0.04 shall perform or continue to perform safety-sensitive functions for an employer, including driving a commercial motor vehicle, nor shall an employer permit the driver to perform or continue to perform safety-sensitive functions, until the start of the driver's next regularly scheduled duty period, but not less than twenty-four hours following administration of the test.
  (b) Except as provided in Paragraph (a) of this section, no employer shall take any action under this part against a driver based solely on test results shown an alcohol concentration less than 0.04. This does not prohibit an employer with authority independent of this part from taking any action otherwise consistent with law.
- **§382.507 Penalties**
  Any employer or driver who violates the requirements of this part shall be subject to the penalty provisions of 49 U.S.C. Section 521(b).

✔ **Important Point:** Title 49 U.S.C. 521(b)(2)(A) provides for civil penalties not to exceed $500 for each instance of refusing or failing of provide the information required by §382.405. Criminal penalties may also be imposed under 49 U.S.C. 521(b)(6).

Subpart F—Alcohol Misuse and Controlled Substances Use Information, Training, and Referral

- **§382.601 Employer obligation to promulgate a policy on the misuse of alcohol and use of controlled substances**
  (a) **General requirements**. Each employer shall provide educational materials that explain the requirements of this part and the employer's policies and procedures with respect to meeting these requirements.

1. The employer shall ensure that a copy of these materials is distributed to each driver prior to the start of alcohol and controlled substances testing under this part and to each driver subsequently hired or transferred into a position requiring driving a commercial motor vehicle.
2. Each employer shall provide written notice to representatives of employee organizations of the availability of this information.

(b) **Required content.** The materials to be made available to drivers shall include detailed discussion of at least the following:

1. The identity of the person designated by the employer to answer driver questions about the materials;
2. The categories of drivers who are subject to the provisions of this part;
3. Sufficient information about the safety-sensitive functions performed by those drivers to make clear what period of the workday the driver is required to comply with this part.
4. Specific information concerning driver conduct that is prohibited by this part;
5. The circumstances under which a driver will be tested for alcohol and/or controlled substances under this part, including post-accident testing under §382.303(d);
6. The procedures that will be used to test for the presence of alcohol and controlled substances, protect the driver and the integrity of the testing processes, safeguard the validity of the test results, and ensure that those results are attributed to the correct driver, including post-accident information, procedures and instructions required by §382.303(d) of this part;
7. The requirement that a driver submit to alcohol and controlled substances tests administered in accordance with this part;
8. An explanation of what constitutes a refusal to submit to an alcohol or controlled substances test and the attendant consequences;
9. The consequences for drivers found to have violated Subpart B of this part, including the requirement that the driver be removed immediately from safety-sensitive functions, and the procedures under §382.605;
10. The consequences for drivers found to have an alcohol concentration of 0.02 or greater but less than 0.04;
11. Information concerning the effects of alcohol and controlled substances use on an individual's health, work, and personal life; signs and symptoms of an alcohol or a controlled substances problem (the driver's or a coworker's); and available methods of intervening when an alcohol or a controlled substances problem is suspected, including confrontation, referral to any employee assistance program and or referral to management.

(c) **Optional provision.** The materials supplied to drivers may also include information on additional employer policies with respect to the use of alcohol or controlled substances, including any consequences for a driver found to have a specified alcohol or controlled substances level, that are based on the employer's authority independent of this part. Any such additional policies or consequences must be clearly and obviously described as being based on independent authority.

(d) **Certificate of receipt.** Each employer shall ensure that each driver is required to sign a statement certifying that he or she has received a copy of these materials described in this section. Each employer shall maintain the original of the signed certificate and may provide a copy of the certificate to the driver.

Because the employer is responsible, the employer would be in violation if using a driver who refuses to comply with §382.601 to perform any safety sensitive function, if a driver refuses to sign a statement certifying that he/she has received a copy of the educational materials required in §382.601. However, the employee would not be in violation if he or she drove without signing for the receipt of the policy.

- **§382.603 Training for supervisors**.
  Each employer shall ensure that all persons designated to supervise drivers receive at least 60 minutes of training on alcohol misuse and receive at least an additional 60 minutes of training on controlled substances use. The training will be used by the supervisors to determine whether reasonable suspicion exists to require a driver to undergo testing under §382.307. The training shall include the physical, behavioral, speech, and performance indicators of probable alcohol misuse and use of controlled substances.

✔ **Important Point:** §382.603 does not require employers to provide recurrent training to supervisory personnel.

✔ **Important Point:** An employer may accept proof of supervisory training from a supervisor for another employer.

- **§382.605 Referral, evaluation, and treatment.**
  - (a) Each driver who has engaged in conduct prohibited by Subpart B of this part shall be advised by the employer of the resources available to the driver in evaluating and resolving problems associated with the misuse of alcohol and use of controlled substances, including the names, addresses, and telephone numbers of substance abuse professionals (SAPs) and counseling and treatment programs.
  - (b) Each driver who engages in conduct prohibited by Subpart B of this part shall be evaluated by a SAP who shall determine what assistance, if any, the employee needs in resolving problems associated with alcohol misuse and controlled substance use. [**Note:** The DOT rules define the SAP to be a licensed physician (medical doctor or doctor of osteopathy), a licensed or certified psychologist, a licensed or certified social worker, or a licensed or certified employee assistance professional. DOT does not certify the SAP, but expects the SAP to have knowledge of and clinical experience in the diagnosis and treatment of substances abuse-related disorders (the degrees and certificates alone do not confer this knowledge). Alcohol and drug abuse counselors certified by the National Association of Alcoholism and Drug Abuse Counselors Certification Commission, a national organization that imposes qualification standards for treatment of alcohol-related disorders, are included in the SAP definition].
  - (c) 1. Before a driver returns to duty requiring the performance of a safety-sensitive function after engaging in conduct prohibited by Subpart B of this part, the driver shall undergo a return-to-duty alcohol test with a result indicating an alcohol concentration of less than 0.02 if the conduct involved alcohol, or a controlled substance.
    2. In addition, each driver identified as needing assistance in resolving problems associated with alcohol misuse or controlled substances use.
       - (i) Shall be evaluated by a SAP abuse professional to determine that the driver has properly followed any rehabilitation program prescribed under Paragraph (b) of this section, and
       - (ii) Shall be subject to unannounced follow-up alcohol and controlled substances tests administered by the employer following the driver's return to duty. The number and frequency of such follow-up testing shall be as directed by the substance abuse professional, and must consist of at least six tests in the first twelve months following the driver's return to duty. The employer may direct the driver to undergo return-to-duty and follow-up testing for both alcohol and controlled substances, if the SAP determines that return-to-duty and follow-up testing for both alcohol and controlled substances is necessary for that particular driver. Any such testing shall be performed in accordance with the requirements of 49 CFR 40. Follow-up testing shall not exceed sixty months from the date of the driver's return to duty. The SAP may terminate the requirement for follow-up testing at any time after the first six tests have been administered, if the SAP determines that such testing is no longer necessary.
  - (d) Evaluation and rehabilitation may be provided by the employer, by a SAP under contract with the employer, or by a SAP not affiliated with the employer. The choice of substance abuse professional and assignment of costs shall be made in accordance with employer/driver agreements and employer policies.
  - (e) The employer shall ensure that a SAP who determines that a driver requires assistance in resolving problems with alcohol misuse or controlled substances use does not refer the driver to the substance abuse professional's private practice or to a person or organization from which the SAP receives remuneration or in which the SAP has a financial interest. This paragraph does not prohibit a substance abuse professional from referring a driver for assistance provide through—
    1. A public agency, such as a State, county, or municipality;
    2. The employer or a person under contract to provide treatment for alcohol or controlled substance problems on behalf of the employer;
    3. The sole source of therapeutically appropriate treatment under the driver's health insurance program; or
    4. The sole source of therapeutically appropriate treatment reasonably assessable to the driver.
  - (f) The requirements of this section with respect to referral, evaluation and rehabilitation do not apply to applicants who refuse to submit to a

pre-employment alcohol or controlled substances test or who have a pre-employment alcohol test with a result indicating an alcohol concentration of 0.04 or greater or a controlled substances test with a verified positive test result.

✔ **Important Point:** Both the initial and follow-up SAP evaluations are clinical processes that must be conducted face-to-face.

An employer who wants to continue to use or hire a driver who has violated the prohibitions in Subpart B in the past must ensure that a driver has complied with any SAP's recommended treatment prior to the driver returning to safety-sensitive functions. However, employers must only refer to an SAP drivers who have tested positive for controlled substances, tested positive for 0.04 or greater alcohol concentration, or have violated other prohibitions in Subpart B.

When an employer discharges an employee, the employer has no further obligation other than to provide a list of resources for evaluation and treatment numbers of SAPs and counseling and treatment programs to the employee. Self-help groups and community lectures qualify as education, but do not qualify as treatment. An employee who has violated the rules is prohibited ffrom performing any DOT safety-sensitive function until being evaluated by the SAP.

✔ **Important Point:** An employer can't overrule an SAP treatment recommendation.

An employer is not obligated to return an employee to safety-sensitive duty following the SAP's finding during the follow-up evaluation that the employee has demonstrated successful compliance with the treatment recommendation. The SAP's findings and successful compliance with prescribed treatment and testing negative on the return-to-duty alcohol test and/or drug test are preconditions only. The employee must meet them to be considered for hiring or reinstatement to safety-sensitive duties by an employer.

✔ **Important Point:** The DOT rules do not affix responsibility for payment for SAP services upon any single party. The DOT has left discussion regarding payment to employer policies and to labor-management agreements.

If the SAP determines that an employee referred for alcohol misuse also uses drugs, or that an employee referred for drugs use also misuses alcohol, the SAP can require that the individual be tested for both substances. The SAP's decision to test for both can be based upon information gathered during the initial treatment program, and/or the information presented during the follow-up evaluation.

In random testing and required follow-up testing, the two test types must be separate; one cannot be substituted for the other, or be conducted in lieu of the other. Follow-up testing is not to be conducted in a random way. An employee's follow-up testing program is to be individualized and designed to ensure that the employee is tested the appropriate number of times as directed by the SAP. If an employee tests positive while in follow-up testing, he/she is subject to the same specific DOT operating administration rules as if they tested positive on the initial test. The employee is also subject to employer policies related to second violation of DOT rules.

Follow-up testing must be conducted a minimum of six times during the first twelve months following the employee's return to safety-sensitive functions. The intent of this requirement is that testing be spread throughout the 12-month period and not grouped into a shorter interval.

A SAP's decision that an individual needs an education program constitutes a clinically based determination that the individual requires assistance in resolving problems with alcohol misuse and controlled substances use. Thus, the SAP is prohibited from referring the individual to his or her own practice for this recommended education unless exempted by DOT rules. SAPs are prohibited from referring an employee to themselves or to any program with which they are financially connected. SAP referrals to treatment programs must not give the impression of a conflict of interest. However, a SAP is not prohibited from referring an employee for assistance through a public agency; the employer or person under contract to provide treatment on behalf of the employer; the sole source of therapeutically appropriate treatment under the employee's health insurance program; or the sole source of therapeutically appropriate reasonably accessible to the employee. Because evaluation by a qualified SAP rarely takes more than one diagnostic session, the requirement for an in-person evaluation is not unreasonable, even if it must be conducted some distance from the employee's home.

✔ **Important Point:** An employee who tests positive may be retained in a non-driving capacity.

✔ **Important Point:** Foreign carriers are not required to have an employee assistance program (EAP).

✔ **Important Point:** Part 382 does not specify who is responsible for paying for (the employer or the driver) any testing under the alcohol and drug-testing program. The employer remains responsible at all times for ensuring compliance with the rule, regardless of who pays for testing.

An employer may use more than one Medical Review Officer, Breath Alcohol Technician, or Substance Abuse Professional. An employer may perform testing beyond that required by the DOT, provided the testing is consistent with applicable law and agreements, and is not represented as a DOT test.

√ **Important Point:** Part 382 does not require a CMV driver to carry proof of compliance with Part 382 and Part 40; instead, the employer must maintain proof.

Workplace Drug and Alcohol Testing Programs (Part 40)
DOT 49 CFR Part 40 deals specifically with procedures for conducting drug and alcohol testing. In this section, a brief summary of various paragraphs and subparagraphs contained within Part 40 is presented. For those seeking a more in depth treatment of this Part, refer to the Code of Federal Regulations, 49 CFR Part 40.

Applicability (§40.1)
This part applies, through regulations that reference it issued by agencies of the DOT, to transportation employers (including self-employed individuals) required to conduct drug and/or alcohol testing programs by DOT agency regulations and to such transportation employers' officers, employees, agents and contractors (including, but not limited to, consortia). Employers are responsible for the compliance of their officers, employees, agents, consortia and/or contractors within the requirements of this part.

Subpart B—Drug Testing

- **§40.21 The drugs**
  - (a) DOT agency drug testing programs require that employers test for marijuana, cocaine, opiates, amphetamines and phencyclidine.
  - (b) An employer may include in its testing protocols other controlled substances or alcohol only pursuant to a DOT agency approval, if testing for those substances is authorized under agency regulations and if the DHHS has established an approved testing protocol and positive threshold for each such substance.
  - (c) Urine specimens collected under DOT agency regulations requiring compliance with this part may only be used to test for controlled substances designated or approved for testing as described in this section and shall not be used to conduct any other analysis or test unless otherwise specifically authorized by DOT agency regulations.
  - (d) This section does not prohibit procedures reasonably incident to analysis of the specimen for controlled substance (e.g., determination of pH or tests for specific gravity, creatinine concentration or presence of adulterants).

✔ **Important Note:** Part 40 specifies that an employer must test for five drugs: marijuana, cocaine, amphetamines, opiates, and phencyclidine; however, an employer **may not** test for any other substances **under DOT authority**. Employers are not prohibited, however, from testing for other controlled substances **as long as that testing remains under the authority of the employer.**

Employers in the transportation industry who establish a drug testing program that tests beyond the five drugs currently required by Part 40 must also make clear to their employees what testing is required by DOT authority and what testing is required by the company. Additionally, employers must ensure that DOT urine specimens are collected in accordance with the provisions outlined in Part 40 and that a separate specimen collection process (including a separate act of urination) is used to obtain specimens for company testing programs.

Even if the drug testing custody and control form fails to indicate what tests are to be performed (which constitutes a collection site error), Part 40 indicates that DOT agency drug testing programs require that employers test for the five specified drugs. All DOT specimens, therefore, must be tested for the five categories of drugs, even if the accompanying drug testing custody and control form fails to indicate this.

While the DOT does not view this type of collection site error as a fatal flaw, it nevertheless jeopardizes the integrity of the entire collection process and could lead to a challenge and subsequent third party review. These errors should be addressed with the site supervisor in the hope of preventing future mistakes.

Briefly, the following sections, paragraphs and subparagraphs are also covered under Part 40.

1. Preparation for testing (§40.23)
2. Specimen collection procedures (§40.25)
   - Designation of collection site
   - Security
   - Chain of Custody
   - Access to authorized personnel only
   - Privacy
   - Integrity and identity of specimen
   - Collection control
   - Transportation to laboratory
   - Failure to cooperate
   - Employee requiring medical attention
   - Use of chain of custody form
3. Laboratory personnel (§40.27)
   - Day-to-day management
   - Test validation
   - Day-to-day operations and supervision of analysts
   - Other personnel

- Training
- Files

4. Laboratory analysis procedures (§40.29)
   - Security and chain of custody
   - Receiving
   - Short-term refrigerated storage
   - Specimen processing
   - Initial test
   - Confirmatory test
   - Reporting results
   - Long-term storage
   - Retesting specimens
   - Subcontracting
   - Laboratory facilities
   - Inspections
   - Documentation
   - Additional requirements for certified laboratories including:
     - Procedure manual
     - Standards and controls
     - Instruments and equipment
     - Remedial actions
     - Personnel available to testify at procedures
5. Quality assurance and quality control (§40.31)
   - Laboratory quality control requirements for initial tests
   - Laboratory quality control requirements for confirmation tests
   - Employer blind performance test procedures
6. Reporting and review of results (§40.33)
   - Medical review officer shall review confirmed positive results
   - Medical review officer—qualifications and responsibilities
   - Positive test result
   - Verification for opiates; review for prescription medication
   - Disclosure of information
7. Protection of employee records (§40.35)
8. Individual access to test and laboratory certification results
9. Use of certified laboratories (§40.39)

Subpart C—Alcohol Testing
Subpart C of Part 40 details DOT's specific requirements related to alcohol testing employees assigned to safety-sensitive positions. Specific sections include:

- The breath and alcohol technician (BAT) (§40.51)
- Devices to be used for breath alcohol tests (§40.53)
- Quality assurance plans for EBT's (§40.55)
- Locations for breath alcohol testing (§40.57)
- The breath alcohol testing form (§40.59)
- Preparation for breath alcohol testing (§40.61)
- Procedures for screening tests (§40.63)
- Procedures for confirmation tests (§40.65)
- Refusals to test and uncompleted tests (§40.67)
- Inability to provide an adequate amount of breath (§40.69)
- Invalid tests (§40.79)
- Availability and disclosure of alcohol testing information about individual employees
- Maintenance and disclosure of records concerning EBTs and BATs

Subpart D—Non-Evidential Alcohol Screening Devices

- for use of non-evidential alcohol screening devices (§40.91)
- The screening test technician (§40.93)
- Quality assurance plans for non-evidential screening devices (§40.95)
- Locations for non-evidential alcohol screening tests (§40.97)
- Testing forms (§40.99)
- Screening test procedure (§40.101)
- Refusals to test and uncompleted tests (§40.103)
- Inability to provide an adequate amount of breath of saliva (§40.105)
- Invalid tests (§40.107)
- Availability and disclosure of alcohol testing information about individual employees (§40.109)
- Maintenance and disclosure of records concerning non- evidential testing devices and STT (Screening Test Technician (§40.111).

Convection: The transfer of heat from one location to another by way of a moving medium (a gas or a liquid). Convection ovens use this principle to transfer heat from an electrode by way of gases in the air to whatever is being baked.

Conventional Mill (Uranium): A facility engineered and built principally for processing of uraniferous ore materials mined from the earth and the recovery, by chemical treatment in the mill's circuits, of uranium and/or other valued co-product components from the processed ore.

Conventional Pollutants: Statutorily listed pollutants understood well by scientists. These may be in the form of organic waste, sediment, acid, bacteria, viruses, nutrients, oil and grease, or heat.

Conventional Site Assessment: Assessment in which most of the sample analysis and interpretation of data is competed off-site; process usually required repeated mobilization of equipment and staff in order to fully determine the extent of contamination.

Conventional Systems: Systems that have been traditionally used to collect municipal wastewater in gravity sewer and convey it to a central primary or secondary treatment plant prior to discharge to surface waters.

Convergence: The movement of two objects toward a common point.

Conversion Factors: Conversion factors refer to conversion of units between different units of measurement for the same quantity. It is important to note that the process of making a conversion cannot produce a more precise result than the original figure. Appropriate round of the results is normally performed after conversion. Conversion factors are given below in alphabetical order in the Table and in unit category listing order in the Table.

Alphabetical Listing of Conversion Factors

Factors	*Metric (SI) or English Conversions*
1 atm (atmosphere) =	1.013 bars
	10.133 newtons/cm^2 (newtons/square centimeter)
	33.90 ft. of H_2O (feet of water)
	101.325 kp (kilopascals)
	1,013.25 mg (millibars)
	13.70psia (pounds/square inch – absolute)
	760 torr
	760 mm Hg (millimeters of mercury)
1 bar =	0.987 atm (atmospheres)
	1×10^6 dynes/cm^2 (dynes/square centimeter)
	33.45 ft of H_2O (feet of water)
	1×10^5 pascals [nt/m^2] (newtons/square meter)
	750.06 torr
	750.06 mm Hg (millimeters of mercury)
1 Bq (becquerel) =	1 radioactive disintegration/second
	2.7×10^{-11} Ci (curie)
	2.7×10^{-8} mCi (millicurie)
1 BTU (British Thermal Unit) =	252 cal (calories)
	1,055.06 j (joules)
	10.41 liter-atmosphere
	0.293 watt-hours
1 cal (calories) =	3.97×10^{-3} BTUs (British Thermal Units)
	4.18 j (joules)
	0.0413 liter-atmospheres
	1.163×10^{-3} watt-hours
1 cm (centimeters) =	0.0328 ft (feet)
	0.394 in (inches)
	10,000 microns (micrometers)
	100,000,000 Å =10^8 Å (Ångstroms)
1 cc (cubic centimeter) =	3.53×10^{-5} ft^3 (cubic feet)
	0.061 in^3 (cubic inches)
	2.64×10^{-4} gal (gallons)
	ℓ (liters)
	ml (milliliters)
1 ft^3 (cubic foot) =	28.317 cc (cubic centimeters)
	1,728 in^3 (cubic inches)
	0.0283 m^3 (cubic meters)
	7.48 gal (gallons)
	28.32 ℓ (liters)
	29.92 qts (quarts)
1 in^3	16.39 cc (cubic centimeters)
	16.39 ml (milliliters)
	5.79×10^{-4} ft^3 (cubic feet)
	1.64×10^{-5} m^3 (cubic meters)
	4.33×10^{-3} gal (gallons)
	0.0164 ℓ (liters)
	0.55 fl oz (fluid ounces)
1 m^3 (cubic meter) =	1,000,000 cc = 10^6 cc (cubic centimeters)
	33.32 ft^3 (cubic feet)
	61,023 in^3 (cubic inches)
	264.17 gal (gallons)
	1,000 ℓ (liters)
1 yd^3 (cubic yard) =	201.97 gal (gallons)
	764.55 ℓ (liters)
1 Ci (curie) =	3.7×10^{10} radioactive disintegrations/second
	3.7×10^{10} Bq (becquerel)
	1,000 mCi (millicurie)
1 day =	24 hrs (hours)
	1,440 min (minutes)
	86,400 sec (seconds)
	0.143 weeks
	2.738×10^{-3} yrs (years)
1°C (expressed as an interval) =	1.8°F = [9/5] °F (degrees Fahrenheit)
	1.8°R (degrees Rankine)
	1.0 K (degrees Kelvin)
°C (degree Celsius) =	[(5/9)(°F – 32°)]
1°F (expressed as an interval) =	0.556°C = [5/9]°C (degrees Celsius)
	1.0°R (degrees Rankine)
	0.556 K (degrees Kelvin)
°F (degree Fahrenheit) =	[(9/5)(°C) + 32°
1 dyne =	1×10^{-5} nt (newton)
1 ev (electron volt) =	1.602×10^{-12} ergs
	1.602×10^{-19} j (joules)
1 erg =	1 dyne-centimeters
	1×10^{-7} j (joules)
	2.78×10^{-11} watt-hours
1 fps (feet/second) =	1.097 kmph (kilometers/hour)
	0.305 mps (meters/second)
	0.01136 mph (miles/hour)
1 ft (foot) =	30.48 cm (centimeters)
	12 in (inches)
	0.3048 m (meters)
	1.65×10^{-4} nt (nautical miles)
	1.89×10^{-4} mi (statute miles)

(continued)

Alphabetical Listing of Conversion Factors *(continued)*

Factors	*Metric (SI) or English Conversions*
1 gal (gallon) =	3,785 cc (cubic centimeters)
	0.134 ft^3 (cubic feet)
	231 in^3 (cubic inches)
	3.785 ℓ (liters)
1 gm (gram)	0.001 kg (kilogram)
	1,000 mg (milligrams)
	1,000,000 ng = 10^6 ng (nanograms)
	2.205 × 10^{-3} lbs (pounds)
1 gm/cc (grams/cubic cent.) =	62.43 lbs/ft^3 (pounds/cubic foot)
	0.0361 lbs/in^3 (pounds/cubic inch)
	8.345 lbs/gal (pounds/gallon)
1 Gy (gray) =	1 j/kg (joules/kilogram)
	100 rad
	1 Sv (sievert) – [unless modified through division by an appropriate factor, such as Q and/or N]
1 hp (horsepower) =	745.7 j/sec (joules/sec)
1 hr (hour) =	0.0417 days
	60 min (minutes)
	3,600 sec (seconds)
	5.95 × 10^{-3} weeks
	1.14 × 10^{-4} yrs (years)
1 in (inch) =	2.54 cm (centimeters)
	1,000 mils
I inch of water =	1.86 mm Hg (millimeters of mercury)
	249.09 pascals
	0.0361 psi (lbs/in^2)
1 j (joule) =	9.48 × 10^{-4} BTUs (British Thermal Units)
	0.239 cal (calories)
	10,000,000 ergs = 1 × 10^7 ergs
	9.87 × 10^{-3} liter-atmospheres
	1.0 nt-m (newton-meters)
1 kcal (kilocalories) =	3.97 BTUs (British Thermal Units)
	1,000 cal (calories)
	4,186.8 j (joules)
1 kg (kilogram) =	1,000 gms (grams)
	2,205 lbs (pounds)
1 km (kilometer) =	3,280 ft (feet)
	0.54 nt (nautical miles)
	0.6214 mi (statute miles)
1 kw (kilowatt) =	56.87 BTU/min (British Thermal Units)
	1.341 hp (horsepower)
	1,000 j/sec (kilocalories)
1 kw-hr (kilowatt-hour) =	3,412.14 BTU (British Thermal Units)
	3.6 × 10^6 j (joules)
	859.8 kcal (kilocalories)
1 ℓ (liter) =	1,000 cc (cubic centimeters)
	1 dm^3 (cubic decimeters)
	0.0353 ft^3 (cubic feet)
	61.02 in^3 (cubic inches)
	0.264 gal (gallons)
	1,000 ml (milliliters)
	1.057 qts (quarts)
1 m (meter) =	1 × 10^{10} Å (Ångstroms)
	100 cm (centimeters)
	3.28 ft (feet)
	39.37 in (inches)
	1 × 10^{-3} km (kilometers)
	1,000 mm (millimeters)
	1,000,000 μ = 1 × 10^6 μ (micrometers)
	1 × 10^9 nm (nanometers)
1 mps (meters/second) =	196.9 fpm (feet/minute)
	3.6 kmph (kilometers/hour)
	2.237 mph (miles/hour)
1 mph (mile/hour) =	88 fpm (feet/minute)
	1.61 kmph (kilometers/hour)
	0.447 mps (meters/second)
1 kt (nautical mile) =	6,076.1 ft (feet)
	1.852 km (kilometers)
	1.15 mi (statute miles)
	2,025.4 yds (yards)
1 mi (statute mile) =	5,280 ft (feet)
	1.609 km (kilometers)
	1,609.3 m (meters)
	0.869 nt (nautical miles)
	1,760 yds (yards)
1 miCi (millicurie) =	0.001 Ci (curie)
	3.7 × 10^{10} radioactive disintegrations/second
	3.7 × 10^{10} Bq (becquerel)
1 mm Hg (mm of mercury) =	1.316 × 10^{-3} atm (atmosphere)
	0.535 in H_2O (inches of water)
	1.33 mb (millibars)
	133.32 pascals
	1 torr
	0.0193 psia (pounds/square inch – absolute
1 min (minute) =	6.94 × 10^{-4} days
	0.0167 hrs (hours)
	60 sec (seconds)
	9.92 × 10^{-5} weeks
	1.90 × 10^{-6} yrs (years)
1 nt (newton) =	1 × 10^5 dynes
1 nt-m (newton-meter) =	1.00 j (joules)
	2.78 × 10^{-4} watt-hours
1 ppm (parts/million-volume) =	1.00 ml/m^3 (milliliters/cubic meter)
1 ppm [wt] (parts/million-weight) =	1.00 mg/kg (milligrams/kilograms)
1 pascal =	9.87 × 10^{-6} atm (atmospheres)
	4.015 × 10^{-3} in H_2O (inches of water)
	1.0 mb (millibars)
	7.5 × 10^{-3} mm Hg (milliliters of mercury)
1 lbs (pound) =	453.59 gms (grams)
	16 oz (ounces)
l lbs/ft^3 (pounds/cubic foot) =	16.02 gms/l (grams/liter)
1 lbs/ft^3 (pounds/cubic inch) =	27.68 gms/cc (grams/cubic centimeter)
	1,728 lbs/ft^3 (pounds/cubic feet)
1 psi (pounds/square inch)=	0.068 atm (atmospheres)

Factors	*Metric (SI) or English Conversions*
	27.67 in H_2O (inches or water)
	68.85 mb (millibars)
	51.71 mm Hg (millimeters of mercury)
	6,894.76 pascals
1 qt (quart) =	946.4 cc (cubic centimeters)
	57.75 in^3 (cubic inches)
	0.946 ℓ (liters)
1 rad =	100 ergs/gm (ergs/gram)
	0.01 Gy (gray)
	1 rem [unless modified through division by an appropriate factor, such as Q and/or N]
1 rem	1 rad [unless modified through division by an appropriate factor, such as Q and/or N]
1 Sv (sievert) =	1 Gy (gray) [unless modified through division by an appropriate factor, such as Q and/or N]
1 cm^2 (square centimeter) =	1.076×10^{-3} ft^2 (square feet)
	0.155 in^2 (square inches)
	1×10^{-4} m^2 (square meters)
1 ft^2 (square foot) =	2.296×10^{-5} acres
	9.296 cm^2 (square centimeters)
	144 in^2 (square inches)

Factors	*Metric (SI) or English Conversions*
	0.0929 m^2 (square meters)
1 m^2 (square meter) =	10.76 ft^2 (square feet)
	1,550 in^2 (square inches)
1 mi^2 (square mile) =	640 acres
	2.79×10^7 ft^2 (square feet)
	2.59×10^6 m^2 (square meters)
1 torr =	1.33 mb (millibars)
1 watt =	3.41 BTI/hr (British Thermal Units/hour)
	1.341×10^{-3} hp (horsepower)
	1.18 j/sec (joules/second)
1 watt-hour =	3.412 BTUs (British Thermal Unit)
	859.8 cal (calories)
	3,600 j (joules)
	35.53 liter-atmosphere
1 week =	7 days
	168 hrs (hours)
	10,080 min (minutes)
	6.048×10^5 sec (seconds)
	0.0192 yrs (years)
1 yr (year) =	365.25 days
	8,766 hrs (hours)
	5.26×10^5 min (minutes)
	3.16×10^7 sec (seconds)
	52.18 weeks

Conversion Factors by Unit Category

Units of Length

1 cm (centimeter) =	0.0328 ft (feet)
	0.394 in (inches)
	10,000 microns (micrometers)
	100,000,000 Å = 10^8 Å (Ångstroms)
1 ft (foot) =	30.48 cm (centimeters)
	12 in (inches)
	0.3048 m (meters)
	1.65×10^{-4} nt (nautical miles)
	1.89×10^{-4} mi (statute miles)
1 in (inch) =	2.54 cm (centimeters)
	1,000 mils
1 km (kilometer) =	3,280.8 ft (feet)
	0.54 nt (nautical miles)
	0.6214 mi (statute miles)
1 m (meter) =	1×10^{10} Å (Ångstroms)
	100 cm (centimeters)
	3.28 ft (feet)
	39.37 in (inches)
	1×10^{-3} km (kilometers)
	1,000 mm (millimeters)
	1,000,000 μ = $1x10^6$ μ (micrometers)
	1×10^9 nm (nanometers)
1 kt (nautical mile) =	6,076.1 ft (feet)
	1.852 km (kilometers)
	1.15 km (statute miles)
	2.025.4 yds (yards)
1 mi (statute mile) =	5,280 ft (feet)
	1.609 km (kilometers)
	1.690.3 m (meters)
	0.869 nt (nautical miles)
	1,760 yds (yards)

Units of Area

1 cm^2 (square centimeter) =	1.076×10^{-3} ft^2 (square feet)
	0.155 in^2 (square inches)
	1×10^{-4} m^2 (square meters)
1 ft^2 (square foot) =	2.296×10^{-5} acres
	929.03 cm^2 (square centimeters)
	144 in^2 (square inches)
	0.0929 m^2 (square meters)
1 m^2 (square meter) =	10.76 ft^2 (square feet)
	1,550 in^2 (square inches)
1 mi^2 (square mile) =	640 acres
	2.79×10^7 ft^2 (square feet)
	2.59×10^6 m^2 (square meters)

Units of Volume

1 cc (cubic centimeter) =	3.53×10^{-5} ft^3 (cubic feet)
	0.061 in^3 (cubic inches)

(continued)

Conversion Factors by Unit Category *(continued)*

	2.64×10^{-4} gal (gallons)
	0.001 ℓ (liters)
	1.00 ml (milliliters)
1 ft^3 (cubic foot) =	28,317 cc (cubic centimeters)
	1,728 in^3 (cubic inches)
	0.0283 m^3 (cubic meters)
	7.48 gal (gallons)
	28.32 ℓ (liters)
	29.92 qts (quarts)
1 in^3 (cubic inch) =	16.39 cc (cubic centimeters)
	16.39 ml (milliliters)
	5.79×10^{-4} ft^3 (cubic feet)
	1.64×10^{-5} m^3 (cubic meters)
	4.33×10^{-3} gal (gallons)
	0.0164 ℓ (liters)
	0.55 fl oz (fluid ounces)
1 m^3 (cubic meter) =	1,000,000 cc = 10^6 cc (cubic centimeters)
	35.31 ft^3 (cubic feet)
	61,023 in^3 (cubic inches)
	264.17 gal (gallons)
	1,000 ℓ (liters)
1 yd^3 (cubic yards) =	201.97 gal (gallons)
	764.55 ℓ (liters)
1 gal (gallon) =	3,785 cc (cubic centimeters)
	0.134 ft^3 (cubic feet)
	231 in^3 (cubic inches)
	3.785 ℓ (liters)
1 ℓ (liter) =	1,000 cc (cubic centimeters)
	1 dm^3 (cubic decimeters)
	0.0353 ft^3 (cubic feet)
	61.02 in^3 (cubic inches)
	0.264 gal (gallons)
	1,000 (milliliters)
	1.057 qts (quarts)
1 qt (quart) =	946.4 cc (cubic centimeters)
	57.75 in^3 (cubic inches)
	0.946 ℓ (liters)

Units of Mass

1 gm (grams) =	0.001 kg (kilograms)
	1,000 mg (milligrams)
	1,000,000 mg = 10^6 ng (nanograms)
	2.205×10^{-3} lbs (pounds)
1 kg (kilogram) =	1,000 gms (grams)
	2.205 lbs (pounds)
1 lbs (pound) =	453.59 gms (grams)
	16 oz (ounces)

Units of Time

1 day =	24 hrs (hours)
	1440 min (minutes)
	86,400 sec (seconds)
	0.143 weeks
	2.738×10^{-3} yrs (years)
1 hr (hours) =	0.0417 days
	60 min (minutes)
	3,600 sec (seconds)
	5.95×10^{-3} yrs (years)
1 hr (hour) =	0.0417 days
	60 min (minutes)
	3,600 sec (seconds)
	5.95×10^{-3} weeks
	1.14×10^{-4} yrs (years)
1 min (minutes) =	6.94×10^{-4} days
	0.0167 hrs (hours)
	60 sec (seconds)
	9.92×10^{-5} weeks
	1.90×10^{-6} yrs (years)
1 week =	7 days
	168 hrs (hours)
	10,080 min (minutes)
	6.048×10^5 sec (seconds)
	0.0192 yrs (years)
1 yr (year) =	365.25 days
	8,766 hrs (hours)
	5.26×10^5 min (minutes)
	3.16×10^7 sec (seconds)
	52.18 weeks

Units of the Measure of Temperature

°C (degrees Celsius) =	[(5/9)(°F – 32°)]
1°C (expressed as an interval) =	1.8°F = [9/5]°F (degrees Fahrenheit)
	1.8°R (degrees Rankine)
K (degrees Kelvin)	
°F (degree Fahrenheit) =	[(9/5)(°C) + 32°]
1°F (expressed as an interval) =	0.556°C = [5/9]°C (degrees Celsius)
	1.0°R (degrees Rankine)
	0.556 K (degrees Kelvin)

Example

Problem:

Find degrees in Celsius of water at 72

Solution: °C = (F – 32) × 5/9 = (72 – 32) × 5/9 = 22.2

Units of Force

1 dyne =	1×10^{-5} nt (newtons)
1 nt (newton) =	1×10^5 dynes

Units of Work or Energy

1 BTU (British Thermal Unit) =	252 cal (calories)
	1,055.06 j (joules)
	10.41 liter-atmospheres
	0.293 watt-hours
1 cal (calories) =	3.97×10^{-3} BTUs (British Thermal Units)
	4.18 j (joules)
	0.0413 liter-atmospheres
	1.163×10^{-3} watt-hours
1 ev (electron volt) =	1.602×10^{-12} ergs
	1.602×10^{-19} j (joules)
erg =	1 dyne-centimeter
1×10^{-7} j (joules)	
	2.78×10^{-11} watt-hours
1 j (joule) =	9.48×10^{-4} BTUs (British Thermal Units)
	0.239 cal (calories)
	10,000,000 ergs = 1×10^{7} ergs
	9.87×10^{-3} liter-atmospheres
	1.00 nt-m (newton-meters)
1 kcal (kilocalorie) =	3.97 BTUs (British Thermal Units)
	1,000 cal (calories)
	4,186.8 j (joules)
1 kw-hr (kilowatt-hour) =	3,412.14 BTU (British Thermal Units)
	3.6×10^{6} j (joules)
	859.8 kcal (kilocalories)
1 nt-m (newton-meter) =	1.00 j (joules)
	2.78×10^{-4} watt-hours
1 watt-hour =	3.412 BTUs (British Thermal Units)
	859.8 cal (calories)
	3,600 j (joules)
	35.53 liter-atmospheres

Units of Power

1 hp (horsepower) =	745.7 j/sec (joules/sec)
1 kw (kilowatt) =	56.87 BTU/min (British Thermal Units/minute)
	1.341 hp (horsepower)
	1,000 j/sec (joules/sec)
1 watt =	3.41 BTU/hr (British Thermal Units/hour)
	1.341×10^{-3} hp (horsepower)
	1.00 j/sec (joules/second)

Units of Pressure

1 atm (atmosphere) =	1.013 bars
	10.133 newtons/cm^2 (newtons/square centimeters)
	33.90 ft. of H_2O (feet of water)
	101.325 kp (kilopascals)
	14.70 psia (pounds/square inch – absolute)
	760 torr
	760 mm Hg (millimeters of mercury)
1 bar =	0.987 atm (atmospheres)
	1×10^{6} dynes/cm^2 (dynes/square centimeter)
	33.45 ft of H_2O (feet of water)
	1×10^{5} pascals [nt/m^2] (newtons/square meter)
	750.06 torr
	750.06 mm Hg (millimeters of mercury)
1 inch of water =	1.86 mm Hg (millimeters of mercury)
	249.09 pascals
	0.0361 psi (lbs/in^2)
1 mm Hg (millimeter of merc.) =	1.316×10^{-3} atm (atmospheres)
	0.535 in H_2O (inches of water)
	1.33 mb (millibars)
	133.32 pascals
	1 torr
	0.0193 psia (pounds/square inch – absolute)
1 pascal =	9.87×10^{-6} atm (atmospheres)
	4.015×10^{-3} in H_2O (inches of water)
	0.01 mb (millibars)
	7.5×10^{-3} mm Hg (millimeters of mercury)
1 psi (pounds/square inch) =	0.068 atm (atmospheres)
	27.67 in H_2O (inches of water)
	68.85 mb (millibars)
	51.71 mm Hg (millimeters of mercury)
	6,894.76 pascals
1 torr =	1.33 mb (millibars)

Units of Velocity or Speed

1 fps (feet/second) =	1.097 kmph (kilometers/hour)
	0.305 mps (meters/second)
	0.01136 mph (miles/hours)
1 mps (meters/second) =	196.9 fpm (feet/minute)
	3.6 kmph (kilometers/hour)
	2.237 mph (miles/hour)
1 mph (mile/hour) =	88 fpm (feet/minute)
	1.61 kmph (kilometers/hour)

(continued)

Conversion Factors by Unit Category ***(continued)***

	0.447 mps (meters/second)
Units of Density	
1 gm/cc (grams/cubic cent.) =	62.43 lbs/ft^3 (pounds/cubic foot) 0.0361 lbs/in^3 (pounds/cubic inch) 8.345 lbs/gal (pounds/gallon)
1 lbs/ft^3 (pounds/cubic foot) =	16.02 gms/ℓ (grams/liter)
1 lbs/in^2 (pounds/cubic inch) =	27.68 gms/cc (grams/cubic centimeter) 1.728 lbs/ft^3 (pounds/cubic foot)
Units of Concentration	
1 ppm (parts/million-volume) =	1.00 ml/m^3 (milliliters/cubic meter)
1 ppm (wt) =	1.00 mg/kg (milligrams/kilograms)
Radiation & Dose Related Units	
1 Bq (becquerel) =	1 radioactive disintegration/second 2.7×10^{-11} Ci (curie) 2.7×10^{-8} (millicurie)
1 Ci (curie) =	3.7×10^{10} radioactive disintegration/second 3.7×10^{10} Bq (becquerel) 1,000 mCi (millicurie)
1 Gy (gray) =	1 j/kg (joule/kilogram) 100 rad 1 Sv (sievert) – [unless modified through division by an appropriate factor, such as Q and/or N]
1 mCi (millicurie) =	0.001 Ci (curie) 3.7×10^{10} radioactive disintegrations/second 3.7×10^{10} Bq (becquerel)
1 rad =	100 ergs/gm (ergs/gm) 0.01 Gy (gray) 1 rem – [unless modified through division by an appropriate factor, such as Q and/or N]
1 rem =	1 rad – [unless modified through division by an appropriate factor, such as Q and/or N]
1 Sv (sievert) =	1 Gy (gray) – [unless modified through division by an appropriate factor, such as Q and/or N]

Conveyance Loss: Water that is lost in transit from a pipe, canal, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a ground-water source and be available for further use.

Cooling Electricity Use: Amount of electricity used to meet the building cooling load.

Cooling Tower: Device which dissipates the heat from hot condensate water-cooled systems by spraying the water through streams of rapidly moving air.

Cooling Tower Method: A treatment method used to treat thermally polluted water by spraying the heated water into the air and allowing it to cool by evaporation.

Cooperative Agreement: An assistance agreement whereby EPA transfers money, property, services or anything of value to a state, university, non-profit, or not-for-profit organization for the accomplishment of authorized activities or tasks.

Coppice: In *biomass*, a method of regenerating a forest stand in which trees in the previous stand are cut and the majority of new growth is associated with vigorous stump sprouting from roots or root suckers.

Core: 1. The uranium-containing heart of a nuclear reactor, where energy is released. 2. In geology, a cylinder of rock recovered from the well by a special coring drill bit.

Core Program Cooperative Agreement: An assistance agreement whereby EPA supports states or tribal governments with funds to help defray the cost of non-item-specific administrative and training activities.

Corn Stover: In biomass, used as a source of fuel; it consists of residue materials from the corn plant obtained after harvesting, consisting of the cob, leaves, and stalk.

Corrective Action: EPA can require treatment, storage and disposal (TSDF) facilities handling hazardous waste to undertake corrective actions to clean up spills resulting from failure to follow hazardous waste management procedures or other mistakes. The process includes cleanup procedures designed to guide TSDFs in handling spills.

Corrosion: The dissolution and wearing away of metal caused by a chemical reaction such as between water and the pipes, chemicals touching a metal surface, or contact between two metals.

Corrosive: A substance that attacks and eats away other materials by strong chemical action.

Corrosive Material: Any material that dissolves metals or other materials, or that burns the skin.

Cotyledon: The seed leaf; the first leaves of an embryo.

Counts Per Minute (cpm): Number of nuclear transformations from radioactive decay able to be detected by a counting instrument in a one minute time interval.

Covalent Bond: A chemical bond produced when two atoms share one or more pairs of electrons.

Cover Material: Soil used to cover compacted solid waste in a sanitary landfill.

Cradle-to-Grave or Manifest System: A procedure for which hazardous materials are identified and followed as they are produced, treated, transported, and disposed of by a series of permanent, linkable, descriptive documents (e.g., manifests). Commonly referred to as the cradle-to-grave system.

Criteria: Descriptive factors taken into account by EPA in setting standards for various pollutants. These factors are used to determine limits on allowable concentration levels, and to limit the number of violations per year. When issued by EPA, the criteria provide guidance to the states on how to establish their standards.

Criteria Pollutants: Criteria air pollutants consist of the six primary criteria pollutants sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), particulates, particulate lead (Pb), and Ozone (O_3).

Sulfur Dioxide

The element sulfur may be contained in certain fossil fuels such as coal. The sulfur is oxidized during burning of these fuels, producing sulfur dioxide gas. Sulfur dioxide is a colorless gas with a sharp, choking odor; it irritates the eyes, nose, throat, and causes chronic bronchitis. Approximately 25 million tons of SO_2 are discharged into the atmosphere in the U.S. each year, mostly from fossil fuel combustion used in electric utility power plants. SO_2 is a constituent of acid rain, and visibility reduction through the presence of suspended sulfate particles in the atmosphere.

Nitrogen Oxides

Characterized collectively as NOx, nitrogen oxides come in many forms. Most emissions are initially in the form of nitrogen oxide (NO), which by itself is not harmful at the concentrations usually found in the atmosphere. However, when NO oxidizes to NO_2 in the presence of sunlight, it can react with hydrocarbons to form photochemical smog. NO_2 also reacts with the hydroxyl radical (OH-) to form nitric acid (HNO_3), a contributor to acid rain. NO is colorless, however when converted to NO_2 it tends to give smog a reddish-brown color. The largest source of nitrogen oxides is from the oxidation of nitrogen compounds during the combustion of certain fossil fuels, such as coal and gasoline.

Carbon Monoxide

Incomplete combustion of fossil fuels produces carbon monoxide (CO). Completely invisible, carbon monoxide is colorless, odorless, and tasteless. CO can be a serious health hazard, causing effects that range from slight headaches to nausea to death, depending on concentration and conditions.

Particulate Matter

Particulates are extremely small fragments of solids or liquid droplets suspended in air. Particulates (lead being the exception) are distinguished on the basis of particle size and source, rather than by chemical composition. Most particulates range in size from 0.1 to 100μ. The particulate materials of most concern for adverse effects on human health (ones which can easily be inhaled and penetrate deeply into the innermost recesses of our lungs and cause upper respiratory infection, cardiac disorder, bronchitis, asthma, pneumonia, and emphysema) are generally less than 10 microns in size and are referred to as PM-10. Smaller-sized particles—those less that 10 micrometers in diameter—tend to pose the greatest health concern because they can pass through the nose and throat and get into the lungs. Particulates also reduce visibility and intensify certain chemical reactions in the atmosphere.

Lead Particulates

Lead can be present in the air as either a particle or gas. Lead particulates in fume form (less than 0.5μ in size) are toxic and can lead to anemia, destructive behavior, learning disabilities, seizures, brain damage, and death. Major sources of lead (Pb) in the past were motor vehicles that burned gasoline containing lead-based antiknock additives. The USEPA now requires the use of unleaded gasoline, but lead is still emitted from petroleum refining and smelting operations, and other industrial activities.

Ozone (O_3)

Ozone (O_3), the key component of photochemical smog (smog = smoke + fog), is a secondary air pollutant in the troposphere formed by a complex chemical reaction between nitrogen dioxide (NO_2) and volatile organic compounds (VOCs). VOCs are hydrocarbons that are gaseous under normal atmospheric conditions. The reactions are initiated by ultraviolet energy in sunlight. Along with producing smog, ozone irritates the eyes, nose, and throat, reduces lung function, damages plants, and causes cracking of paints, rubber and textiles.

Critical Barrier: In asbestos abatement, one or more layers of plastic sealed over all openings into a work area or any other similarly placed physical barrier sufficient to prevent airborne asbestos in a work area from migrating to an adjacent area.

Critical Effect: The first adverse effect, or its known precursor, that occurs as a dose rate increases. Designation is based on evaluation of overall database.

Critical Pressure: The vapor pressure at the critical temperature.

Critical Temperature: The temperature above which a gas can not liquefied, regardless of the pressure applied.

Crop Consumptive Use: The amount of water transpired during plant growth plus what evaporated from the soil surface and foliage in the crop area.

Crop Failure: Consists mainly of the acreage on which crops failed because of weather, insects, and diseases, but includes some land not harvested due to lack of labor, lower market prices, or other factors. The acreage planted to cover and sol improvement crops not intended for harvest in excluded from crop failure and is considered idle.

Cross-Connection: Any actual or potential connection between a drinking water system and an unapproved water supply or other source of contamination.

Cross Contamination: The movement of underground contaminants from one level or area to another due to invasive subsurface activities.

Crosslinked Gel: A gel to which a crosslinker has been added.

Crosslinker: And additive that when added to a linear gel, will create a complex, high viscosity, pseduoplastic fracturing fluid.

Cryogenic: A material at a very low temperature.

Cryptanalysis: The mathematical science that deals with analysis of a cryptographic system to gain knowledge needed to break or circumvent the cipher text to plaintext without knowing the key.

Cryptosporidium: Ernest E. Tyzzer first described the protozoan parasite Cryptosporidium in 1907. Tyzzer frequently found a parasite in the gastric glands of laboratory mice. Tyzzer identified the parasite as a sporozoan, but of uncertain taxonomic status; he named it *Cryptosporidium muris.* Later, in 1910, after more detailed study, he proposed *Cryptosporidium* as a new genus and *C. muris* as the type of species. Amazingly, except for developmental stages, Tyzzer's original description of the life cycle was later confirmed by electron microscopy. Later, in 1912, Tyzzer described a new species, *Cryptosporidium parvum* (Tyzzer 1912).

For almost 50 years, Tyzzer's discovery of the genus *Cryptosporidium* (because it appeared to be of no medical or economic importance) remained (like himself) relatively obscure. However, slight rumblings of the genus' importance were felt in the medical community when Slavin (1955) wrote about a new species, *Cryptosporidium melagridis,* associated with illness and death in turkeys. Interest remained slight even when *Cryptosporidium* was found to be associated with bovine diarrhea (Panciera 1971).

Not until 1982 did worldwide interest focus in on the study of organisms in the genus *Cryptosporidium.* During this period, the medical community and other interested parties were beginning to attempt a full-scale, frantic effort to find out as much as possible about Acquired Immune Deficiency Syndrome (AIDS). The CDC reported that 21 AIDS-infected males from six large cities in the U.S. had severe protracted diarrhea caused by *Cryptosporidium.*

However, 1993 was when the "bug—the pernicious parasite *Cryptosporidium*—made [itself and] Milwaukee famous (Mayo Foundation 1996)."

Note: The *Cryptosporidium* outbreak in Milwaukee caused the deaths of 100 people—the largest episode of waterborne disease in the U.S. in the 70 years since health officials began tracking such outbreaks.

Today we know that the massive waterborne outbreak in Milwaukee (more than 400,000 persons developed acute and often prolonged diarrhea or other gastrointestinal symptoms) increased in interest in *Cryptosporidium* at an exponential level. The Milwaukee Incident spurred both public interest and the interest of public health agencies, agricultural agencies and groups, environmental agencies and groups, and suppliers of drinking water. This increase in interest level and concern has spurred on new studies of *Cryptosporidium* with emphasis on developing methods for recovery, detection, prevention, and treatment (Fayer et al. 1997).

The USEPA has become particularly interested in this "new" pathogen. For example, in the reexamination of regulations on water treatment and disinfection, the

USEPA issued MCLG and CCL for *Cryptosporidium.* The similarity to *Giardia lamblia* and the necessity to provide an efficient conventional water treatment capable of eliminating viruses at the same time forced the USEPA to regulate the surface water supplies in particular. The proposed "Enhanced Surface Water Treatment Rule" (ESWTR) included regulations from watershed protection to specialized operation of treatment plants (certification of operators and state overview) and effective chlorination. Protection against *Cryptosporidium* included control of waterborne pathogens such as *Giardia* and viruses (DeZuane 1997).

Cryptosporidiosis: Denis D. Juranek from the Centers for Disease Control has written in *Clinical Infectious Diseases:*

> Cryptosporidium *parvum* is an important emerging pathogen in the U.S. and a cause of severe, life-threatening disease in patients with AIDS. No safe and effective form of specific treatment for Cryptosporidiosis has been identified to date. The parasite is transmitted by ingestion of oocysts excreted in the feces of infected humans or animals. The infection can therefore be transmitted from person-to-person, through ingestion of contaminated water (drinking water and water used for recreational purposes) or food, from animal to person, or by contact with fecally contaminated environmental surfaces. Outbreaks associated with all of these modes of transmission have been documented. Patients with human immunodeficiency virus infection should be made more aware of the many ways that *Cryptosporidium* species are transmitted, and they should be given guidance on how to reduce their risk of exposure (Juranek 1995).

The CDC points out that since the Milwaukee outbreak, concern about the safety of drinking water in the United States has increased, and new attention has been focused on determining and reducing the risk of Cryptosporidiosis from community and municipal water supplies.

Cryptosporidiosis is spread by putting something in the mouth that has been contaminated with the stool of an infected person or animal. In this way, people swallow the *Cryptosporidium* parasite. As previously mentioned, a person can become infected by drinking contaminated water or eating raw or undercooked food contaminated with *Cryptosporidium* oocysts; direct contact with the droppings of infected animals or stools of infected humans; or hand-to-mouth transfer of oocysts from surfaces that may have become contaminated with microscopic amounts of stool from an infected person or animal.

The symptoms may appear two to ten days after infection by the parasite. Although some persons may not have symptoms, others have watery diarrhea, headache, abdominal cramps, nausea, vomiting, and low-grade fever. These symptoms may lead to weight loss and dehydration.

In otherwise healthy persons, these symptoms usually last one to two weeks, at which time the immune system is able to stop the infection. In persons with suppressed immune systems, such as persons who have AIDS or who recently have had an organ or bone marrow transplant, the infection may continue and become life threatening.

Now, no safe and effective cure for Cryptosporidiosis exists. People with normal immune systems improve without taking antibiotic or antiparasitic medications. The treatment recommend for this diarrheal illness is to drink plenty of fluids and to get extra rest. Physicians may prescribe medication to slow the diarrhea during recovery.

The best way to prevent Cryptosporidiosis is

- Avoid water or food that may be contaminated.
- Wash hands after using the toilet and before handling food.
- If you work in a childcare center where you change diapers, be sure to wash your hands thoroughly with plenty of soap and warm water after every diaper change, even if you wear gloves.

During community-wide outbreaks caused by contaminated drinking water, drinking water practitioners should inform the public to boil drinking water for one minute to kill the *Cryptosporidium* parasite.

Cubic Centimeter (cc): A volumetric measurement that is equal to 1 milliliter.

Cubic Feet per Hour (cfh): Amount of cubic feet of air flowing past a specific point per hour of time.

Cubic Feet per Minute (cfm): A measure of the volume of a substance flowing through air within a fixed period of time. With regard to indoor air, refers tot the amount of air, in cubic feet, that is exchanged with outdoor air in a minute's time; i.e., the air exchange rate.

Cubic Feet per Second (cfs): A rate of the flow, in streams and rivers, for example. It is equal to a volume of water one foot high and one foot wide flowing a distance of one foot in one second. One "cfs" is equal to 7.48 gallons of water flowing each second. As an example, if your car's gas tank is 2 feet by 1 foot by 1 foot (2 cubic feet), then gas flowing at a rate of 1 cubic foot/second would fill the tank in two seconds.

Cubic Foot (cu. ft.): One cubic foot is equal to 7.48 gallons, 28.3162 liters, or 1728 cubic inches.

Cubic Foot of Water: Measurement equal to approximately 62.5 pounds.

Cubic Meter: The space inside of a box that is 1 meter wide, 1 meter high, and1 meter deep; commonly used to measure a volume of air.

Cull Tree: A live tree, 5.0 inches in diameter at breast height (d.b.h) or larger than is non-merchantable for saw logs now or prospectively because of rot, roughness, or species.

Cultivar: A domestic variety of plant: a variety produced in cultivation, and generally maintained only in cultivation.

Cultural Eutrophication: Over-nourishment of aquatic ecosystems with plant nutrients resulting from human activities , including agriculture, urbanization, and industrial discharge.

Cultures and Stocks: Infectious agents and associated biologicals including cultures from medical and pathological laboratories; cultures and stocks of infectious agents from research and industrial laboratories; waste from the production of biologicals; discarded live and attenuated vaccines; and culture dishes and devices used to transfer, inoculate, and mix cultures.

Cumulative Dose: In *radiation*, total dose resulting from repeated or continuous exposures to radiation.

Cumulative Ecological Risk Assessment: Consideration of the total ecological risk from multiple stressors to a given eco-zone.

Cumulative Exposure: The sum of exposures of an organism to a pollutant over a period of time.

Cumulative Total Effective Dose Equivalent: The sum of all total effective dose equivalent values recorded foe an individual, where available, for each year occupation doses was received.

Cumulative Trauma Disorder: A disorder caused by the highly repetitive motion required of one or more parts of a worker's body, which in some cases, can result in moderate to total disability.

Cumulative Working Level Months (CWLM): The sum of lifetime exposure to radon working levels expressed in total working level months.

Curb Stop: A water service shutoff valve locate din a water service pipe near the curb and between the water main and the building.

Curbside Collection: Method of collecting recyclable materials at homes, community districts or businesses.

Curie (Ci): Unit of activity equal to 37 billion disintegrations per second.

Current Collector: In *renewable energy*, the conductive plates or wires in a fuel cell that collect electrons n the negative (anode) side and distribute them on the positive (cathode) side.

Cutie-Pie: An instrument used to measure radiation levels**.**

Cutoff grade: The lowest grade, in percent U_3O_8, of uranium ore at a minimum specified thickness that can be mined at specified cost.

Cutting Plane Line: This viewing plane lien is either a thick (heavy) lien with one long and two short dashers or a series of thick (long), equally spaced long dashes.

Cuttings: Spoils left by conventional drilling with hollow stem auger or rotary drilling equipment.

Cyanide: Any chemical compound that contains the cyano groups (C≡N), which consists of a carbon atom-triple-bonded to a nitrogen atom.

Cyanide Poisoning: Cyanide makes the cells of an organism unable to use oxygen, primarily through the inhibition of cytochrome oxidase. Inhalation of high concentrations of cyanide causes a coma with seizers, apnea and cardiac arrest, with death following in a matter of minutes.

Cyanobacteria: In ecology, a large and widespread group of bacteria, typically having a blueish-green pigmentation and thus also know as blue-green algae, that are capable of photosynthesis and that play an important role in the nitrogen cycle.

Cyanosis: Bluish discoloration of the skin due to deficient oxygenation of the blood.

Cyber Attacks: Computer-to-computer attack.

Cyclone Collector: In air pollution control, a cyclone collector is used to remove particles from gas stream by centrifugal force. The cyclone (or centrifugal) collector provides a low-cost, low-maintenance method of removing larger particulates from a gas stream. The cyclone removes particles by inertia separation causing the entire gas stream to flow in a spiral pattern inside a tube and is the collector of choice for removing particles greater than 10 µm in diameter. By centrifugal force, the larger particles more outward and collide with the narrowing wall of the tube. The particles slide down the wall and fall to the bottom of the cone, where they are removed. The cleaned gas flows out the top of the cyclone. Along with their relatively low construction costs, cyclones need relatively small space requirements for installation. However, cyclones are efficient in removing large particles but are not as efficient with smaller particles, especially on particles below 10 µm in size—and they do not handle sticky materials well. For this reason, they are used with other particulate control devices. The most serious problems encountered with cyclones are with air flow equalization, and their tendency to plug. Cyclones have been used successfully at feed and grain mills, cement plants, fertilizer plants, petroleum refineries, and other applications involving large quantities of gas containing relatively large particles.

Cyclone Degritter: In wastewater treatment, uses a rapid spinning motion (centrifugal force) to separate the heavy inorganic solids or grit from the light organic solids. This unit process is normally used on primary sludge (biosolids) rather than the entire wastewater flow. The critical control factor for the process is the inlet pressure. If the pressure exceeds the recommendations of manufacturer, the unit will flood, and grit will carry through with the flow. Grit is separated from flow, washed, and discharged directly to a storage container.

Cyclospora: *Cyclospora* organisms, which until recently were considered blue-green algae, were discovered at the turn of the century. The first human cases of *Cyclospora* infection were reported in the 1970s. In the early 1980s, *Cyclospora* was recognized as pathogen in patients with AIDS. We now know that *Cyclospora* is endemic in many parts of the world, and appears to be an important cause of traveler's diarrhea. *Cyclospora* are two to three times larger than *Cryptosporidium*, but otherwise have similar features. *Cyclospora* diarrheal illness in patients with healthy immune systems can be cured with a week of therapy with timethoprim-sulfamethoxazole (TMP-SMX).

So, exactly what is *Cyclospora?* In 1998, the CDC described *Cyclospora cayetanensis* as a unicellular parasite previously known as a cyanobacterium-like (blue-green algae-like) or coccidian-like body (CLB). The disease is known as Cyclosporasis. *Cyclospora* infects the small intestine and causes an illness characterized by diarrhea with frequent stools. Other symptoms can include loss of appetite, bloating, gas, stomach cramps, nausea, vomiting, fatigue, muscle ache, and fever. Some individuals infected with Cyclospora may not show symptoms. Since the first known cases of illness caused by *Cyclospora* infection were reported in the medial journals in the 1970s, cases have been reported with increased frequency from various countries since the mid-1980s (in part because of the availability of better techniques for detecting the parasite in stool specimens).

Huang et al. (1995) detailed what they believe is the first known outbreak of diarrheal illness associated with *Cyclospora* in the United States. The outbreak, which occurred in 1990, consisted of twenty-one cases of illness among physicians and others working at a Chicago hospital. Contaminated tap water from a physicians' dormitory at the hospital was the probable source of the organisms. The tap water probably picked up the organism while in a storage tank at the top of the dormitory after the failure of a water pump.

The transmission of *Cyclospora* is not a straightforward process. When infected persons excrete the oocyst state of *Cyclospora* in their feces, the oocysts are not infectious and may require from days to weeks to become so (i.e., to sporulate). Therefore, transmission of *Cyclospora* directly from an infected person to someone else is unlikely. However, indirect transmission can occur if an infected person contaminates the environment and oocysts have sufficient time, under appropriate conditions, to become infectious. For example, *Cyclospora* may be transmitted by ingestion of water or food contaminated with oocysts. Outbreaks linked to contaminated water, as well as outbreaks linked to various types of fresh produce, have been reported in recent years (Herwaldt 1997). How common the various modes of transmission and sources of infection is not yet known, nor is it known whether animals can be infected and serve as sources of infection for humans.

Note: *Cyclospora* organisms have not yet been grown in tissue cultures or laboratory animal models.

Persons of all ages are at risk for infection. Persons living or traveling in developing countries may be at increased risk; but infection can be acquired worldwide, including in the United States. In some countries of the world, infection appears to be seasonal.

Based on currently available information, avoiding water or food that may be contaminated with stool is the best way to prevent infection. Reinfection can occur.

Cytotoxic: Having a harmful effect on cells; cell-killing or cell-harming.

D

Dalton's Law of Partial Pressures: In a mixture of theoretically ideal gases, the pressure exerted by the mixture is the sum of the pressures exerted by each component gas of the mixture.

Darcy: A measure of the permeability of rock or sediment. It was originally defined (Wyckoff and others, 1934, 166) as the volume in cubic centimeters of water of 1 centipoise viscosity flowing in 1 sec through an area of 1 cm^2 under a pressure gradient of 1 atmosphere per cm^2 per cm. Although not stated in the definition, the direction of flow must be horizontal to negate gravitation effects. The volume was later changed to 1 ml; thus the darcy now contains the inconsistent unit's cm, ml, and atmosphere. The darcy has a value of 0.987 $(\mu m)^2$, which corresponds closely with the unit proposed for Geological Survey usage.

Darcy's Law: Derived equation for the flow of fluids on the assumption that the flow is laminar and that inertia can be neglected.

Darwinian Theory: Evolution of a species results from the process of natural selection of variations in plants and animals that are best suited to promote survival in their environmental surroundings.

Data Aggregation: The ability to get a more complete picture of the information by analyzing several different types of records at once.

Data Call-In: A part of the Office of Pesticide Programs (OPP) process of developing key required test data, especially on the long-term, chronic effects of exiting pesticides, in advance of scheduled Registration Standard reviews. Data Call-In from manufacturers is an adjunct of the Registration Standards program intended to expedite re-registration.

Data Custodian: The entity currently using or manipulating the data, and therefore, temporarily taking responsibility for the data.

Data Protection: Once your system is in place, daily maintenance must occur to prevent trouble. Individual tasks must be scheduled to fit the individual needs of the organization, and should include a number of different measures and concerns. These include backing up data, ensuring continued operation during high-level problems, and viral protection in a number of different ways.

Datum Plane: An arbitrary surface (or plane) used in the measurement of groundwater heads. The datum most commonly used is the National Geodetic Vertical Datum of 1929, which closely approximates sea level.

Daylighting: Daylighting is the practice of placing windows or other openings and reflective surfaces so that during the day natural light provides effective internal lighting. When properly designed and effectively integrated with the electric lighting system, daylighting can offer significant energy savings by offsetting a portion of the electric lighting load. A related benefit is the reduction in cooling capacity and use by lowering a significant component of internal gains. In addition to energy savings, daylighting generally improves occupant satisfaction and comfort. Windows also provide visual relief, a contact with nature, time orientation, the possibility of ventilation, and emergency egress.

The Daylight Zone—high daylight potential is found particularly in those spaces that are predominantly daytime occupied. Site solar analysis should assess the access to daylight by considering what is "seen" from the various potential window orientations. What proportion of the sky is seen from typical task locations in the room? What are the exterior obstructions and glare sources? Is the building design going to shade a neighboring building or landscape feature that is dependent on daylight or solar access? It is important to establish which spaces will most benefit from daylight and which spaces have little or no need for daylight. Within the spaces that can use daylight, place the most critical visual tasks in positions near the window. Try to group tasks by similar lighting requirements and occupancy patterns. Avoid placing the windows to the direct line of sight of the occupant as this can cause extreme contrast and glare. It is best to orient the occupant at 90 degrees from the window. Where privacy is not a major concern, consider interior glazing (known as relights or borrow lights) that allow light from one space to be shared with another. This can be achieved with transom lights, vision glass, or translucent panels if privacy is required. The floor plan configuration should maximize the perimeter daylight zone. This may result in a building with a higher skin-to-volume ratio than a typical compact building design. A standard widow can produce useful illumination to a depth of about 1.5 times the height of the window. With lightshelves or other reflector systems this can be increased to 2.0 times or more. As a general rule-of-thumb, the higher the window is placed on the wall, the deeper the daylight penetration.

Window Design Considerations—the daylight that arrives at a work surface comes from three sources:

1. The exterior reflected component. This includes ground surfaces, pavement, adjacent buildings, wide windowsills, and objects. Remember that excessive rough reflectance will result in glare.
2. The direct sun/sky component. Typically the direct sun component is blocked from occupied spaces because of heat gain, glare, and UV degradation issues. The sky dome then becomes an important contribution to daylighting the pace.
3. The internal reflected component. Once the daylight enters the room, the surrounding wall, ceiling, and floor surfaces are important light reflectors. Using high reflectance surfaces will better bounce the daylight around the room and it will reduce extreme brightness contrast. Window frame material should be light-colored to reduce contrast with the view and have a non-specular finish to eliminate glare spots. The window jambs and sills can be beneficial light reflectors. Deep jambs should be splayed (angled toward the interior) to reduce the contrast around the perimeter of the window.

Major room furnishings such as office cubicles or partitions can have a significant impact on reflected light so select light-colored materials. Suggested reflectance levels for various room surfaces are:

- Ceilings: > 80 percent
- Walls: 50–70 percent
- Floors: 20–40 percent
- Furnishings: 25–45 percent

Did You Know?

The most important interior light-reflecting surface is the ceiling. High reflectance paints and ceiling tiles are now available with .90 or higher reflectance values. Titling the ceiling plant toward the daylight source increases the daylight that is reflected from this surface. In small rooms should also be a high reflectance matte finish. The sidewalls followed by the floor have less impact on the reflected daylight in the space.

Because light essentially has no scale for architectural purposes, the proportions of the room are more important than the dimensions. A room that has a higher ceiling compared to the room depth will have deeper penetration of daylight whether from side lighting (windows) or top lighting (skylights and clerestories). Raiding the window head height will also result in deeper penetration and more even illumination in the room. Punched window openings, such as small, square windows separated by wall area, result in uneven illumination and harsh contrast between the window and adjacent wall surfaces. A more even distribution is achieved with horizontal strip windows.

Did You Know?

There is no direct sunlight on the polar-side wall of a structure from the autumnal equinox to the spring equinox in parts of the globe north of the Tropic of Cancer and in parts of the globe south of the Tropic of Capricorn.

Effective Aperture (EA)—One method of assessing the relationship between visible light and the size of the window is the effective aperture method. The *effective aperture* (EA) is defined as the product of the visible transmittance and the window-to-wall ratio (WWR). The window-to-wall ratio is the proportion of window area compared to the total wall area where the window is located. For example, if a window covers 25 square feet in a 100 square-foot wall then the WWR is 25/100 or 0.25. A good starting target for EA is in the range of 0.20 to 0.30. For a given EA number, a higher WWR (larger window) results in a lower visible transmittance.

Example: WWR = .5 (half the wall in glazing)
VT= .6, EA = 0.3
Or WWR = .75, VT = .4 for the same EA of 0.3

Did You Know?

Typically, lowering the visible transmittances will also lower the shading coefficient but you must verify this with glazing manufacturer data since this is not always the case.

Light Shelves—are effective horizontal light-reflecting overhangs placed above the eye-level with a transom window placed above it. Light shelves enhance the lighting from windows o the equator-facing side of a building. Exterior shelves are more effective shading devices than interior shelves. A combination of exterior and interior will work best in providing an even illumination gradient.

Toplighting Strategies—large single level floor areas and the top floors of multi-story buildings can benefit from toplighting. The general types of toplighting include skylights, clerestories, monitors, and sawtooth roofs.

- Skylights—horizontal skylights can be an energy problem because they tend to receive maximum solar gain at the peak of the day. The daylight contribution also peaks at midday and falls off severely in the morning and afternoon. There are high performance skylight deigns that incorporate reflectors or prismatic lenses tat reduce eth peak daylight and heat gain while increasing early and late afternoon daylight contributions. Another option is lightpipes where a high reflectance duct channels the light from a skylight down to a diffusing lens in the room. These many be advantageous in deep roof constructions.
- Clerestory window—is a vertical glazing located high on an interior wall. South-facing clerestories can be effectively shaded from direct sunlight by a properly designed horizontal overhand. In this design the interior north wall can be sloped to better reflect the light down into the room. Use light-colored overhangs and adjacent roof surfaces to improve the reflected component. If exterior shading is not possible, consider interior vertical baffles to better diffuse the light. A south-facing clerestory will produce higher daylight illumination that a northern-facing clerestory. East and west facing clerestories have the same problems as east and west windows: difficult shading and potentially high heat gains.
- Roof monitor—consists of a flat roof section raised above the adjacent roof with vertical glazing on all sides. This design often results in excessive glazing area, which results in higher heat losses and gains than a clerestory design. The multiple orientations of the glazing can also create shading problems.
- Sawtooth roof—is an old design often seen in industrial buildings. Typically one sloped surface is opaque and the other is glazed. A contemporary sawtooth roof may have solar collectors or photovoltaic cells on the south-facing slope and daylight glazing on the north-facing slope. Unprotected glazing on the south-facing sawtooth surface may result in high heat gains. In these applications an insulated diffusing panel may be a good choice.

Did You Know?

A building designed for daylighting but without an integrated electrical lighting system will be a net energy loser because of the increased thermal loads. Only when the electric lighting load is reduced will there be more than offsetting savings in electrical and cooling loads. The benefits from daylighting are maximized when both occupancy and lighting sensors are used to control the electric lighting system.

D.B.H: The diameter measured at approximately breast high from the ground.

DDT: The insecticide DDT was first produced in the 1920s, and was extensively used between 1945 and 1965 to control insects. DDT was an excellent insecticide because it was very effective at killing a wide variety of insects at low levels. However, the chemical properties that made this a good insecticide also made it persist in the environment for a long time. This persistence led to accumulation of the pesticide in non-target species, especially raptorial birds (e.g., falcons). Due to the properties of DDT, the concentration of DDT in birds could be much higher than concentrations in insects or soil. Birds at the top of the food chain (e.g., pelicans, falcons, eagles, and grebes) had the highest concentrations of DDT. Although the amount of DDT did not kill the birds, it interfered with calcium metabolism, which led to thin eggshells. As a result, eggs would crack during development, allowing bacteria to enter, which killed the developing embryos. This had a great impact on the population levels of these birds. Peregrine falcons and brown pelicans were placed on the endangered species list in the US, partially due to declining reproductive success of the birds from DDT exposure.

Rachel Carson, a journalist, published *Silent Spring* in 1962, helping to draw attention to this problem. This was the very beginning of the environmental movement in the United States, and is an excellent example of reporting by someone affiliated with the media that identified a problem and warned of many similar problems that could occur unless restrictions were put in place related to chemical pesticide use. Partially as a result of this book, scientists documented the link between DDT and eggshell thinning. This led to DDT being banned for all uses in the United States in the early 1970s. DDT is also banned in Europe. Although it is an excellent insecticide, the known effects on other species, such as raptors, were not acceptable for continued use in the US and Europe because other alternatives were available. However, DDT is still used in developing countries because it is inexpensive and highly effective. Other alternatives are too expensive for these other countries to use.

Deactivation: Placing a facility in a stable and known condition including the removal of hazardous and radioactive materials to ensure adequate protection of the worker, public health and safety, and the environment, thereby limiting the long-term cost of surveillance and maintenance. Actions include the removal of fuel, draining and/or deenergizing nonessential systems, removal of stored radioactive and hazardous materials, and related actions. Deactivation does not include all decontamination necessary for the dismantlement and demolition phase of decommission, e.g., removal of contamination remaining in the fixed structures and equipment after deactivation (DOE O 430.1B).

Dead End: The end of a water main which is not connected to other parts of the distribution system.

Deadmen: Anchors drilled or cemented into the ground to provide additional "reactive" means for DP sampling rigs.

Debris: Any solid material exceeding a 60 mm particle size that is intended for disposal and that is a manufactured object, or plant or animal matter, or natural geologic material.

Decant: To draw off the upper layer of liquid after the heaviest material (a solid or another liquid) has settled.

Decay Products: Degraded radioactive materials, often referred to as "daughters" or "progeny"; radon decay products of most concern from a public health standpoint are polonium-214 and polonium-218.

Decentralized System: Onsite and/or cluster wastewater systems used to treat and disperse or discharge small volumes of wastewater, generally from dwellings and businesses that are located relatively close together. Decentralized system sin a particular management area of jurisdiction are managed by a common management entity.

Decharacterize: Treat a characteristic waste so that is no longer exhibits a characteristic property. For characteristic waste related in clean Water Act and Safety Drinking Water Act systems, decharacterize means dilution.

Dechlorination: Removal of chlorine from a substance.

Decibel (dB): A unit of measure used originally to compare sound intensities and subsequently electrical or electronic power outputs; now also used to compare voltages. In hearing conservation, a logarithmic unit used to express the magnitude of a change in level of sound intensity.

Deciduous: Trees (and other plants) that shed their leaves periodically are said to be deciduous.

Decompose: Breaking apart into smaller different chemicals.

Decomposers: Organisms such as bacteria, mushrooms, and fungi that obtain nutrients by breaking down complex matter in the wastes and dead bodies of other organisms into simpler chemicals, most of which are returned to the soil and water for reuse by producers.

Decomposition: Process whereby a chemical compound is reduced to its component substances. In biology, the destruction of dead organisms either by chemical reduction or by the action of decomposers.

Decontamination: The process of reducing or eliminating the presence of harmful substances such as infectious agents, to reduce the likelihood of disease transmission from those substances.

Decontamination Area: An enclosed area adjacent and connected to the regulated area and consisting of an equipment room, shower area, and clean room, which is used for the decontamination workers, materials, and equipment that are contaminated with asbestos.

Deep Ancient Lakes: These lakes contain animals found nowhere else (endemic fauna). For example, Lake Baikal in Russia.

Deep Dose Equivalent: The dose equivalent derived from external radiation at a depth of 1 cm in tissue.

Deep Percolation: The downward movement of water through the soil and below the root zone.

Defecation: The discharge of feces.

Deferrization: Removal of iron from water in an industrial process.

Deflagration: A rapid chemical reaction in which the output of heat is sufficient to enable the reaction to proceed and be accelerated without input of heat from another source. Deflagration is a surface phenomenon, with the reaction products flowing away from the unreacted material along the surface at subsonic velocity. The effect of a true deflagration under confinement is an explosion. Confinement of the reaction increases pressure, rate of reaction and temperature, and may cause transition into a detonation.

Deflocculating Agent: A material added to a suspension to prevent settling.

Defluoridation: The removal of excess fluoride in drinking water to prevent the staining of teeth.

Defoliant: An herbicide that removes leaves from trees and growing plants.

Deforestation: In *forestry* and *environmental science*, process of clearing land of trees or forest, as for logging or fuelwood, agriculture and livestock raising, settlement, mining, dam building, and so on.

Deforming: Changing shape.

Degasification: A water treatment that removes dissolved gases from the water.

Degradation: In ecology, damage to the ecosystem and loss to biodiversity.

Degree-Day: A rough measure used to estimate the amount of heating required in a given area; is defined as the difference between the mean daily temperature and 65 degrees Fahrenheit. Degree-days are also calculated to estimate cooling requirements.

Delayed Heath Effect: A disease or an injury that happens as a result of exposures that might have occurred in the past.

Delegated State: A state (or other governmental entity such as a tribal government) that has received authority to administer an environmental regulatory program in lieu of a federal counterpart. As use din connection with NPDES, UIC, and PWS programs, the term does not connote any transfer of federal authority to a state.

Deliquescent: Tending to dissolve and become liquid by the absorption of moisture for the air.

Delist: Use of the petition process to have a facility's toxic designation rescinded.

Deluge: A flooding quantity of water.

Deluge Showers: Emergency shower.

Demagnetization: Removal of magnetic properties from material.

Demand-side Waste Management: Prices whereby consumers use purchasing decisions to communicate to product manufacturers that they prefer environmentally sound precuts packaged with the least amount of waste, made from recycled or recyclable materials, and containing no hazardous substances.

Dementia: Marked decline in mental function.

Demineralization: Total removal of all ions (dissolved minerals).

Demolition: The wrecking or taking out of any load-supporting structural member and any related razing, removing, or stripping of asbestos products.

Demulsifier: A chemical used to break an emulsion.

Denitrification: The anaerobic biological reduction of nitrates with nitrogen gas evolved as an end product.

Dense Non-Aqueous Phase Liquid (DNAPL): Of particular concern in groundwater pollution are nonaqueous-phase liquids (NAPLs). NAPLs are classified as either light (LNAPLs) or dense (DNAPLs). LNAPLs include such products (referred to as products because of their potential for commercial reuse) as gasoline, heating oil, and kerosene. The widespread use of underground storage tanks has made these products common in many soils. Because LNAPLs are light, they tend to float on the groundwater, penetrating the capillary fringe and depressing the water surface. Even when the source of the spill is controlled, the soil will remain contaminated, and the floating layer will serve as a long-term source of contamination (McGhee, 1991). From a health standpoint, DNAPLs are a much more serious problem. They include trichloroethane, carbon tetrachloride, creosote, dichlorobenzene, and others. Because these compounds are toxic, with low viscosity, great density, and low solubility, they are not only health hazards, they are also very mobile in groundwater and spread quickly throughout a localized aquifer.

Densification: A mechanical process to compress biomass (usually wood waste) into pellets, briquettes, cubes, or densified logs.

Density: 1. A measure of the compactness of a substance; it is equal to its mass per unit volume and is measure in kg per cubic meter/lb per cubic foot (D = mass/Volume). 2. The weight of a substance per unit of its volume; e.g., pounds per cubic foot.

Density Correction Factor: A factor applied to correct or convert dry air density of any temperature to velocity pressure; the ratio of actual flow to ideal flow.

Density Gradient: Variation in the density of a solution due to variation of the concentration of a solute in a confined solution.

Deoxygenation: A chemical reaction involving the removal of molecular oxygen (O_2) from a reaction mixture or solvent, or the removal of oxygen atoms from a molecule.

Depletion: In evaluating ambient air quality, pertains to the fact that pollutants emitted into the atmosphere do not remain there forever.

Depletion Curve: In hydraulics, a graphical representation of water depletion from storage-stream channels, surface soil, and groundwater. A depletion curve can be drawn for base flow, direct runoff, or total flow.

Depletion Factor: Annual percentage of the depletion of the thermal resource.

Deposition: 1. In chemistry, molecules settling out of a solution. 2. In geology, material (like sediment) being added to a landform. 3. In physics, the process of gas transformation into solid. 4. In air science, a process where aerosol particles set down onto surfaces.

Depressurization: A condition that occurs when the air pressure inside a structure is lower than the air process outdoors. Depressurization can occur when household appliances such as fireplaces or furnaces, that consume or exhaust house air, are not supplied with enough makeup air. Radon may be drawn into a house more rapidly under depressurized conditions.

Derealization: A feeling of altered reality.

Dermacentor: Genus of ticks that includes the species that transmits Rock Mountain spotted fever.

Dermal: Of or relating to the skin or dermis.

Dermal Absorption/Penetration: Process by which a chemical penetrates the skin and enters the body as an internal dose.

Dermal Contact: Contact with (touching) the skin.

Dermal Epidemiology: The study of the amount and distribution of a disease in a specified population by person, place, and time.

Dermal Exposure: This pathway of exposure occurs when a chemical touches the skin. Similar to the oral route of exposure, contact with the skin does not directly lead to a dose. The chemical must move through the skin, the outer layers of which are dead tissue, to the bloodstream before it enters the body. Because the outer layers of the skin are dead, they represent a barrier against absorption. In order for a chemical to be absorbed across the skin, the chemical must be dissolved in fluid. The fluid can diffuse through the skin, moving chemicals with it, until living tissue is reached. At that point, absorption occurs.

One common example of a chemical to which we are primarily exposed via the dermal route is DEET (N-N-diethyl-m-toluamide), which is used in mosquito repellants. Because DEET is typically in a gel or liquid form, some of the applied chemical can cross the skin and be absorbed into the body.

Another example is formalin used as a preservative for biological tissues in school labs. Formalin is a solution containing about one-third formaldehyde, which can cause many different toxic effects, depending on the amount of exposure. Preserved animals are often stored in formalin until distributed to students for dissections, etc. Dermal exposure to formalin will then occur, primarily through the hands. The instructors will generally have a higher exposure because they directly contact the formalin solution. Formalin dermal exposure will lead to very dry skin, but typical exposures in school lab settings should not lead to toxic effects. Wearing gloves will (basically) eliminate this exposure because the formalin will not contact the skin through gloves. This indicates that the dermal exposure route can be controlled through the use of protective clothing. This is the basis of many health and safety requirements in the workplace.

Dermal Toxicity: The ability of a pesticide or toxic chemical to poison people or animals by contact with the skin.

Dermatitis: Inflammation or irritation of the skin from any cause. Industrial dermatitis is an occupational skin disease. design load: The weight that can be safely supported by a floor, equipment or structure, as defined by its design characteristics.

Dermatosis: A skin disease, especially one that is not accompanied by inflammation. (Plural= dermatoses.)

DES: A synthetic estrogen, diethylstilbestrol is used as growth stimulation in food animals. Residues in meat are thought to be carcinogenic.

Desalination: The removal of salts from saline water to provide freshwater. This method is becoming a more popular way of providing freshwater to populations.

Desertification: Creation of deserts by changes in climate, or by human-aided processes.

Desiccant: A chemical agent that absorbs moisture; some desiccants are capable of drying out plants or insects, causing death.

Design Capacity: The average daily flow that a treatment plant or other facility is designed to accommodate.

Design Life: The time period during which satisfactory performance can be expected for a specific set of service conditions.

Design Value: The monitored reading used by EPA to determine an area's air quality status; e.g., for ozone, the fourth highest reading measured over the most recent three years in the design value.

Designated Pollutant: An air pollutant which is neither a criteria nor hazardous pollutant, as described in the Clean Air Act, but for which new source performance standards exist. The Clean Air Act does require states to control these pollutants, which include acid mist, total reduced sulfur (TRS), and fluorides.

Designated Uses: Those water uses identified in state water quality standards that must be achieved and maintained as required under the Clean Water Act. Uses can include cold water fisheries, public water supply, and irrigation.

Designer Bugs: Popular term for microbes developed through biotechnology that can degrade specific toxic chemical at their source in toxic waste dumps or in groundwater.

Desorption: The release of sorbed ions or compounds from solid surfaces. Liberation of tightly held methane gas molecules previously bound to the solid surface of the coal.

Destination Facility: The facility to which regulated medical waste is shipped for treatment and destruction, incineration, and/or disposal.

Destratification: Vertical mixing within a take or reservoir to totally or partially eliminate separate layers of temperature, plant, or animal life.

Destroyed Medical Waste: Regulated medical waste that has been ruined, torn apart, or mutilated through thermal treatment, melting, shredding, grinding, tearing, or breaking, so that it is no longer generally recognized as medical waste, but has not yet been treated (excludes compacted regulate medical waste).

Destruction and Removal Efficiency (DRE): A percentage that represents the number of molecules of a compound removed or destroyed in an incinerator relative to the number of molecules entering the system (e.g., a DRE of 99.99 percent means that 9,999 are destroyed for every 10,000 that enter; 99.99 percent is known as "four nines." For some pollutants, the RCRA removal requirement may be as stringent as "six nines").

Destruction Facility: A facility that destroys regulated medical waste.

Desulphurization: Removal of sulfur from fossil fuels to reduce pollution.

Detection Limit: The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Detection Threshold: Volume of non-odorous air needed to dilute a unit volume of odorous sample air to the point where trained panelists can detect a difference between the two.

Detention Time: 1. The theoretical calculated rime required for a small amount of water to pass through a tank at a given rate of flow. 2. The actual time that a small amount of water is in a settling chamber. 3. In storage reservoirs, the length of time water will be held before being used.

Detergents: Synthetic washing agent that helps to remove dirt and oil. Some contain compounds which kill useful bacteria and encourage algae growth when they are in wastewater that reaches receiving waters.

Determination of Equivalent Treatment (DET): A type of variance from the treatment standards in 40 CFR 268.40; applicable when a technology is specified as the treatment standard. Allows an alternative technology to be used in lieu of the specified technology, if the petitioner can demonstrate that the alternative technology can achieve a mean of performance equivalent to that of the specified technology.

Detonate: The rapid decomposition of an explosive material leading to a rapidly moving wave of high temperature and high pressure. May be started by impact, friction, or heat.

Detonation: A violent chemical reaction within a chemical compound or mechanical mixture involving heat and pressure. A detonation is a reaction that proceeds through the reacted material toward the unreacted material at a supersonic velocity. The result of the chemical reaction is the exertion of extremely high pressure of the surrounding medium, forming a propagating shock wave that is originally of supersonic velocity. When the material is located on or near the surface of the ground, a detonation is normally characterized by a crater.

Detoxification: Biological conversion of a toxic substance to one less toxic.

Detoxify: To treat (an individual), usually under a medically supervised program designed to rid the body of toxic substances.

Detrivores: Also know as detritus feeders or saprophages, are heterotrophs that obtain nutrients by consuming detritus (decomposing organic matter).

Deviation: Failure to meet a required critical limit for a critical control point.

Developable Surface: Is a simple geometric form capable of being flattened without stretching. Many map projections can then be grouped by a particular developable surface: cylinder, cone, or plane.

Development Effects: Adverse effects such as altered growth, structural abnormality, functional deficiency, or death observed in a developing organism.

Dew Point: Temperature at which a sample of air becomes saturated, i.e., has a relative humidity of 100 percent.

Dewatering: The physical or chemical process of removing water from sludge or biosolids.

Diamagnetic Materials: A substance that is repelled by a magnet, includes bismuth, antimony, sodium chloride, gold, and mercury.

Diatomaceous Earth: A chalk-like material (fossilized diatoms) used to filter out solid waste in wastewater treatment plants; also used as an active ingredient in some powdered pesticides.

Diatoms: Microscopic single-celled alga found in all parts of the world.

Diazinon: An insecticide. In 1986, EPA banned its use on open areas such as sod farms and golf courses because it posed danger to migratory birds. The band did not apply to agriculture, home lawn or commercial establishment uses.

Dibenzofurans: A group of organic compounds, some of which are toxic.

Dictionary Attack: An attack that tries all of the phrases or words in a dictionary, trying to crack a password or key. A dictionary attack uses a predefined list of words compared to a brute force attack that tries all possible combinations.

Differential Pressure: The pressure drop along a conveyance component in fluid flow between the inlet and outlet.

Diffused Air: A type of aeration that forces oxygen into sewage by pumping air through perforated pipes inside a holding tank.

Diffuser: In *wastewater treatment*, an aerating device for sewage and industrial waste water treatment plants; a membrane with fine pores, through which fine bubbles are generated by the supply of air provided by blowers.

Diffusion: (1) Mixing of substances, usually gases and liquids, from molecular motion. (2) The spreading out of a substance to fill a space.

Digester: In *wastewater treatment*, the stabilization of organic matter is accomplished biologically in a digester using variety of organisms. The microorganisms convert the colloidal and dissolved organic matter into various gases and into protoplasm. Because protoplasm has a specific gravity slightly higher than that of water, it can be removed from the treated liquid by gravity.

Digester Gas: Biogas that is produced using a digester which is an airtight vessels or enclosure in which bacteria decomposes biomass in water to produce biogas.

Digestion: In *wastewater treatment*, the purpose of aerobic digestion is to stabilize organic matter, to reduce volume, and to eliminate pathogenic organisms. Aerobic digestion is similar to the activated biosolids process. Biosolids are aerated for 20 days or more. Volatile solids are reduced by biological activity. In anaerobic digestion the purpose is the same as aerobic digestion: to stabilize organic matter, to reduce volume, and to eliminate pathogenic organism. Equipment used in anaerobic digestion includes an anaerobic digester of either the floating or fixed cover type. These include biosolids pumps for biosolids addition and withdrawal, as well as heating equipment such as heat exchangers, heaters and pumps, and mixing equipment for recirculation. Typical ancillaries include gas storage, cleaning equipment, and safety equipment such as vacuum relief and pressure relief devices, flame traps, and explosion-proof electrical equipment. In the anaerobic process, biosolids enter the sealed digester where organic matter decomposes anaerobically. Anaerobic digestion is a two-stage process: (1) sugars, starches, and carbohydrates are converted to volatile acids carbon dioxide, and hydrogen sulfide, and (2) volatile acids are converted to methane gas.

Dike: An embankment or ridge of either natural or man-made materials used to prevent the movement of liquids, sludges, solids, or other materials.

Diluent: Any liquid or solid material used to dilute or carry an active ingredient.

Dilute: Adding material to a chemical by the user or manufacturer to reduce the concentration of active ingredient in the mixture.

Dilute Solutions: A solution weakened by the addition of water, oil, or other liquid or solid.

Dilution Ratio: The relationship between the volume of water in a stream and the volume of incoming water. It affects the ability of the stream to assimilate waste.

Dilution Ventilation (General Exhaust Ventilation): A form of exposure control that involves diluting contaminated air with uncontaminated air, to reduce the concentration below a given level (usually the threshold limit value of the contaminant) to control potential airborne health hazards, fire and explosive conditions, odors, and nuisance type contaminants. This is accomplished by removing or supplying air, to cause the air in the workplace to move, and as a result, mix the contaminated with incoming uncontaminated air.

Dinoflagellates: Unicellular, photosynthetic protistan algae.

Dinoseb: A herbicide that is also used as a fungicide and insecticide. It was banned by EPA in 1986 because it posed the risk of birth defects and sterility.

Dioxin: Any of a family of compounds known chemically as dibenzo-p-dioxins. Concern about them arises from their potential toxicity as contaminants in commercial products. Tests on laboratory animals indicate that it is one of the more toxic anthropogenic (man-made) compounds.

Direct Discharger: A municipal or industrial facility which introduces pollution through a defined conveyance or system such as outlet pipes; a point source.

Direct Filtration: A method of treating water which consists of the addition of coagulant chemicals, flashing mixing, coagulation, minimal flocculation, and filtration.

Direct Flame Combustion (flaring): Used in air pollution control technology to burn-off process off gases (for example, methane).

Direct Push: Technology used for performing subsurface investigations by driving, pushing, and /or vibrating small-diameter hollow steel rods into the ground. Also known as direct drive, drive point, or push technology.

Direct Reading Instruments for Air Sampling: Direct reading instruments are used for on-site evaluations for a number of reasons, including:

- To find the sources of emission of hazardous contaminants on the spot
- To ascertain if select OSHA air standards are being exceeded
- To check the performance of control equipment
- As continuous monitors at fixed locations,
    - to trigger an alarm system in the event of breakdown in a process control which could result in the accidental release of copious amounts of harmful substances to the workroom atmosphere
    - To obtain permanent recorded documentation of the concentrations of a contaminant in the atmospheric environment for future use in epidemiological and other types of occupational studies, in legal actions, to inform employees as to their exposure, and for information required for improved design of control measures.

Such on-site evaluations of the atmospheric concentrations of hazardous substances make possible the immediate assessment of undesirable exposures and enable the industrial hygienist to make an immediate correction of an operation, in accordance with his/her judgment of the seriousness of a situation, without permitting further risk of injury to the workers (NIOSH, 2005).

Types of Direct Reading Instruments

There are two types of direct reading instruments used in air sampling: direct reading physical instruments and direct reading colorimetric devices.

1. Direct Reading Physical Instruments

The physical properties of gases, aerosols, and vapors are used in the design of direct reading physical instruments for quantitative estimations of these types of contaminants in the atmosphere. The various types of these instruments, the principle of operation, and a brief description of application are presented in the following discussion.

- *Aerosol Photometry*—measures, records and controls particulates continuously in areas requiring sensitive detection of aerosol levels; detection of 0.05 to 40 μm diameter particles. Computer interface equipment is available.
- *Chemiluminescence*—measurement of NO in ambient air selectivity and NO_x after conversion to NO by hot catalyst. Specific measurement of O_2. No atmospheric interferences.
- *Colorimetry*—measure and separate recording of NO_{2-}, NO_x, SO_2, total oxidants, H_2S, HF, NH_3, Cl_2 and aldehydes in ambient air.
- *Combustion*—detects and analyzes combustible gases in terms of percent LEL (Lower Explosive Limit) on graduated scale. Available with alarm set at 1/3 LEL.
- *Conductivity, Electrical*—records SO_2 concentrations in ambient air. Some operate off a 12-volt car battery. Operate unattended for periods up to thirty days.
- *Coulometry*—continuous monitoring of NO, NO_2, O_x, and SO_2 in ambient air. Provided with strip chart recorders. Some require attention only once a month.
- *Flame Ionization (with gas chromatograph)*—continuous determination and recording of methane, total hydrocarbons and carbon monoxide. Catalytic conversion of SO to CH_4. Operates up to three days unattended. Separate model for continuous monitoring of SO_2, H_2S and total sulfur in air. Unattended operation up to three days.
- *Flame Ionization (Hydrocarbon Analyzer)*—continuous monitoring of total hydrocarbons in ambient air; potentiometric or optional current outputs compatible with any recorded. Electronic stability from 32° to 110°F.
- *Gas Chromatograph, Portable*—on site determination of fixed gases, solvent vapors, nitro and halogenated compounds and light hydrocarbons. Instruments available with choice of flame ionization, electron capture or thermal conductivity detectors and appropriate columns for desired analyses. Rechargeable batteries.
- *Infrared Analyzer (Photometry)*—continuous determination of a given component in a gaseous or liquid stream by measuring amount of infrared energy absorbed by component of interest using pressure sensor technique. Wide variety of applications include CO, CO_2, Freons, hydrocarbons, nitrous oxide, NH_3, SO_2 and water vapor.
- *Photometry, Ultraviolet (tuned to 253.7 mμ)*—direct readout of mercury vapor; calibration filter is built into the meter. Other gases or vapors which interfere include acetone, aniline, benzene, ozone and others with absorb radiation at 253.7 mμ.
- *Photometry, Visible (Narrow-centered 394 mμ band pass)*—continuous monitoring of SO_2, SO_3, H_2S, mercaptans and total sulfur compounds in ambient air. Operates more than 3 days unattended.
- *Particle Counting (Near Forward Scattering)*—Reads and prints directly particle concentrations at 1 of 3 preset time intervals of 100, 1000 or10,000 seconds, corresponding to 0.01, 0.1 and 1 cubic foot of sampled air.
- *Polarography*—monitor gaseous oxygen in flue gases, auto exhausts, hazardous environments and in food storage atmospheres and dissolved oxygen in wastewater samples. Battery operated, portable, sample temperature 32° to 110°F, up to 95 percent relative humidity. Potentiometric recorder output. Maximum distance between sensor and amplifier is 1000 feet.
- *Radioactivity*—Continuous monitoring of ambient gamma and x-radiation by measurement of ion chamber currents, averaging or integrating over a constant recycling time interval, sample temperature limits 32°F to 120°F; 0 to 95 percent relative humidity (weatherproof detector); up to 1,000 feet remote sensing capability. Recorder and computer outputs. Complete with alert, scram and failure alarm systems. All solid-state circuitry.
- *Radioactivity*—Continuous monitoring of beta or gamma emitting radioactive materials within gaseous or liquid effluents; either a thin wall Geiger-Mueller tube or a gamma scintillation crystal detector is selected depending on the isotope of interest; gaseous effluent flow—4 cfm; effluent sample temperature limits 32°F to 120°F using scintillation detector and -65°F to 165°F using G-M detector. Complete with high radiation, alert and failure alarms.
- *Radioactivity*—Continuous monitoring of radioactive airborne particulates collected on a filter tape transport system; rate or air flow – 10 SCFM; scintillation and G-M detectors, optional but a beta sensitive plastic scintillator is provided to reduce shielding requirements and offer grater sensitivity. Air sample temperature limits 32°F to 120°F; weight 550 pounds. Complete with high and low flow alarm and a filter failure alarm.

2. Direct-Reading Colorimetric Devices

Direct-reading colorimetric devices are widely used, easy to operate, and inexpensive. They utilize the chemical properties of an atmospheric contaminant for the reaction of that substance with a color-producing reagent, revealing stain length or color intensity. Stain lengths or color intensities can be read directly to provide an instantaneous value of the concentration accurate within ± 25 percent. Reagents used in detector kits may be in either a liquid or a solid phase or provided in the form of chemical treated papers. The liquid and solid reagents are generally supported in sampling devices through which a measured amount of contaminated air is drawn. On the other hand, chemically treated papers are usually exposed to the atmosphere and the reaction time noted for a color change to occur (NIOSH, 2005).

Calibration of Direct-Reading Instruments
Two common methods used for calibrating direct-reading instruments are:

- The static method—is easy to use and efficient. A known volume of gas is introduced into the instrument and sampling is performed for a limited period of time.
- The dynamic method—the instrument is used to monitor a known concentration of the contaminant to test its accuracy.

Disaster Recovery Plan (DRP): A program and system for the recovery of IT systems in the event of a disruption or disaster.

Discharge: The volume of water that passes a given location within a given period of time. Usually expressed in cubic feet per second.

Discharge Criteria: When used in this text, discharge criteria refers to conditions established in the CAFO regulations to describe the circumstances under which a medium-size AFO is defined as a CAFO or a small-size AFO may be designated as a CAFO. These conditions are the following:

1. Pollutants are discharged into waters of the United States through a man-made ditch, flushing system, or other similar man-made device.
2. Pollutants are discharged directly into waters of the U.S. which originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operation (40 CFR 122.23(b)(6)(ii)).

Disease Prevention: Measures used to prevent a disease or reduce its severity.

Disease Registry: A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

Disinfectant: A chemical or physical process that kills pathogenic organism in water, air, or on surfaces. Chlorine is often used to disinfect sewage treatment effluent, water supplies, wells, and swimming pools.

Disinfectant By-Product: Natural organic matter (NOM) is used to describe the complex mixture of organic material, such as humic and hydrophilic acids present in all drinking water sources. NOM can cause major problems in the treatment of water as it reacted with chlorine to form disinfection by-products (DBPs). Many of the disinfection DBPs formed by the reaction of NOM with disinfectants, are reported to be toxic and carcinogenic to humans if ingested over an extended period. The removal of NOM and hence reduction in DBPs is a major goal in the treatment of any water source.

Disinfectant Time: The time it takes water to move from the point of disinfectant application (or the previous point of residual disinfectant measurement) to a point before or at the point where the residual disinfectant is measured. In pipelines, the time is calculated by dividing the internal volume of the pipe by the maximum hourly flow rate; within mixing basins and storage reservoirs it is determined by tracer studies of an equivalent demonstration.

Disinfection: Effective killing by chemical or physical processes all organisms capable of causing infectious disease (chlorination is commonly employed for disinfection in water and wastewater treatment processes).

Disinfection of Water/Wastewater (Chlorination): Like drinking water, liquid wastewater effluent is disinfected. Unlike drinking water, wastewater effluent is disinfected not to directly (direct end-of-pipe connection—at least in most cases) protect a drinking water supply, but instead is treated to protect public health in general. This is particularly important when the secondary effluent is discharged into a body of water used for swimming or water supply for a downstream water supply.

In the treatment of water for human consumption, treated water is typically chlorinated (although ozonation is also currently being applied in many cases). Chlorination is the preferred disinfection in potable water supplies because of chlorine's unique ability to provide a residual. This chlorine residual is important because when treated water leaves the waterworks facility and enters the distribution system; the possibility of contamination is increased. The residual works to continuously disinfect water right up to the consumer's tap.

CHLORINE DISINFECTION
Chlorination for disinfection follows all other steps in conventional wastewater treatment. The purpose of chlorination is to reduce the population of organisms in the wastewater to levels low enough to ensure that pathogenic organisms will not be present in sufficient quantities to cause disease when discharged.

Note: Chlorine gas is heavier than (vapor density of 2.5). Therefore, exhaust from a chlorinator room should be taken from floor level.

Note: The safest action to take in the event of a major chlorine container leak is to call the fire department.

Note: You might wonder why it is that chlorination of critical waters such as natural trout streams is not normal practice. This practice is strictly prohibited because chlorine and its by-products (i.e., chloramines) are extremely toxic to aquatic organisms.

Chlorination Terminology
Remember that there are several terms used in discussion of disinfection by chlorination. Because it is important for the operator to be familiar with these terms, we repeat key terms again.

- *Chlorine*—a strong oxidizing agent which has strong disinfecting capability. A yellow-green gas which is extremely corrosive, and is toxic to humans in extremely low concentrations in air.
- *Contact Time*—the length of time the time the disinfecting agent and the wastewater remain in contact.
- *Demand*—the chemical reactions, which must be satisfied before a residual or excess chemical will appear.
- *Disinfection*—refers to the selective destruction of disease-causing organisms. All the organisms are not destroyed during the process. This differentiates disinfection from sterilization, which is the destruction of all organisms.
- *Dose*—the amount of chemical being added in milligrams/liter.
- *Feed Rate*—the amount of chemical being added in pounds per day.
- *Residual*—the amount of disinfecting chemical remaining after the demand has been satisfied.
- *Sterilization*—the removal of all living organisms.

Wastewater Chlorination Facts
Chlorine Facts

- Elemental chlorine (Cl_2—gaseous) is a yellow-green gas, 2.5 times heavier than air.
- The most common use of chlorine in wastewater treatment is for disinfection. Other uses include odor control and activated sludge bulking control. Chlorination takes place prior to the discharge of the final effluent to the receiving waters.
- Chlorine may also be used for nitrogen removal, through a process called *breakpoint chlorination.* For nitrogen removal, enough chlorine is added to the wastewater to convert all the ammonium nitrogen gas. To do this, approximately 10 mg/l of chlorine must be added for every 1 mg/l of ammonium nitrogen in the wastewater.
- For disinfection, chlorine is fed manually or automatically into a chlorine contact tank or basin, where it contacts flowing wastewater for at least 30 minutes to destroy disease-causing microorganisms (pathogens) found in treated wastewater.
- Chorine may be applied as a gas, a solid, or in liquid hypochlorite form.
- Chorine is a very reactive substance. It has the potential to react with many different chemicals (including ammonia), as well as with organic matter. When chlorine is added to wastewater, several reactions occur:
    1. Chlorine will react with any reducing agent (i.e., sulfide, nitrite, iron, and thiosulfate) present in wastewater. These reactions are known as *chlorine demand.* The chlorine used for these reactions is not available for disinfection.
    2. Chlorine also reacts with organic compounds and ammonia compounds to form chlor-organics and chloramines. Chloramines are part of the group of chlorine compounds that have disinfecting properties and show up as part of the chlorine residual test.
    3. After all of the chlorine demands are met, addition of more chlorine will produce free residual chlorine. Producing free residual chlorine in wastewater requires very large additions of chlorine.

Hypochlorite Facts
Hypochlorite, though there are some minor hazards associated with its use (skin irritation, nose irritation, and burning eyes), is relatively safe to work with. It is normally available in dry form as a white powder, pellet or tablet or in liquid form. It can be added directly using a dry chemical feeder or dissolved and fed as a solution.

Note*:* In most wastewater treatment systems, disinfection is accomplished by means of combined residual.

Disintegrations Per Minute (dpm): Number of nuclear transformation from radioactive decay in a one-minute time interval.

Dispersant: A chemical agent used to break up concentrations of organic material such as spilled oil.

Disperse: To scatter in different directions.

Dispersion: The dilution and reduction of concentration of pollutants in either air or water. Air pollution dispersion mechanisms are a function of the prevailing meteorological conditions.

Dispersion: The spreading and mixing of chemical constituents in ground water caused by diffusion and mixing because of microscopic variations in velocities within and between pores.

Disposables: Consumer products, other items, and packaging used once or a few times and discarded.

Disposal: Final placement or destruction of toxic, radioactive, or other wastes; surplus or banned pesticides or other chemicals; polluted soils; and drums containing hazardous materials from removal actions or accidental releases. Disposal may be accomplished though use of approved security landfills, surface impoundments, land farming, deep-well injection, ocean dumping, or incineration.

Disposal Facilities: Repositories for solid waste, including landfills and combustors intended for permanent containment or destruction of waste material. Excludes trans stations and composting facilities.

Dissolved Oxygen (DO): The molecular oxygen dissolved in water, wastewater, or other liquid; generally expressed in milligrams per liter, parts per million, or percent of saturation.

Dissolved Solids: Disintegrated organic and inorganic material in water. Excessive amounts make water unfit to drink or use in industrial processes.

Distillation: The act of purifying liquids through boiling, so that the steam or gaseous vapors condense to a pure liquid. Pollutants and contaminants may remain in a concentrated residue.

Disturbance: Any event or series of events that disrupt ecosystem, community, or population structure and alters the physical environment.

Diuretic: Tending to increase the discharge of urine.

Diurnal Flow Variation: Fluctuations that occur during the day.

Diversion: 1. Use of part of a stream flow as water supply. 2. A channel with a supporting ridge on the lower side constructed across a slope to divert water at a non-erosive velocity to sites where it can be used and disposed of.

Diversion Rate: The percentage of waste materials diverted from traditional display such as landfilling or incineration to be recycled, composted, or re-used.

DM: Dry matter.

DNA: A nucleic acid that carries the genetic information in the cell and is capable of self-replication and synthesis of RNA.

DNA Hybridization: Use of a segment of DNA, called a DNA probe, to identify its complementary DNA; used to detect specific genes.

DNAPLs (Dense Nonaqueous-Phase Liquids): Dense nonaqueous-phase liquids including carbon tetrachloride, creosote, trichloroethane, dichlorobenzene, and others, which can contaminate groundwater supplies.

Dobson Unit (DU): Units of ozone level measurement. If, for example, 100 DU of ozone were brought to the earth's surface they would form a layer one millimeter thick. Ozone levels vary geographically, even in the absence of ozone depletion.

Dobsonflies: Dobsonfly larvae are extremely ugly (thus, they are rather easy to identify) and can be rather large, anywhere from 25 to 90 mm (1–3") in length. The body is stout, with eight pairs of appendages on abdomen. Brush-like gills at base of each appendage look like "hairy armpits". The elongated body has spiracles (spines) and has three pairs of walking legs near the upper body and one pair of hooked legs at the rear. The head bears four segmented antennae, small compound eyes, and strong mouth parts (large chewing pinchers). Coloration varies from yellowish, brown, gray and black, often mottled. Dobsonfly larvae, commonly known as hellgrammites, are customarily found along stream banks under and between stones. As indicated by the mouthparts, they are predators and feed on all kinds of aquatic organisms. They are an important food source for larger game fish.

Doghouse: The room or vehicle that houses the seismic recording equipment.

DOI: U.S. Department of Interior. The government agency that protects and provides access to our Nation's natural resources.

Domestic Application: Pesticide application in and around houses, office buildings, motels, and other living or working areas.

Domestic Uranium Industry: Collectively, those businesses (whether U.S. or foreign-based) that operate under the laws and regulations pertaining to the conduct of commerce within the United States and its territories and possessions and that engage in activities within the United States, its territories, and possessions specifically directed toward uranium exploration, development, mining, and milling; marketing of uranium materials; enrichment; fabrication; or acquisition and management of uranium materials for use in commercial nuclear power plants.

Domestic Wastewater: Consists mainly of human and animal wastes, household wastes, and small amounts of groundwater infiltration and perhaps small amounts of industrial wastes.

Domestic Water Use: Water used for household purposes; such as drinking, food preparation, bathing, washing clothes, dishes, and dogs, flushing toilets, and watering lawns and gardens. About 85 percent of domestic water is delivered to homes by a public-supply facility, such as a county water department. About 15 percent of the Nation's population supply their own water, mainly from wells.

Dormancy: In *botany*, a special condition in which seeds or buds enter a state of arrested development.

Dosage/Dose: 1. An exposure level. The actual quantity of a chemical administered to an organism or to which it is exposed. 2. The amount of substance that reaches a specific tissue (e.g., the liver). 3. The amount of a substance available for interaction with metabolic processes after crossing the outer boundary of an organism. 4. Exposure is expressed as weight or volume of test substance per volume of air (mg/l), or as parts per million (ppm).

Dose Equivalent: Quantity of radiation dose expressing all radiation on a common scale for calculating the effective absorbed dose. The units of dose equivalent are the rem and sievert (SV).

Dose Rate: In exposure assessment, dose per time unit (e.g., mg/day) sometimes also called dosage.

Dose Response: This is typically the primary thrust of basic toxicology courses. The dose-response relationship defines the potency of a chemical. It relates the amount of chemical to a specific effect. There are two types of basic does-response relationships: threshold and non-threshold. Potency is only meaningful if used in comparison with another chemical (e.g., strychnine is more potent than table salt). Similarly, "highly toxic" is a subjective term when used alone. If used in comparison with other chemicals (dioxin is highly toxic to guinea pigs compared to hamsters); the term has more meaning.

Dose-Response Assessment: 1. Estimating the potency of a chemical. 2. In exposure assessment, the process of determining the relationship between the dose of a stressor and a specific biological response. 3. Evaluating the quantitative relationship between dose and toxicological responses.

Dose-Response Curve: A visual means of determining, based on collected data, the percent mortality to dose administered.

Dose-response Evaluation: The toxicological evaluation of the potency of a chemical.

Dose-Response Relationship: Used by toxicologists upon which to base toxicological considerations. A dose is administered to test animals, and depending on the outcome, is increased or decreased until a range is found where at the upper end all animals die, and at the lower end, all animals survive.

Dosimeter: 1. Measuring tool that provides a time-weighted average over a period of time such as one complete work shift. 2. A device used to determine the external radiation dose a person has received.

DOT: An acronym for United States Department of Transportation.

DOT Emergency Response (Subpart G—§172.600): With billions of tons of hazardous materials and wastes transported each year throughout the United States, and with Truck Transport accounting for approximately half of the hazardous materials shipments per day, accidents happen.

The most common Hazmat accident is relatively minor (for example, a package becomes punctured or crushed, and a minor leak or spill results). However, no matter how minor the incident, Hazmat employers and employees must be trained to properly respond.

Proper preparation for mitigation of Hazmat incidents begins with having a plan—a written plan. The second step is to make sure that the plan is accessible to all of those who may have to employ it during an actual incident. The third step is to make sure that those who use the plan are properly trained—not only to mitigate the situation but to do it safely.

When we speak of "safely," we are speaking of a three-branched process. One branch requires us to ensure the responder's safety. Another branch requires us to ensure the safety of the public. The final branch of this process is to ensure the safety of the environment (air, water, and soil), which, of course, affects all of us.

The safe handling and transport of hazardous materials, which include explosives, flammables, corrosive or toxic chemicals, spent reactor fuel, low-level radioactive wastes, and disease-causing biological agents, are a major concern to those agencies and organizations responsible for responding to incidents involving them.

What happens in the first few seconds and minutes of any hazardous materials incident can determine its outcome. The actions of the first responder on the scene may therefore be crucial. It does not take a rocket scientist to determine who is most likely to be the first responder. In a trucking incident, it will probably be the driver—a Hazmat employee—(that is, if the driver is still able to respond).

If the incident is responded to by professional firefighters, law enforcement officers, emergency medical services personnel, and transporters of hazardous materials, one thing is certain: They all face immediate challenges at the scene of any accident that involves or could involve hazardous materials—thus their training is of primary importance. Indeed, an untrained responder who is overcome by the effects of the hazardous materials will simply have to be rescued along with other victims on the scene. This is, obviously, a result that the DOT Hazardous Materials Regulations are trying to prevent.

DOT's Emergency Response Information is contained in Subpart G §§§§172.600, 172.602, 172.604, and 172.606. We present the basic tenets of each of these sections below.

The standard general precautions the Hazmat employee should take any time a Hazmat incident occurs include:

1. Always protect yourself. Always use protective equipment at all times.
2. Identify the hazard, both to protect yourself and to provide guidance for an appropriate response.
3. Secure the scene immediately. Keep bystanders away and cordon off the area.
4. Request assistance. Contact your dispatcher or CHEMTREC directly to request that proper authorities are notified of the incident.

✔ **Important Point:** CHEMTREC, the Chemical Transportation Emergency Center, is operated by the Chemical Manufacturers Association. CHEMTREC is available twenty-four hours a day, seven days a week. Responders can dial CHEMTREC's toll-free number (1-800-424-9300) from anywhere in the U.S. CHEMTREC provides immediate advice at the scene of the emergency.

5. CHEMTREC communicators can help more efficiently if they receive the basic information needed. If the vehicle is placarded, provide the ID number from the placard or orange panel on the vehicle, and the name of the product from the shipping papers, if they are available. The shipping papers also contain information about the shipper and the point of origin and destination.

The dispatcher selects a response team based on the information gathered at the scene by the first responder and additional information and assistance provided by CHEMTREC and the manufacturer.

✔ **Important Point:** Emergency response information must be printed in English and offered with most Hazmat shipments in one of three ways:

- On a shipping paper
- In a separate document that includes both the proper shipping name and technical name of the material (e.g., MSDS)
- In a separate document that cross-references the description of the material on the shipping paper with the response information in the document (e.g., the North American Emergency Response Guidebook)

North American Emergency Response Guidebook

The *North American Emergency Response Guidebook* is published every three to four years by DOT's **Research and Special Programs Administration (RSPA).** RSPA is responsible for making and revising the Hazardous Materials Regulations.

The purpose of the *Guidebook* is to assist responders in making initial decisions upon arriving at the scene of a dangerous goods incident. In addition, the *Guidebook* is designed to assist the driver in relaying information, if necessary, about the dangerous goods he or she is transporting to the emergency responders.

If you are a carrier, you should keep a copy of the *Guidebook* close at hand in the cab of your vehicle at all times. You will find the phone number of CHEMTREC (for United States), SETIQ (Mexico), CANUTEC (Canada) in the guide, along with the phone number for the National Response Center [CHEMTREC and the National Response Center (NRC) work cooperatively to provide twenty-four-hour assistance to emergency responders, carriers, shippers, and anyone handling hazardous materials].

If the need arises to call any of these emergency information centers, try to provide as much information as possible about the incident. Five basic pieces of information that should be provided are:

- Caller name and call back number
- Name of carrier, shipper/manufacturer or facility operator, and responsible party
- Nature, location and time of the incident
- Name of material released or any identifying information
- Container type, railcar/truck number, vessel name, or other identifying information

Table of Placards and Initial Response Guides

The *Table of Placards and Initial Response Guides To Use On-Scene* (pp. 14-15 in the *North American Emergency Response Guidebook*) should only be used if materials can't be specifically identified by using shipping papers, numbered placard or the orange panel number. The placards themselves are referred to as Guides. Each guide has an identifying number. For example, Guide 153 on this table shows the placard for a shipment of corrosives. The number at the apex of the guide number (number "8") refers to the Hazard Class or Division (Corrosives). Page 11 of the Guidebook lists the hazard classes. These Guides are referenced later in the Guidebook.

Guidebook Yellow Pages

The yellow section of the Guidebook provides a listing of chemicals chronologically in the order of their UN shipping number. For example:

ID No.	GUIDE No.	Name of Material
1590	153	Dichloroanilines

The number 1590 is the UN shipping number designation for the material dichloroanilines, which must appear on the shipping manifest. Turning back to the Table of Placards, we see that Guide 153 is a placard showing the skull and crossbones (**Note:** Guide 153 is also used for class 8 corrosives), and the hazard class or division is 6. Class 6 is a poison.

Guidebook Blue Pages

The blue section contains the same information on materials found in the yellow section, but listed alphabetically.

Example 1:
Look up kerosene and obtain
1. the UN shipping number
2. the Guide number you should refer to
3. the hazard class or division

From the Guidebook blue section we find: UN 1223, Guide 128, and Hazard Class 3 (fuel oil, a flammable liquid).

Example 2:
Look up the material london purple and obtain
1. the UN shipping number
2. the Guide number you should refer to
3. the hazard class or division

From the Guidebook blue section we find: UN 1621, Guide 151, and Hazard Class 6 (Harmful: Stow Away from Foodstuffs).

Guidebook Orange Pages

The orange section provides specific information on the potential hazards and the emergency response actions to be taken in the event of a spill. For london purple, look up Guide 151. Guide 151 provides us with information on how to handle this material in a spill or fire, as well as first aid information.

Guidebook Green Pages

The green section contains a Table of Initial Isolation and Protective Action Distances. This provides some guidance on safe distances to retreat in the event of a spill. As an example, if we have a hazardous materials highway incident where coal gas is spilled (UN 1023), by examining the table we find that for a small spill, we would have to isolate a minimum of 100 feet in all directions and up to 0.1 mile downwind from the source. For a large spill, the initial isolation distance recommended from the tale is 100 feet in all directions, and a minimum of 0.2 miles downwind.

✔ **Important Point:** Exactly what constitutes a large spill and a small spill is subjective and depends on personal judgment.

✔ **Important Point:** The *North American Emergency Response Guidebook* can be obtained From Labelmaster, 5724 N. Pulaski Road, Chicago, IL 60646-6797, 1-800-621-5808.

DOT Marking and Labeling Requirements: When anyone offers a hazmat for transportation, or transports a hazmat, each package, freight container, and transport vehicle containing the hazmat must be marked in the manner required by the HMR. The term *marking* as used in the HMR refers to placing the required information on the outer package containing the hazardous materials. This includes a proper shipping name, identification number with the appropriate prefix, specifications or UN markings, plus any other required information, instructions and/or cautions.

OSHA's impact on the safety of individuals involved in some facet of the trucking industry is important, especially in shipping, handling, producing, and transporting of hazardous materials. However, DOT's part in protecting the safety and well-being of all those involved in any and all aspects of hazmat transportation certainly is not insignificant.

HM-181, HM-215C Dockets

Hazardous Materials Certification Training for DOT 49 CFR Transportation employees (Hazmat employees) entails several individual elements that work together comprehensively.

For example, along with training on the laws and regulations applicable to hazardous materials, in all recent dockets including HM-181 and HM-215C, Hazmat employees must be informed about newly expanded registration requirements.

The organizational training person responsible for training Hazmat employees according to DOT's guidelines must determine who must be trained at each of the general awareness, function specific, and safety training levels, and must also determine the required scope of training at each level. The minimum training frequency must also be determined, as well as how to document the training.

✔ **Important Point:** Training employees is a standard requirement under OSHA, USEPA, DOT and other regulatory agencies. The organization responsible for such training must be careful in several regards but especially when it comes to proper documentation of the training. As mentioned, if training is not properly documented, in the eyes of the concerned regulators and lawyers and judges, the training NEVER took place. Be careful on this item; it is critical to your success—to your compliance effort.

As obvious and critical as properly documenting training, the training content is also critically important. Along with the elements of the required 49 CFR DOT training mentioned earlier, several other training elements must be included.

Each Hazmat employee must know, for example, what a Hazardous Material is. More specifically, they must know:

- How to determine which materials are classified by DOT as hazardous
- How to distinguish between hazardous materials, hazardous wastes, hazardous chemicals, and hazardous substances
- Hazard class definitions
- How to use the hazardous materials table
- Subsidiary hazard classes and the Precedence of Hazard Table
- How to determine which packing group applies to your hazardous materials: Packing Group I, II, or III
- How to safely manage and handle containers
- Performance-oriented containers
- Non-bulk container codes
- Container performance tests
- Requirements for container reuse
- How to select the appropriate primary and subsidiary labels
- Bulk and non-bulk marking requirements
- Requirements for bills of lading (shipping papers) and hazardous waste manifests
- Step-by-step procedures for completing shipping papers
- How to determine the correct proper shipping name
- Special shipping paper entries for toxics, hazardous substances, and limited quantities
- Practical exercises on selecting shipping names, packaging, marking, labeling, and placarding shipments of hazardous materials
- Separation and segregation requirements
- Safe handling procedures for working with hazardous materials
- How to avoid accidents
- How to select the appropriate placard and when to use the dangerous placard
- Emergency response procedures and spill notification requirements
- How to use emergency response information in the North American Emergency Response Guidebook, shipping papers, MSDS, and other sources

Labeling of Hazardous Materials (§172.400)

Except as specified in exceptions from labeling (§172.400a), DOT requires each person who offers for transportation or transports a hazardous material in any of the following packages or containment devices to label the package or containment device with labels specified for the material in the Hazardous Materials Table (§172.101).

1. A non-bulk package
2. A bulk packaging, other than a cargo tank, portable tank, or tank car, with a volumetric capacity of less than 640 cubic feet, unless placarded.
3. A portable tank of less than 1000 gallons capacity, unless placarded.
4. A DOT Specification 106 or 110 multi-unit tank car tank, unless placarded.
5. An overpack, freight container or unit load device of less than 640 cubic feet that contains a package for which labels are required, unless placarded or marked.

✔ **Important Note:** Hazardous Material Warning Labels are designed and color-coded so that the hazards can be quickly recognized. Warning labels correspond to the placards that must appear on each bulk packaging, freight container, unit load device, transport vehicle or rail car that contains a hazardous material. The labels must include both the hazard class and the division of hazard, if required, according to the Hazardous Material Table. Unless excepted, all hazardous materials packages must be labeled.

✔ **Important Point:** Be careful with the distinction between "labels" and "markings." In Hazmat parlance, hazard warning labels are called "labels." Any other

Hazard class or division	*Label name*	*Label design or section*
1.1	EXPLOSIVES 1.1 172.411	1.1
1.2	EXPLOSIVES 1.2 172.411	1.2
1.3	EXPLOSIVES 1.3 172.411	1.3
1.4	EXPLOSIVES 1.4 172.411	1.4
1.5	EXPLOSIVES 1.5 172.411	1.5
1.6	EXPLOSIVES 1.6	172.411
2.1	FLAMMABLE GAS	172.417
2.2	NONFLAMMABLE GAS	172.415
2.3	POISON GAS	
3 (flammable liquid) Combustible liquid	FLAMMABLE LIQUID (none)	172.419
4.1	FLAMMABLE	172.420
4.2	SPONTANEOUSLY COMBUSTIBLE	172.422
4.3	DANGEROUS WHEN WET	172.423
5.1	OXIDIZER	172.426
5.2	ORGANIC	PEROXIDE
6.1 (inhalation hazard, Zone A or B)	POISON INHALATION HAZARD	
6.1 (other than inhalation hazard, Zone A or B)	POISON	172.430
6.2	INFECTIOUS SUBSTANCE*	
7	RADIOACTIVE	WHITE-I
7	RADIOACTIVE YELLOW-II	172.438
7	RADIOACTIVE YELLOW-III	172.440
7	EMPTY	
8	CORROSIVE	172.442
9	CLASS 9	172.446

* The ETIOLOGIC AGENT label specified in regulations of the Department of Health and Human Services at 42 CFR 72.3 may apply to packages of infectious substances.

information required on the exterior of a package is called a "marking."

Where Labeling Is Required
Labeling is required for a hazardous material that meets one or more hazard class definitions, in accordance with Column 6 of the Hazardous Materials Table (§172.101) and as shown in the Table.

Where Labeling Is Not Required
Notwithstanding the provisions of §172.400, a label is not required on:

1. A cylinder, or a flask conforming to §173.320 of this subchapter containing a Division 2.1 or Division 2.2 gas that is:
   - Not poisonous
   - Carried by a private or contract motor carrier
   - Not overpacked
   - Durably and legibly marked in accordance with CGA Pamphlet C-7, Appendix A.
2. A package or unit of military explosives (including ammunition) shipped by or on behalf of the DOD when in:
   - Freight container load, carload or truckload shipments, if loaded and unloaded by the shipper or DOD; or
   - Unitized or palletized break-bulk shipments by cargo vessel under charter to DOD if at least one required label is displayed on each unitized or palletized load.
3. A package containing a hazardous material other than ammunition that is:
   - Loaded and unloaded under the supervision of DOD personnel, and
   - Escorted by DOD personnel in a separate vehicle.
4. A compressed gas cylinder permanently mounted in or on a transport vehicle.
5. A freight container, aircraft unit load device or portable tank, which:
   - Is placarded in accordance with Subpart F of this part, or
   - Conforms to Paragraph (a)(3) or (b)(3) of §172.512.
6. An overpack or unit load device in or on which labels representative of each hazardous material in the overpack or unit load device are visible.
7. A package of low specific activity radioactive material, when transported under §173.427(a)(6)(vi) of this subchapter.

✔ **Important Point:** Certain exceptions to labeling requirements are provided for small quantities and limited quantities in applicable sections in Part 173 of this subchapter. Notwithstanding the provisions of

§172.402(a), a subsidiary hazard label is not required on a package containing Class 8 (corrosive) material that has a subsidiary hazard of Division 6.1 (poisonous), if the toxicity of the material is based solely on the corrosive destruction of tissue rather than systemic poisoning.

Where Labeling Is Prohibited (§172.401)
Except where otherwise provided, no person may offer for transportation and no carrier may transport a package bearing a label specified in this subpart unless:

1. The package contains a material that is a hazardous material, and
2. The label represents a hazard of the hazardous material in the package.

✔ **Important Point:** No person may offer for transportation and no carrier may transport a package bearing any marking or label which by its color, design, or shape could be confused with or conflict with a label prescribed by this part. The restrictions in Paragraph 1 and 2 of this section do not apply to packages labeled in conformance with:

- Any UN recommendation, including the class number
- The International Maritime Organization (IMO) requirements, including the class number, in the document entitled "International Maritime Dangerous Goods Code"
- The ICAO Technical Instructions
- The TDG Regulations

The provisions of Paragraph (a) of this section do not apply to a packaging bearing a label if that packaging is:

- Unused or cleaned and purged of all residue
- Transported in a transport vehicle or freight container in such a manner that the packaging is not visible during transportation
- Loaded by the shipper and unloaded by the shipper or consignee.

Additional Labeling Requirements (§172.402)
Subsidiary hazard labels—Each package containing a hazardous material must be labeled with primary and subsidiary hazard labels as specified in Column 6 of the §172.101 Hazardous Materials Table. Materials other than Class 1 or Class 2 materials, if not already labeled under other provisions, must be labeled with subsidiary labels in accordance as shown in the Table.

Display of hazard class on labels—the appropriate hazard class, or for Division 5.1 or 5.2, the division number, must be displayed in the lower corner of a primary hazard label and may not be displayed on a subsidiary label.

SUBSIDIARY HAZARD LABELS

Subsidiary hazard level (packing group)	*Subsidiary Hazard (Class or Division)*						
	3	4.1	4.2	4.3	5.1	6.1	8
I	X	***	***	X	X	X	X
II	X	X	X	X	X	X	X
III	*	X	X	X	X	X	X

X Required for all modes.
* Required for all modes, except for a material with a flash point at or above 38°C (100°F) transported by rail or highway.
*** Impossible as subsidiary hazard.

Labels for Mixed and Consolidated Packaging (§172.404)
Mixed packaging—when hazardous materials having different hazard classes are packed within the same packaging, or within the same outside container or overpack, and authorized by §173.21, the packaging, outside container or overpack must be labeled as required for each class of hazardous material contained therein.

Consolidated packaging—when two or more packages containing compatible hazardous material are placed within the same outside container or overpack, the outside container or overpack must be labeled as required for each class of hazardous material contained therein.

Authorized Label Modifications (§172.405)
For Classes 1, 2, 3, 4, 5, 6, and 8, text indicating a hazard (FLAMMABLE LIQUID, for example) is not required on a primary or subsidiary label when:

- The label otherwise conforms to the provisions of this subpart, and
- The hazard class, or for Division 5.1 or 5.2, the division number is displayed in the lower corner of the label, if the label corresponds to the primary hazard class of the hazardous material.

For a package containing Oxygen, compressed, or Oxygen, refrigerated liquid, the OXIDIZER label specified in §172.426, modified to display the word "OXYGEN" instead of "OXIDIZER", and the class number "2" instead of "5.1," may be used in place of the NON-FLAMMABLE GAS and OXIDIZER labels. The word "OXYGEN" must appear on the label.

For a package containing a Division 6.1, Packing Group III material, the POISON label specified in §172.430 may be modified to display the text "PG III" instead of "POISON" or "TOXIC" below the mid line of the label.

Placement of Labels (§172.406)
Each label required by this subpart must:

- Be printed on or affixed to a surface (other than the bottom) of the package or containment device containing the hazardous material

- Be located on the same surface of the package and near the proper shipping name marking, if the package dimensions are adequate

Except for where otherwise specified, duplicate labeling is not required on a package containment device (such as to satisfy redundant labeling requirements).

Exceptions include:

- A label may be printed on or placed on a securely affixed tag, or may be affixed by other suitable means to
- A package that contains no radioactive material and which has dimensions less than those of the required label
- a cylinder
- a package which has such an irregular surface that a label cannot be satisfactorily affixed.

When primary and subsidiary hazard labels are required, they must be displayed next to each other. Placement conforms to this requirement if labels are within six inches of one another.

Each label must be printed on or affixed to a background of contrasting color, or must have a dotted or solid line outer border.

As stated earlier, generally, only one of each different required label must be displayed on a package. However, duplicate labels must be displayed on at least two sides and two ends (other than the bottom of):

1. Each package or overpack having a volume of 64 cubic feet or more
2. Each non-bulk package containing a radioactive material
3. *Each DOT 106 or 110 multi-unit tank care tank. Labels must be displayed on each end*
4. Each portable tank of less than 1000 gallon capacity
5. Each freight container or aircraft unit load device having a volume of 64 cubic feet or more, but less than 640 cubic feet. One of each required label must be displayed on or near the closure.

✔ **Important Point**: A label must be clearly visible and not be obscured by markings or attachment.

Label Specifications (§172.407)

Each label, whether printed on or affixed to a package, must be durable and weather resistant. A label on a package must be able to withstand, without deterioration or a substantial change in color, a thirty-day exposure to conditions incident to transportation that reasonably could be expected to be encountered by the labeled package.

The **design**, except for size and color, the printing, inner border and symbol on each label must be shown as HMR dictates.

The **size** of each diamond (square-on-point) label prescribed in this subpart must be at least 3.9 inches on each side with each side having a solid line inner border (0.2 to 0.25 inches) from the edge.

The CARGO AIRCRAFT ONLY label must be a rectangle measuring at least 4.3 inches in height by 4.7 inches in width. The word "DANGER" must be shown in letters measuring at least 0.5 inches in height.

Except as otherwise specified, the hazard class number, or division number, as appropriate, must be at least (0.25 inches) and not greater than (0.5 inches).

When text indicating a hazard is displayed on a label, the label name must be shown in letters measuring at least 0.3 inches in height. For SPONTANEOUSLY COMBUSTIBLE or DANGEROUS WHEN WET labels, the words "Spontaneously" and "When Wet" must be shown in letters measuring at least 0.2 inches in height.

The symbol on each label must be proportionate in size to that shown in the appropriate section of this subpart.

The **color** and the background color on each label must be as prescribed or as appropriate.

The symbol, text, numbers, and border must be shown in black on a label on a label except that

- White may be used on a label with a one color background of green, red or blue
- White must be used for the text and class number for the CORROSIVE label

Black and any color on a label must be able to withstand, without substantial change, a 72-hour fadeometer test.

A color on a label, upon visual examination, must fall within the color tolerances:

- Displayed on color charts conforming to the technical specifications for charts set forth by DOT
- For labels printed on packaging surfaces, specified by DOT

✔ **Important Point:** Color charts conforming to DOT standards are on display in Room 8421, Nassif Building, 400 Seventh Street, SW., Washington, DC.

The specified label color must extend to the edge of the label in the area designated on each label except the CORROSIVE, RADIOACTIVE YELLOW-II AND RADIOACTIVE YELLOW-III labels on which the color must extend only to the inner border.

For **form identification**, a label may contain form identification information, including the name of its maker, provided that information is printed outside the solid line inner border in no larger than 10-point type.

Exceptions. A label conforming to specifications in the UN Recommendations may be used in place of a corresponding label that conforms to the requirements of this subpart.

Trefoil symbol. The trefoil symbol on the RADIOACTIVE WHITE-I, RADIOACTIVE YELLOW-II, and RADIOACTIVE YELLOW-III labels must meet the appropriate DOT specifications.

✔ **Important Point:** When compatible materials are packaged together, the labels for each individual material must appear on the exterior of the package.

Placarding

Placarding is covered in Subpart F of the 49 CFR Standard.

Though similar to labels, placards are larger; they are square-on-point signs used to show the hazard or hazards associated with hazardous materials contained:

- in bulk packages;
- transport vehicles, railcars, freight containers, or unit load devices containing bulk or non-bulk packages. For placarding, the following rules apply (§172.500):

✔ **Important Point:** The color, design, symbol and class or division number on a primary placard corresponds to the hazard class or division the placard represents.

Each person who offers for transportation or transports any hazardous material must comply with the following applicable placarding requirements:

- Infectious substances
- Hazardous materials classed as ORM-D
- Hazardous materials authorized by this subchapter to be offered for transportation as Limited Quantities when identified as such on shipping papers in accordance with §172.203(b)
- Hazardous materials packaged as small quantities under the provisions of §173.4
- Combustible liquids in non-bulk packagings.

Prohibited Placarding (§172.502)

No person may affix or display on a packaging, freight container, unit load device, motor vehicle or rail car:

- Any placard described in §172.502 unless:
    - ○ The material being offered or transported is a hazardous material
    - ○ The placard represents a hazard of the hazardous material being offered or transported
    - ○ Any placarding conforms to the requirements of §172.502
- Any sign, advertisement, or other device that, by its color, design, shape or content, could be confused with any placard prescribed §172.502.

Exceptions

- The restrictions of §172.502(a) do not apply to bulk packaging, freight container, unit load device, transport vehicle or rail car which is placarded in conformance with the TDG Regulations, the IMDG Code or the UN Recommendations.
- The restrictions of §172.502(a)(2) do not apply to the display of an identification number on a white square-on-point configuration in accordance with §172.336(b) of this part.
- The restrictions in Paragraph (a)(2) of this section do not apply until October 1, 2001 to a safety sign or safety slogan (e.g., “Drive Safely” or “Drive Carefully”), which was permanently marked on a transport vehicle, bulk packaging, or freight container on or before August 21, 1997.

Permissive Placarding

Placards may be displayed for a hazardous material, even when not required, if the placarding otherwise conforms to the requirements of this subpart.

✔ **Important Point:** For procedures and limitations pertaining to the display of identification numbers on placards, see §172.334.

General Placarding Requirements

Each bulk packaging, freight container, unit load device, transport vehicle or rail car containing any quantity of a hazardous material must be placarded on each side and each end with the type of placards specified in Tables 3 and 4.

A freight container, unit load device, transport vehicle or rail car that contains non-bulk packagings with two or more categories of hazardous materials that require different placards specified in Table 6.4 may be placarded with DANGEROUS placards instead of the separate placarding specified for each of the materials in Table 6.4. However, when 2,205 aggregate gross weight or more of one category of material is loaded therein at one loading facility on a freight container, unit load device, transport vehicle, or rail car, the placard specified in Table 6.4 of Paragraph (e) of this section for that category must be applied.

Category of Material (Hazard class or section reference division number and (§) additional description as appropriate)	*Placard Name*	*Placard Design Section Reference (§)*
1.1	EXPLOSIVES 1.1	172.522
1.2	EXPLOSIVES 1.2	172.522
1.3	EXPLOSIVES 1.3	172.522
2.3	POISON GAS	172.540
4.3	DANGEROUS WHEN WET	172.548
5.2 (Organic Peroxide, type B)	ORGANIC PEROXIDE	172.552
6.1 (Inhalation hazard, Zone A or B)	POISON INHALATION HAZARD	172.555
7 (Radioactive Yellow III label only)	RADIOACTIVE*	172.556

Exception for Less Than 1,001 Pounds

Except for bulk packagings and hazardous materials subject to §172.505, when hazardous materials covered by Table 4 of this section are transported by highway or rail, placards are not required on:

- A transport vehicle or freight container that contains less than 1001 pounds aggregate gross weight of hazardous materials covered by Table 4.
- A rail car loaded with transport vehicles or freight containers, none of which is required to be placarded.

✔ **Important Point:** The prohibitions provided in this section do not prohibit the display of placards in the manner prescribed in this subpart, if not otherwise prohibited (see §172.502), on transport vehicles or freight containers that are not required to be placarded.

Exception for Empty Non-Bulk Packages

A non-bulk packaging that contains only the residue of a hazardous material.

Placarding Tables (§172.504 (e))

Placards are specified for hazardous materials in accordance with the tables:

- RADIOACTIVE placard also required for exclusive use shipments of low specific activity material and surface contaminated objects transported in accordance with §173.427(a) of this subchapter.

✔ **Important Point:** Placarding is not required for Class 9 materials that are transported in the U.S. A bulk package of Class 9 hazardous materials is excepted from placarding, but it is still required to display the ID number according to the marking requirements.

Additional Placarding Exceptions (§172.504 (f))

When more than one division placard is required for Class 1 materials on a transport vehicle, rail car, freight container or unit load device, only the placard representing the lowest division number must be displayed.

Category of Material (Hazard class or section division number and reference (§) additional description, as appropriate)	*Placard Name*	*Placard Design Section Reference (§)*
1.4	EXPLOSIVES 1.4	172.523
1.5	EXPLOSIVES 1.5	172.524
1.6	EXPLOSIVES 1.6	172.525
2.1	FLAMMABLE GAS	172.532
2.2	NON-FLAMMABLE GAS	172.528
3	FLAMMABLE	172.542
Combustible liquid	COMBUSTIBLE	172.544
4.1	FLAMMABLE SOLID	172.546
4.2	SPONTANEOUSLY COMBUSTIBLE	172.547
5.1	OXIDIZER	172.550
5.2 (Other than organic peroxide, type B)	ORGANIC PEROXIDE	172.552
6.1 (other than inhalation hazard, Zone A or B)	POISON	172.554
6.2	(None)	
8	CORROSIVE	172.558
9	CLASS 9	172.560
ORM-D	(None)	

- A FLAMMABLE placard may be used in place of a COMBUSTIBLE placard on:
    - ○ A cargo tank or portable tank
    - ○ A compartmented tank car which contains both flammable and combustible liquids
- A NON-FLAMMABLE GAS placard is not required on a transport vehicle that contains non-flammable gas if the transport vehicle also contains flammable gas or oxygen and it is placarded with FLAMMABLE GAS or OXYGEN placards, as required.
- OXIDIZER placards are not required for Division 5.1 materials on freight containers, unit load devices, transport vehicles or rail cars that also contain Division 1.1 or 1.2 materials and that are placarded with EXPLOSIVES 1.1 or 1.2 placards, as required.
- For transportation by transport vehicle or rail car only, an OXIDIZER placard is not required for Division 5.1 materials on a transport vehicle, rail car or freight container that also contains Division 1.5 explosives and is placarded with EXPLOSIVES 1.5 placards, as required.
- The EXPLOSIVE 1.4 placard is not required for those Division 1.4 Compatibility Group S (1.4S) materials that are not required to be labeled 1.4S.
- For domestic transportation of oxygen, compressed or oxygen, refrigerated liquid, the OXYGEN placard in §172.530 of this subpart may be used in place of a NON-FLAMMABLE GAS placard.
- Except for a material classed as a combustible liquid that also meets the definition of a Class 9 material, a COMBUSTIBLE placard is not required for a material classed as a combustible liquid when transported in a non-bulk packaging classed as a bulk packaging.
- For domestic transportation, a Class 9 placard is not required. A bulk packaging containing a Class 9 material must be marked on each side and each end with the appropriate identification number displayed on an orange panel, or a white-square-on-point display configuration are required.
- For Division 6.1, PG III materials, a POISON placard may be modified to display the text "PG III" below the mid-line of the placard.
- For domestic transportation, a POISON placard is not required on a transport vehicle or freight container required to display a POISON INHALATION HAZARD or POISON GAS placard.
- For shipments of Class 1 (explosive) materials by aircraft or vessel, the applicable compatibility group letter must be displayed on the placards required by this section.

Placarding for Subsidiary Hazards (§172.505)

a. Each transport vehicle, freight container, portable tank, unit load device, or rail car that contains a poisonous material subject to the "Poison-inhalation Hazard" shipping description of §172.203(m)(3) must be placarded with a POISON INHALATION HAZARD or POISON GAS placard, as appropriate, on each side and each end, in addition to any other placard required for that material in §172.504. Duplication of the POISON INHALATION HAZARD or POISON GAS placard is not required.
b. In addition to the RADIOACTIVE placard that may be required by §172.504(e) of this subpart, each transport vehicle, portable tank or freight container that contains 1001 pounds or more gross weight of fissile or low specific activity uranium hexafluoride must be placarded with a CORROSIVE placard on each side and each end.
c. Each transport vehicle, portable tank, freight container or unit load device that contains a material that has a subsidiary hazard of being dangerous when wet (as defined in §173.124 of this subchapter) must be placarded with DANGEROUS WHEN WET placards, on each side and each end, in addition to the placards required by §172.504.
d. Hazardous materials that possess secondary hazards may exhibit subsidiary placards that correspond to the placards described in this part, even when not required by this part (see also §172.519(b)(4) of this subpart).

✔ **Important Point**: You must label each package containing a hazardous material with the primary and, if applicable, the subsidiary hazard label(s) specified in column 6 of the HMT. If the more than one label code is listed in column 6, the first code listed indicates the primary hazard, and the others are subsidiary labels. For those packages containing a hazardous material not in class 1 or Class 2, the material must be labeled with a subsidiary hazard label.

Providing and Affixing Placards: Highway (§172.506)

a. Each person offering a motor carrier a hazardous material for transportation by highway must provide to the motor carrier the required placards for the material being offered prior to or at the same time the material is offered for transportation, unless the carrier's motor vehicle is already placarded for the material as required.

✔ **Important Point:** Transport vehicles, freight containers, unit load devices, or rail cars are always placarded as described earlier, unless the placard(s) on the package are clearly visible from the exterior of the transportation device.

Special Placarding Provisions: Highway (§172.507)

a. Each motor vehicle used to transport a package of highway controlled quantity Class 7 (radioactive) materials must have the required RADIOACTIVE warning placard placed on a square background as described in §172.527.

b. A nurse tank meeting the provisions of §173.315(m) is not required to be placarded on an end containing valves, fittings, regulators or gauges when those appurtenances prevent the markings and placard from being properly placed and visible.

Providing and Affixing Placards: Rail (§172.508)

a. Each person offering a hazardous material for transportation by rail must affixed to the rail car containing the material, the placards specified by this subpart. Placards displayed on motor vehicles transport containers or portable tanks may be used to satisfy this requirement, if the placards otherwise conform to the provisions of this subpart.
b. No rail carrier may accept a rail car containing a hazardous material for transportation unless the placards for the hazardous material are affixed thereto as required by this subpart.

Special Placarding Provisions: Rail (§172.510)

a. **White square background**. The following must have the specified placards placed on a white square background, as described in §172.527:
    - Division 1.1 and 1.2 (explosive) materials that require EXPLOSIVES 1.1 or EXPLOSIVES 1.2 placards affixed to the rail car.
    - Materials classed in Division 2.3 Hazard Zone A or 6.1 Packing Group I Hazard Zone A that require POISON GAS or POISON placards affixed to the rail car, including tank cars containing only a residue of the material.
    - Class DOT 113 tank cars used to transport a Division 2.1 (flammable gas) material, including tank cars containing only a residue of the material.
b. **Chemical ammunition**. Each rail car containing Division 1.1 or 1.2 (explosive) ammunition that also meets the definition of a material poisonous by inhalation must be placarded EXPLOSIVES 1.1 or EXPLOSIVES 1.2 and POISON GAS or POISON INHALATION HAZARD.

Freight Containers and Aircraft Unit Load Devices

a. **Capacity of 640 cubic feet or more**. Each person who offers for transportation, and each person who loads and transports, a hazardous material in a freight container or aircraft unit load device having a capacity of 640 cubic feet or more must affix to the freight container or aircraft unit load device the placards specified for the material in accordance with §172.504. However:
    - The placarding exception provided in §172.504(c) applies to motor vehicles transporting freight containers and aircraft unit load devices.
    - The placarding exception provided in §172.504(c) applies to each freight container and aircraft unit load device being transported for delivery to a consignee immediately following an air or water shipment.
    - Placarding is not required on a freight container or aircraft unit load device if it is only transported by air and is identified as containing a hazardous material in the manner provided in Part 5, Chapter 2, Section 2.7 of the ICAO Technical Instructions.
b. **Capacity less than 640 cubic feet.** Each person who offers for transportation by air, and each person who loads and transports by air, a hazardous material in a freight container or aircraft unit load device having a capacity of less than 640 cubic feet must affix one placard of the type specified by Paragraph (a) of this section unless the freight container or aircraft unit load device:
    - Labeled in accordance with Subpart E of this part, including §172.406(e);
    - Contains radioactive materials requiring the Radioactive Yellow III label and is placarded with one Radioactive placard and is labeled in accordance with Subpart E of this part, including §172.406(e); or
    - Is identified as containing a hazardous material in the manner provided in Part 5, Chapter 2, Section 2.7 of the ICAO Technical Instructions.

When hazardous materials are offered for transportation not involving air transportation in a freight container having a capacity of less than 640 cubic feet, the freight container need not be placarded. However, if not placarded, it must be labeled in accordance with Subpart E of this part.

Notwithstanding paragraphs (a) and (b) of this section, packages containing hazardous materials (other than ORM-D) offered for transportation by air in freight containers are subject to the inspection requirements of §175.30.

✔ **Important Point**: A rail car, freight container, truck body or trailer in which the lading has been fumigated with any hazardous material, or is undergoing fumigation, must be marked as specified in §173.9 with a FUMIGANT marking.

Bulk Packagings (§172.514)

For hazardous materials transported in **bulk packagings**, placards (as specified in §§172.504 and 172.505) are generally used instead of labels to communicate the hazard(s).

Each bulk packaging that is required to be placarded when it contains a hazardous material must remain placarded when it is emptied, unless it is:

- Sufficiently cleaned of residue and purged of vapors to remove any potential hazard; or
- Refilled with a material requiring different placards or no placards, to such an extent that any residue remaining in the packaging is no longer hazardous.

✔ **Important Point:** The point can't be made strongly enough that packagings that are "empty" but still contain hazardous material residue or vapors are transported as if they were full. The packaging is considered empty **only** if it is completely purged of residue or refilled with a non-hazardous material so that a hazard no longer exists. **Note:** "RESIDUE" placards may no longer be used.

- **Exceptions.** The following packagings may be placarded on only two opposite sides, or alternatively, may be labeled instead of placarded in accordance with Subpart E of this part:

  1. A portable tank having a capacity of less than 1000 gallons
  2. A DOT 106 or 110 multi-unit tank car tank
  3. A bulk packaging other than a portable tank, cargo tank, or tank car (for example, a bulk bag or box) with a volumetric capacity of less than 640 cubic feet
  4. An intermediate bulk container

Visibility and Display of Placards (§172.516)

Each placard on a motor vehicle and each placard on a rail car must be readily visible from the direction it faces except from the direction of another motor vehicle or rail car to which the motor vehicle or rail car is coupled. This requirement may be met by the placards displayed on the freight containers or portable tanks loaded on a motor vehicle or rail car.

The required placarding of the front of a motor vehicle may be on the front of a truck-tractor, instead of or in addition to the placarding on the front of the cargo body to which a truck-tractor is attached.

Each placard on a transport vehicle, bulk packaging, freight container or aircraft unit load device must:

- Be securely attached or affixed thereto or placed in a holder thereon.
- Be located clear of appurtenances and devices such as ladders, pipes, doors, and tarpaulins.
- So far as practicable, be located so that dirt or water is not directed to it from the wheels of the transport vehicle;
- Be located away from any marking (such as advertising) that could substantially reduce its effectiveness, and in any case at least 3 inches away from such marking;
- Have the words or identification number (when authorized) printed on it displayed horizontally, reading from left to right;
- Be maintained by the carrier in a condition so that the format, legibility, color, and visibility of the placard will not be substantially reduced due to damage, deterioration, or obscurement by dirt or other matter;
- Be affixed to a background of contrasting color, or must have a dotted or solid line outer border that contrasts with the background color.

✔ **Important Point**: You may not use abbreviations in a proper shipping name marking except as provided for in §172.308.

A placard or placard holder may be hinged provided the required format, color, and legibility of the placard are maintained.

✔ **Important Point:** A placard may be made of any plastic, metal or other material capable of withstanding, without deterioration or a substantial reduction in effectiveness, a 30-day exposure to open weather conditions (§172.519(a)(1)).

Types of Placards

As with hazardous materials labels and markings, several different placards are mandated for use in identifying specific materials being shipped. The primary purpose of these placards is twofold: (1) to alert the public to the potential dangers of hazardous materials; and (2) to guide emergency response personnel in their actions during a Hazmat incident.

Shipping placards must conform to specific size specifications. For example, each placard must measure at least 10.8 inches on each side and must have a solid line inner border approximately 0.5 inches from each edge.

Hazard class or division number (as appropriate) must be shown in numbers measuring at least 1.6 inches in height.

When text is used on a placard to indicate a hazard, the printing must be in letters measuring at least 1.6 inches in height.

✔ **Important Point**: You may not display hazard class labels which are nor representative of the hazardous material or the hazards posed, or which incorporate label colors or designs which could be confused with or conflict with a label prescribed it the HMR. The labels required by the HMR are normally used for domestic shipments, but may sometimes be used for international shipments as well. Several international organizations prescribe labeling requirements that may be used in addition to or in place of the domestic labels. The two previous restrictions do not apply to packages labeled in conformance with the Untied Nations (UN) recommendations; the International Maritime Dangerous Goods (IMDG) Code; the International Civil Aviation Organization (ICAO) Technical Instructions; or the Canadian Dangerous Goods (TDG) Regulations. The provisions of this section do not apply to a packaging that is unused or cleaned and purged of all residue, transported in a transport vehicle or freight container in such a manner that the packaging is not visible during transportation, and transported on a vehicle that is loaded by the shipper and unloaded by the shipper of consignee.

✔ **Important Point**: For Classes 1, 2, 3, 4, 5, 6, and 8, the text indicating a hazard, such as Flammable Liquid or Oxidizer is not required on a primary or subsidiary label.

DOT Packaging Requirements (49 CFR 173): After manufacture and processing, hazardous materials may be used on site for various applications, or, more likely, are shipped from the manufacturer and/or processor to another end-user. Because the materials we are discussing are “hazardous,” their proper delivery is crucial to the safety of everyone involved in their handling and transport, for good reason. To help ensure their safe handling and transport, DOT regulations protect the handlers of these hazardous materials and the environment in which we live. Shipping hazardous materials in anything less than fully certified packaging not only risks damage to the environment, but also could be costly to your business.

✔ **Important Point:** *Packaging* refers to Receptacles or Containers or Components that meet DOT requirements of 49 CFR. A package must meet minimum packaging requirements. Packagings include fiberboard boxes, drums, jerricans, portable tanks, cargo tanks, tank cars, multi-unit tanks car tanks, cylinders, and containers other than freight containers and overpacks. The term packaging is also used extensively through the HMR. To use the HMR correctly, you must know the difference between a package—a packaging plus its contents—and a packaging, which does not include the hazard materials being shipped.

Who is required to comply with the HMR?

According to 171.2 of the HMR, anyone who offers or accepts a hazardous material shipment must comply with the HMR. Providers of packagings used in the transportation of hazardous materials must comply as well. No person, individual or company may offer or accept a hazardous material for transportation in commerce unless the shipment complies with the HMR.

If you transport hazardous materials in commerce within the jurisdiction of the United States, you are regulated and must comply with the HMR. The main function of HMR packaging requirements is to assure that hazardous materials stay in the package during transportation.

To comply with DOT’s packaging requirements, certain steps must be followed.

✔ **Important Point:** Specific instructions for all types of packagings and all modes of transportation can be found in the Hazardous Material Regulations, Part 173: Shippers General Requirements for Shipments and Packagings.

Packagings and Packages: General Requirements (§173.24)

§173.24 applies to bulk and non-bulk packagings, both new and reused packagings, and specification and non-specification packagings.

Specifically, each package used for the shipment of hazardous materials must be designed, constructed, maintained, filled, its contents limited, and closed, so that under conditions normally incident to transportation:

1. no identifiable (without the use of instruments) release of hazardous materials to the environment can occur.
2. the effectiveness of the package will not be substantially reduced (for example, impact resistance, strength, packaging compatibility, etc. must be maintained for the minimum and maximum temperatures encountered during transportation).
3. no mixture of gases or vapors in the package occur that could, through any credible spontaneous increase of heat or pressure, significantly reduce the effectiveness of the packing.

✔ **Important Point:** You must package hazardous materials for transportation in any mode as specified in the HMR. The initial carrier and the U.S. Department of Transportation and its designated agencies are authorized to inspect hazardous materials packages for HMR compliance. They may inspect for methods of manufacture, packing, closure and storage of hazardous materials that affect safety in transportation.

Authorized Packagings

The packaging prescribed or permitted for the hazardous material in a packing section is specified for that material in Column 8 of the §172.101 Table; the material must also conform to applicable requirements in the special provisions of Column 7 of the §172.101 Table.

✔ **Important Point:** Packing authorizations can be found in Columns (8A)-(8C) of the Hazardous Materials Table.

Specification Packagings

A **specification** packaging, including a UN standard packaging manufactured in the United States, must conform in all details to the applicable specification or standard in Part 178 or Part 179.

A UN standard packaging manufactured outside the United States, in accordance with national or international regulations based on the UN Recommendations on the Transport of Dangerous Goods, may be incorporated and used and is considered to be an authorized packaging under the provisions of this section, subject to the following conditions and limitations:

1. The packaging fully conforms to applicable provisions in the UN Recommendations on the Transport of Dangerous Goods and the requirements of this subpart, including reuse provisions;
2. The packaging is capable of passing the prescribed tests in Part 178 of this subchapter applicable to that standard; and
3. The competent authority of the country of manufacture provides reciprocal treatment for UN standard packagings manufactured in the United States.

Compatibility

The person offering a hazardous material for transportation has the responsibility of ensuring that such packagings are compatible with their lading. This particularly applies to corrosivity, permeability, softening, premature aging and embrittlement.

Packaging materials and contents must be designed and manufactured to allow no significant chemical or galvanic reaction between the materials and contents of the package.

Plastic used in packagings and receptacles must be of a type compatible with the lading and may not be permeable to an extent that a hazardous condition is likely to occur during transportation, handling or refilling.

Hazardous materials may not be mixed or packed together in the same outer packaging with other hazardous or nonhazardous materials if such materials are capable of reacting dangerously with each other and causing:

- combustion or dangerous evolution of heat
- evolution of flammable, poisonous, or asphyxiant gases
- formation of unstable or corrosive materials.

Packagings used for solids that may become liquid at temperatures likely to be encountered during transportation, must be capable of containing the hazardous materials in the liquid state.

Standard Packaging

Standard hazardous materials packaging consists of outer packaging and inner packaging, or combination packaging. Combination packaging is comprised of one or more inner packagings used in combination with a non-bulk outer packaging (not including a composite packaging).

The outermost packaging is a combination or composite package used with cushioning or absorbent materials designed to protect and contain the inner packagings.

We are concerned with three types of packagings: single packaging, composite packaging and overpacks.

Single Packaging is usually a non-bulk packaging other than a combination packaging. The package is simply a single receptacle into which the material is directly loaded (for example, a single drum).

Composite Packaging is a combination outer packaging + an inner receptacle. Both the inner receptacle and outer packaging form an integral packaging (for example, a drum with an inner lining).

Overpacks are enclosures used by a single consignor to provide either protection or convenience in the handling operation, or to consolidate two or more single packages.

✔ **Important Point:** To be in compliance for overpacks, specific rules must be followed:

- Each package in an overpack must be in full compliance with all applicable packaging regulations. Each package must be properly marked and labeled as per §173.25.
- The Markings and Labels on each of the packages overpacked **must** be reproduced on the outside of the overpack. An exception to this rule is if the overpacked packages are visible from the outside of the Overpack, remarking and labeling is not necessary (§173.25(a)(2)),
- Packages are subject to orientation markings as per §173.312 (§173.(a)(3)).
- Overpacks of Specification Packagings must be marked with an indication that the overpacked packages inside comply with prescribed specifications (§173.25(a)(5)).

✔ **Important Point**: When you ship hazmats as a Limited Quantity, it is excepted from specification packaging and placarding in all modes of transportation. Also, except for Division 6.1 materials transported by aircraft, a limited quantity is excepted from labeling. Section 171.8 defines “Limited Quantity” as the maximum amount of a hazardous material for which there is a specific labeling or packaging exception.

Performance-Oriented Packaging (POP)

The *Performance-Oriented Packaging (POP) Standard* was developed by the UN Committee of Experts on the Transport of Dangerous Goods. It provides for packaging safety while facilitating the free flow of these packagings within international commerce. These standards can be found in the *"UN Recommendations for the Transport of Dangerous Goods"* (aka the "Orange Book"), which serves as the basis and authority for the Performance Oriented Packaging requirements. It also serves as the basis for the Performance Oriented Packaging standards adopted by individual countries. The 49 CFR authorizes the use of the UN Performance Oriented Packaging standards for Non-Bulk packagings for most domestic transportation of Hazardous Materials §171.14(a). Unless excepted, the use of UN Performance Oriented Packaging (POP) Standards is mandatory. UN POP standards apply to Non-Bulk packagings; they do not apply to cylinders, Radioactive Materials and bulk packagings.

✔ **Important Point:** The UN Performance Oriented Packaging (POP) standard is based on the anticipated **performance** of the packaging within the transportation system, rather than the **detailed design and construction** of packaging.

✔ **Important Point:** The objective of POP standards is to secure the level of safety desired by ensuring the ability of a given package type to **successfully pass a series of performance tests** designed to test its ability to withstand the normal conditions incident to transportation, rather than its design or construction.

✔ **Important Point:** POP tests are generally based on the Packing Group for which the packaging is being tested or qualified. Remember, the Packing Group gives the **degree of the hazard**, while the Hazard Class gives the **type of Hazard**.

POP Packaging Design Tests

Recall that the performance criteria in the Hazardous Material Regulations are based on the UN Recommendation for the Transport of Dangerous Goods. In light of this, each POP packaging design must pass specific tests, including:

- Drop—to contain and protect the Dangerous Goods if the package is dropped
- Leakproofness—to prevent leakage of liquids under conditions of normal transport
- Hydrostatic pressure—to prevent leakage of liquids under pressure
- Stacking—to maintain stability within a stack while stacked with similar packages

✔ **Important Point:** In addition to the standard tests listed above, hazardous materials packagings transported in the U.S. must be capable of withstanding the vibration standard.

In the actual testing process, the Hazardous Material Regulation specifies how many samples must be tested, how often testing is required, and how each test must be conducted. Packaging manufacturers are required to "mark" each package that meets the POP standard.

✔ **Important Point:** POP marking is made up of a series of symbols, numbers, and letters that indicate specific characteristics of the package.

✔ **Important Point**: Performance testing requirements for all packaging designs are contained in Part 178. Packagings tested to meet the Part 178 performance requirements are called "UN Standard Packagings." Section 171.8 defines "UN standard packaging" as a packaging conforming to standards in the UN Recommendations on the Transport of Dangerous Goods.

POP Marking Codes

Markings must be stamped, embossed, printed, burned, or otherwise marked on the packaging in a way that provides adequate accessibility, permanency, legibility, and contrast (§178.3(a)(3)).

All POP markings must contain codes for the following information, in the order listed below.

1. UN symbol or letters (**"u"** over the top of the letter **"n"** inside a circle) must be embossed metal packagings.
2. Packaging code—the type of packaging, the material of construction and the category of packaging (§178.503(a)(2). The most commonly used "Codes" are as shown in the Table:

Examples: From the preceding table, we see that the outer packaging code 4D is for a plywood box; 4H2 is for a solid plastic box; 1G is for a fiber drum, and so forth.

3. Performance—an uppercase **X, Y** or **Z** indicates the performance standard or level for which the packaging has been successfully tested. The following codes should be committed to memory:
   X Meets Packing Group I, II, and III
   Y Meets Packing Group II, and III
   Z Meets Packing Group III only
4. Specific Gravity (Relative Density or Gross Mass)—a number designating either the Specific Gravity or Gross Mass, as appropriate, for which the packing has

Type	*Material*	*Category*
1 Drums	**A** Steel	**A, B,** or **H Drums-Jerricans**
2 Barrels	**B** Aluminum	**1** Closed Head **2** Open Head
3 Jerricans	**C** Natural Wood	**A** or **B Boxes**
4 Boxes	**D** Plywood	**1** Ordinary **A** or **B**
5 Bags	**F** Reconstituted Wood	**2 A** or **B** w/inner liner or coating
6 Composite Packagings	**G** Fiber	C Boxes
	H Plastic	**1** Ordinary **2** w/sht proof walls
7 Pressure Receptacle	**L** Textile	H Boxes
	M Paper, multiwall	**1** Expanded Plastic **2** Solid Plastic
	N Metal other than steel or aluminum	**L Bags 2** Sift proof
	P Glass Porcelain, or stoneware	**M Bags**
		2 Multi wall, water resistant

been successfully tested should come right after the Performance standard Code (§178.503(a)(4)).

✔ **Important Note:** Packagings without inner packagings intended to contain liquids must be marked with the specific gravity rounded down to the first decimal place for which the packaging has been successfully tested. The specific gravity is not required when the specific gravity does not exceed 1.2.

5. Hydrostatic test pressure—for liquids or gases or “S” for solids or inner packagings.
6. Year the package was manufactured.
7. Country the package was manufactured in.
8. Name and address or registration number of manufacturer.
9. Minimum thickness (for reusable or reconditioned packagings). **Note:** Additional information is required for reconditioned containers.

The following is an example of the amount of information that can be obtained from the manufacturer’s marking on the package.

4G/Y145/S/94USA/VL824

“4G” means fiberboard box
“Y” means it meets Packing Groups II and III tests
“145” means gross weight of solid
“S” means solids
“94” is the year of manufacture
“USA” country the package was manufactured in
“VL824” is the code of the manufacturer

✔ **Important Point**: Many liquid hazardous materials expand when heated. For this reason, all containers or liquid hazardous materials must have vacant space of outage.

✔ **Important Point**: All cylinders transported by air must have protection to prevent operation of or damage to valves. Equip cylinders with securely attached valve caps, protective headrings or place cylinders in a box or crate. Vented closures are used to reduce internal pressure and prevent the unintentional release of the product. Aircraft may not transport cargo tanks, tank cars or packages with vented closures.

✔ **Important Point**: Farmers transporting agricultural products other than gases between fields of the same farm using local roads are excepted from the requirements in the HMR. The farmer must be an intrastate private motor carrier. This exception does not apply to Class 2 gases, such as liquefied petroleum gas or anhydrous ammonia. To use this exception, you must use the agricultural products on your own farm. Each state must authorize these exceptions by aw or regulation. You must comply with all state requirements.

DOT Reportable Quantity (RQ): The quantity of a substance specified in a U.S. Department of Transportation regulation that triggers labeling, packaging and other requirements elated to shipping such substances.

DOT Shipping Papers: Shipping paper requirements for the transportation of hazardous materials are addressed in DOT’s 49 CFR 172.200. Because time is critical in an emergency, information on hazardous materials must be easily and quickly found on the shipping paper. Therefore, each person who offers a hazardous material for transportation, by highway, rail, air, or water, must properly describe the material on the shipping paper. DOT defines a *shipping paper* as a bill of lading (the Straight Bill of Lading is the most commonly used), a shipping order, manifest, or other shipping document serving a similar purpose and containing the required information. The shipping paper provides vital information when responding to a hazardous materials incident, and contains information needed to identify the hazardous materials involved and help initiate protective measures for your safety and the safety of public.

✔ **Important Point**: The basic rule for shipping papers is that if you transport any quantity of any hazardous material, a properly prepared shipping paper must accompany the shipment.

Shipping Paper Requirements

General Requirements

When hazardous materials are the shipment or part of the shipment, the shipping paper must contain certain specific items of information. The DOT basic shipping description consists of the following parts, all found in the Hazardous Materials Table (see Appendix A) and required by §172.202:

- Proper shipping name
- Hazard class or division number
- UN (United Nations) or NA (North America) identification (ID) number
- Packing Group (PG) number, in Roman numerals. [Note: a few materials do not have a Packing Group number.]

✔ **Important Point**: As used in the HMR, a shipping paper for hazardous materials transportation is any document that contains the information required to describe the hazardous material being transported. It may include a shipping order, a bill of lading, a hazardous materials manifest, or any other type shipping document serving a similar purpose and containing the required information. Only in the case of hazardous wastes is there a prescribed shipping paper format—the hazardous waste manifest.

When a description of a hazardous material must be included on a shipping paper that description must conform to the following requirements (§172.201):

1. When a hazardous material and a material not subject to the requirements of this subchapter are described on the same shipping paper, the hazardous material description entries required by §172.202 (see above) and those additional entries that may be required by §172.203:

   Must be entered first, or

- Must be entered in a color that clearly contrasts with any description on the shipping paper of a material not subject to the requirements of this subchapter, except that a description on a reproduction of a shipping paper may be highlighted, rather than printed, in a contrasting color, or
- Must be identified by the entry of an "X" placed before the proper shipping name in a column captioned "HM." [**Note:** the "X" may be replaced by "RQ," if appropriate.]
- The regulations require that the basic description must be legibly printed (manually or mechanically), and spelled correctly in English.
- Unless it is specifically authorized or required, the required shipping description may not contain any code or abbreviation.
- A shipping paper may contain additional information concerning the material provided the information is not inconsistent with the required description. Unless otherwise permitted or required, additional information must be placed after the basic description required §172.202 (see above).
- A shipping paper may consist of more than one page, if each page is consecutively numbered and the first page bears a notation specifying the total number of pages included in the shipping paper. For example, "Page 1 of 4 pages."
- A shipping paper must contain an emergency response telephone number. That is, the contact information of a knowledgeable person or someone who has immediate access to such a person must be on the shipping papers.
- The quantity of material shipped, by weight, volume, etc.

In addition to the information required on shipping papers discussed to this point, certain additional information may also be required. For example,

- When certain N.O.S. (not otherwise specified) or other shipping names are used that do not specifically identify the hazardous material or hazardous ingredient, the technical name of the material or ingredient must be entered in parentheses in association with the basic description. Usually this means after the proper shipping name or after the Packing Group number. If the material is a mixture containing two or more hazardous material components, the technical names of at least two components most predominately contributing to the hazard must be entered.
- If the material is a hazardous substance, the letters "RQ" (reportable quantity) must be entered either before or after the basic description. When a package has been emptied but contains a residue that meets the hazardous substance definition, the letters "RQ" must be entered.
- In addition, if the proper shipping name does not identify the hazardous substance(s) by name (as shown in Appendix A to the Hazardous Materials Ta-

ble), the name(s) of the hazardous substance component(s) must be shown in parentheses in association with the basic description. The word “contains” may precede the component names if desired.

- If the material is a marine pollutant and is transported in bulk packaging via air, rail, or truck, or in any size packaging by vessel, the words “Marine Pollutant” must be added in association with the basic description. If the proper shipping name does not identify the marine pollutant component by means as shown in Appendix B to the Hazardous Materials Table, the name of the component(s) must be entered in parentheses in association with the basic description.
- The words “Residue: Last Contained” must precede the proper shipping name for tank cars that have been unloaded but still contain the residue of a hazardous material, and for any type of packaging that contains a residue that is a hazardous substance.
- Unless already included in the proper shipping name for waste materials, the word “Waste” must precede the proper shipping name for a hazardous waste.
- If a liquid material in a package meets the definition of an elevated temperature material (other than molten sulfur or molten aluminum) and that fact is not disclosed in the proper shipping name, the word “HOT” must immediately precede the proper shipping name.
- In the case that a material is a poison (as defined by Division 6.1, Packing Group I or II), and is not disclosed as such in the shipping name or class entry, the word “POISON” must be entered on the shipping paper in association with the shipping description. If the material is poisonous by inhalation, the words “POISON—INHALATION HAZARD” followed by the hazard zone designation must be entered immediately following the basic description. The word “poison” need not be repeated if it otherwise appears in the shipping description.
- As specified in 49 CFR 172.203 (d), additional information is required for radioactive materials.
- The notation “Dangerous When Wet” must be entered in association with the basic description for any material meeting the Class 4.3 definition.
- The notation “Limited Quantity” or “LTD QTY” must be added following the basic description for any shipment moving under a limited quantity exception.
- For shipments moving under a DOT exemption, the notation “DOT-E” must be added, followed by the exemption number assigned, and so located that it is clearly associated with the description to which it applies.

✔ **Important Point:** Although not required, other information **may**, at the shipper’s option, be included on the shipping paper (for example, flashpoint, trade name, subsidiary hazard class, and other).

There are certain shipments of hazardous materials that do not require description as hazardous materials on a shipping paper. Some of the more common exceptions include:

- Hazardous materials with an ‘A’ I column 1 of the HMT offered or intended for transportation only by highway, rail, or vessel, unless the material is identified as a hazardous substance, a hazardous waste, or a marine pollutant and then it is regulated in all modes of transportation;
- Hazardous materials with ‘W’ in column I of the HMT offered or intended for transportation only by highway, rail, or air, unless the material is identified as a hazardous substance, a hazardous waste, or a marine pollutant and then it is regulated in all modes of transportation;
- Small quantity shipments prepared in accordance with §173.4;
- Certain agricultural shipments prepared and transported in accordance with §173.5;
- Materials of Trade shipments prepared in accordance with §173.6;
- Certain U.S. Department of Energy and U.S. Department of Defense shipments prepared in accordance with §173.7; and
- Shipments of ORM-D, unless transported by air, in accordance with §172.200(b) (3).
- The USDOT has granted exemptions or relief from certain hazardous materials regulations for specific packagings or shipping procedures. If a shipment is made under a DOT Exemption, the shipping paper must include the letters ’DOT-E’ followed by the assigned exemption number. The exemption number must be placed on the shipping paper so that it is clearly associated with the basic description to which the exemption applies. DOT exemptions are specific. They detail procedures the person holding the exemption, or a person who is party to an exemption, must follow, in order to be exempt from one or more provisions of the HMR—so it is critical that the procedures outlined in the DOT Exemption be followed. Otherwise, the shipment is treated as not exempt from the requirements of the HMR from which the person sought relief. If a package is shipped to you noting a DOT Exemption number on its shipping paper, you may not claim the same exemption when shipping the package with new shipping papers, unless you are named a party to the exemption. It the shipment moves to its final destination without preparation of

new shipping papers, however the exemption is still in force.

Emergency Response Information

Anyone who offers for transportation a hazardous material that requires hazardous materials shipping paper, must include an emergency response telephone number for use in the event of an emergency involving the hazardous material. The emergency response telephone number:

- Must be monitored at all times the hazardous material is in transportation.
- The number must be of someone who s knowledgeable about the hazardous material being shipped and has comprehensive emergency response and incident mitigation information, or has immediate access to a person who possesses such knowledge and information. This would include immediate hazards o health, the risks of fire and explosion, the immediate precautions to be taken in the event of an incident, the immediate methods for handling fires, the initial methods for handling spills or leaks in the absence of fire, and preliminary first aid measures.
- The telephone number must be entered on the shipping paper immediately following the description of the hazardous material or entered once on the shipping paper in a clearly visible location. See §172.604 (C) for a list of materials and limited quantity materials that do not require the display of an emergency response telephone number on the shipping paper document.

Maintenance of Shipping Papers

The shipper must keep a copy of the shipping paper, either electronic or paper, for 2 years after the material is accepted by the initial carrier. The carrier must keep a copy of shipping paper for 1 year after initial acceptance. However, both the shipper and the carrier must keep a copy of a Hazardous Waste Manifest (HWM) for 3 years after it is accepted by the initial carrier. In all cases, a copy must be accessible at or available through the principal place of business of the shipper and the carrier, respectively, and must be made available if requested by an authorized Federal, State, or local agency at reasonable times and locations.

The shipping paper must include the date of acceptance by the initial motor carrier. Fro rail, vessel, or air shipments, the date of the waybill or bill of lading may be used in place of the acceptance date by the initial carrier.

Motor carriers that use a shipping paper without changing it for multiple shipments of one or more hazardous materials having the same shipping name and identification number may retain a single copy of the shipping paper on file, instead of a copy for each shipment made, if the carrier also retains a record of each shipmen made, to include shipping name, identification number, quantity transported, and the date of shipment.

A shipping paper must accurately communicate the hazards of the material being transported. The shipping description for a hazmat must include these six items in the proper order. The basic description includes four of these six items and may be presented in one of two sequences. The first sequence includes the proper shipping name, the hazard class or division number, the identification number, and the packing group in that order. The second sequence places the identification number first, followed then by the proper shipping name, the hazard class/division number, and finally the packing group. The next item involves the total quantity of material in the package, and finally the last item involves the number and type of packages being shipped.

The four items of information that combine to form the basic description are found in columns 2-5 of the HMT. The regulations allow for certain limited modifications or additions to the proper shipping names. Except for combustible liquids, subsidiary hazard class or division numbers must be entered following the numeric hazard class. Subsidiary hazard class/division risk(s) should be listed in parenthesis as appropriate. The ability to provide the proper response to a hazardous materials incident depends on having the correct identification of the hazardous material involved and this means accurately describing the material on the shipping paper.

In addition to the basic description, the shipping paper must contain an indication by mass or volume of the total quantity of the hazardous material being transported. The quantity must include a unit of measure, e.g., pounds, gallons, kilograms, etc. For explosive materials, the quantity must be the net explosive mass. The total quantity may appear before or after, or both before an after the basic description. The units of measurement and packaging types may be abbreviated.

The number and type of package(s) must be indicated for each shipping description. The type of packaging must be indicated by a description of the package (e.g., 12 drums). The packaging specification may be included with the description (e.g., 12 1H1 drums). The number and type of packaging must be indicated either before or after the basic description.

✔ **Important Point**: The basic description is the primary building block for the shipping description displayed on each shipping paper document.

✔ **Important Point**: Entries in the HMT identified with the letter ‘G’ in column 1 are required to have one or more technical names accompany the proper shipping name on the shipping papers and packaging markings. Technical names must be entered on the shipping paper, in parentheses, either immediately after the proper shipping name, or following the basic description. The HMR allows modifiers, such as 'contains' or 'containing', and/or the percentage of the technical constituent.

Modal Requirements

The HMR prohibits or forbids transporting some materials aboard passenger carrying aircraft. The words 'Cargo Aircraft Only' must be entered after the basic description of a hazardous material that is offered for transportation by air, but prohibited for transportation aboard passenger carrying aircraft.

When a hazardous material is transported in rail car, freight container, transport vehicle or portable tank and the reporting mark and number are also displayed, the shipping paper prepared by the rail carrier must also include the reporting mark and number. Additional notations must appear on the shipping paper when a Division 2.1 flammable gas material is being transported in a DOT-113 tank car. These additional notations include: Identify the type of tank car, in this case, DOT-113, ad state the prohibition "Do Not Hump or Cut Off Car While in Motion." This prohibition forbids moving the car under its own momentum, called "humping". Uncoupling or cutting the car loose while in motion is also forbidden. For elevated temperature materials shipped according to §173.247(h)(3), the notation such as 'Maximum operating speed 15 mph' must be entered on the shipping paper.

When anhydrous ammonia containing 0.2 percent water or more by weight is transported by highway in either an MC 330 or MC 331 cargo tank, the shipping paper must have the notation: "0.2 PERCENT WATER" to indicate the suitability for shipping anhydrous ammonia in a cargo tank made of quenched and tempered steel. The notation must follow the basic description. When anhydrous ammonia contains less than 0.2 percent water by weight, the words "NOT FOR Q AND T TANKS" must be entered on the shipping paper, following the basic description.

✔ **Important Point**: For grades of noncorrosive liquefied petroleum gas, the word Noncorrosive or Noncor must be indicated on the shipping paper to indicate the suitability for shipment in cargo tanks made of quenched and tempered steel. For grades of LPG other than noncorrosive, the words 'Not for Q and T Tank' must be indicated on the shipping paper.

Each shipment by water must have the following additional shipping paper entries. These additional entries must include the name of the shipper and the minimum flash point if it is 61 degrees C or below in association with the basic description.

Poisonous Materials

The regulations regarding the identification of marine pollutants apply only to transportation by vessel and/or by air, highway, or rail. If you have a marine pollutant, packaged in non-bulk quantities and being transported by air, rail, or highway, you do not need to identify a hazardous material as a marine pollutant on a shipping paper. If the proper shipping name for a material, which is a marine pollutant, does not identify by name and component that makes the material a marine pollutant, the name of that component must appear in parentheses in association with the basic description.

Poisonous or toxic materials are subject to additional description requirements in §172.203(m). When the basic description or hazard class of a poisonous or toxic liquid or solid material in Packing Group I or II does not include the word Poison or toxic, the word Poison or Toxic must be entered in association with the basic description. Nitric acid, red fuming meets the definition of a Class 8, Division 6.1, PG 1, and Division 5.1 material, as indicated by the entries in Column 6 of the HMT. The word Poison must be entered in association with the basic description.

For a material meeting the poisonous or toxic by inhalation criteria, the words Poisonous-Inhalation Hazard or Toxic-Inhalation Hazard and the appropriate hazard zone shall be entered on the shipping paper immediately following the shipping description. Hazard zones consist of Zone A, Zone B, Zone C, or Zone D for gases, and Zone A or Zone B for liquids. The word 'Poison' or 'Toxic' need not be repeated if it otherwise appears in the shipping description. Nitric acid, red fuming meets the definition of a material that is poisonous by inhalation and assigned to Zone B. It is identified as such by the special provision number "2" in Column 7 of the HMT.

Temperature Factors

If a liquid material in a package meets the definition of an elevated temperature material, and the fact that it is an elevated temperature material is not disclosed in the shipping name with the use of the words 'Molten' or 'Elevated temperature' as a part of the proper shipping name; the word 'HOT' must immediately precede the proper shipping name of the material on the shipping paper.

Self-Reactive Materials

The additional description requirements on a shipping paper for a Division 4.1, self-reactive material or a Division 5.2, organic peroxide material, must include the following additional information, as appropriate:

- A statement of approval of the classification and conditions of transport when notification or competent authority approval is required.

- The control and emergency temperature for Division 4.1 or 5.2 materials that require temperature control during transport.
- The word "SAMPLE" must be included in association with the basic description, for samples of Division 4.1 or 5.2 materials when offered for transportation or transported.

Last Shipping Paper Entries

The last shipping paper entry is the shipper's certification stating that hazardous materials are being properly offered for transportation according to the HMR. It is the duty of the shipper to certify that the hazardous materials being shipped are properly prepared for transportation by printing the appropriate certificate on the shipping paper. The certification must be legibly signed by a principal, officer, partner, or employee of the shipper or his agent. A legal signature may include signing manually, by typewriter, or by other mechanical means. The regulation provides for four different certifications on the shipping paper, depending on the shipment destination and mode of transportation.

Shipping Paper Certification

The shipper must enter the selected certification on the shipping paper and sign it, manually, by typewriter, or by other mechanical means. This certification can be used for domestic or international transportation and must be printed word for word.

The air transportation certificate is used primarily for air shipments, but may be used in all modes of transportation. The shipper must enter the selected certification, word for word, on the shipping paper and sign it, manually, by typewriter, or by other mechanical means. For air shipments, the shipper must add the statement, "This shipment is within the limitations prescribed for passenger aircraft/cargo aircraft only;" delete the type of aircraft that does not apply; and provide two copies of the certification.

Each person who offers any radioactive material for transportation aboard a passenger-carrying aircraft shall sign a printed certificate stating that the shipment contains radioactive material intended for use in, or incident to, research, or medical diagnosis or treatment. The radioactive material certificate is used only in conjunction with air shipments. The shipper must enter the selected certification, word for word, on the shipping paper and sign it, manually, by typewriter, or by other mechanical means.

Shipping paper certification is required for all hazardous waste shipments, and if a hazardous material is reshipped or transferred from one carrier to another.

Except for hazardous waste, shipping paper certification is not required for a hazardous material offered for transportation by motor vehicle and transported in a cargo tank supplied by the carrier; by the shipper as a private carrier; or for the return of an empty tank car containing a hazardous material residue.

Hazardous Wastes

The term manifest or hazardous waste manifest means a shipping paper on which hazardous wastes are described. The hazardous waste manifest must be on EPA form 8700-22 and 8700-22A (when necessary), and prepared in a manner prescribed in §172.205 and 40 CFR 262.0. It must be dated and hand-signed by the person representing the shipper of the waste and of the initial carrier accepting the waste for transportation. Hazardous waste manifests must accompany the shipment from pickup to destination, and copies must be given to each carrier involved in the movement of the waste and to the designated disposal facility. Some states require the use of a state-designated manifest document. It is recommended that prior to accepting and/or transporting any hazardous wastes, check with the state agency responsible for regulating those materials.

The waste shipper/generator must prepare the Hazardous Waste Manifest and provide a copy to each waste carrier and each designated waste facility. The waste shipper and each waste carrier must retain a copy of the Hazardous Waste Manifest for three years from the date the waste was accepted by the initial carrier. If you are a shipper, be sure the accompanying paperwork is accurate and contains all required information before you offer a shipment of hazardous waste. If you are a carrier, verify the information on the shipping paper. If the paperwork is not correct or the packages are not intact, do not accept the shipment.

DOT Training Requirements: The flagship regulation, Hazardous Materials Transportation Uniform Safety Act (HMTUSA) of 1990 (Public Law 101-615) established standards for training by "hazmat employers" of all "hazmat employees."

HMTUSA required the Secretary of Transportation to establish standards for training by Hazmat employers of all Hazmat employees. This key act virtually changed the face (and requirements) of transportation training as it was known (or unknown) before 1990.

HM-126F, an amendment to the Hazardous Materials Regulations, sets training requirements for individuals involved in all modes of transportation (over-the-road, rail, aircraft or vessel) of hazardous materials. This amendment ensures that Hazmat employers train their Hazmat employees in safe work practices in the following areas:

- loading and unloading
- handling
- storing

- transporting
- preparedness to accidents involving hazardous materials

The implementation of HM-126F added two key definitions to the regulation:

Hazmat Employer

1. A company/person who utilizes one or more employees to transport or cause to transport, hazardous materials in commerce, or
2. One who represents, marks, certifies, sells, offers, reconditions, tests, repairs, or modifies containers, drums, or packaging for use in transporting hazardous materials. This includes:
    - owners and operators of vehicles that transport hazardous materials
    - any department or agency of the U.S.
    - a state or political subdivision of a state
    - an Indian tribe that deals with hazardous material as a form of business

Hazmat Employee

1. One who directly affects the safe transportation of hazardous materials, either as a self-employed person or one who performs duties relating to hazardous materials as part of the job. This includes the owner/operator of a motor vehicle that transports hazardous materials in commerce.

✔ **Important Note:** Based on the above definitions, workers who must be trained include those who:

- load or unload hazardous materials
- test, recondition, repair, modify, or mark containers, drums or packaging used in transporting hazardous materials
- prepare hazardous materials for transporting
- are responsible for the safe transporting of hazardous materials (e.g., supervisors),

Downgradient: The direction that groundwater flows; similar to "downstream" for surface water.

Downstream Processors: Industries dependent on crop production (e.g., canneries and food processors).

Draft: 1. The act of drawing or removing water from a tank or reservoir. 2. The water which is drawn or removed.

Draft Permit: A preliminary permit drafted and published by EPA; subject to public review and comment before final action on the application.

Draft Tube: A water conduit, which can be straight or curved depending upon the turbine installation that maintains a column of water from the turbine outlet and the downstream water level.

Dragonflies: Dragonflies are also known as darning needles. [**Note**: Myths about dragonflies warned children to keep quiet lest the dragonfly's 'darning needles' would sew the child's mouth shut]. The nymphal stage of dragonflies is grotesque creatures, robust and stoutly elongated. They do not have long 'tails'. They are commonly gray, greenish, or brown to black in color. They are medium to large aquatic insect's size ranging from 15 to 45 mm the legs are short and used for perching. They are often found on submerged vegetation and at the bottom of streams in the shallows. They are rarely found in polluted waters. Food consists of other aquatic insects, annelids, small crustacea and mollusks. Transformation occurs when the nymph crawls out of the water, usually onto vegetation. There it splits its skin and emerges prepared for flight. The adult dragonfly is a strong flier, capable of great speed (>60 mph) and maneuverability (fly backward, stop on a dime, zip twenty feet straight up, and slip sideways in the blink of an eye!). When at rest the wings remain open and out to the sides of the body. A dragonfly's freely movable head has large, hemispherical eyes (nearly 30,000 facets each), which the insects use to locate prey with their excellent vision. Dragonflies eat small insects, mainly mosquitoes (large numbers of mosquitoes), while in flight. Depending on the species, dragonflies lay hundreds of eggs by dropping them into the water and leaving them to hatch or by inserting eggs singly into a slit in the stem of a submerged plant. The incomplete metamorphosis (egg, nymph, mature nymph, and adult) can take two to three years. Nymphs are often covered by algal growth.

Drain Field: Shallow, covered, excavation made in unsaturated soil into which pretreated wastewater is discharged through distribution piping for application onto soil infiltration surfaces though porous media or manufactured (gravelless) components placed in the excavations. The soils accepts, treats, and disperse wastewater as it percolates through the soil, ultimately discharging to groundwater.

Drainage: Improving the productivity of agricultural land by removing excess water from the soil by such means as ditches or subsurface drainage tiles.

Drainage Basin: The geographical region drained by a river or stream. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large drainage basins, like the area that drains into the Mississippi River contain thousands of smaller drainage basins. Also called a "watershed."

Drainage Well: A well drilled to carry excess water off agriculture fields; they act as a funnel from the surface to the groundwater below. Drainage wells can contribute to groundwater pollution.

Drift: One process in which influenza virus undergoes mutation. The amount of change can be subtle or dramatic, but eventually as drift occurs, a new variant strain will become dominant. This process allows influenza viruses to change and re-infect people repeatedly through their lifetime and is the reason influenza virus strains in vaccine must be updated each year.

Drinking Water Equivalent Level: Protective level of exposure related to potentially non-carcinogenic effects of chemicals that are also known to cause cancer.

Drinking Water State Revolving Fund: The Fund provides capitalization grants to states to develop drinking water revolving loan funds to help finance system infrastructure improvement, assure source-water protection, enhance operation and management of drinking-water systems, and otherwise promote local water-system compliance and protection of public health.

Drip Irrigation: A common irrigation method where pipes or tubes filled with water slowly drip onto crops. Drip irrigation is a low-pressure method of irrigation and less water is lost to evaporation than high-pressure spray irrigation.

Drug Testing: Workplace Drug Testing Programs are implemented to:

- avoid hiring individuals who use illegal drugs;
- deter employees from abusing drugs or alcohol;
- provide early identification and referral to treatment.

Jacobson (1998) points out that in 1981 only 3 percent of the companies polled conducted drug tests. In 1991, an estimated over 50 percent of major U.S. corporations had policies that include testing. Note that the prevalence of testing programs is positively associated with workplace size, with most found in manufacturing companies and utilities (Blum, 1992).

After the organization establishes a drug-testing program, and with the guidance of professionals, drug testing should be conducted in three areas: “pre-employment,” “random,” and “for cause or reasonable suspicion.”

Dry Adiabatic Lapse Rate: When a dry parcel of air is lifted in the atmosphere, it undergoes adiabatic expansion and cooling that results in a lapse rate (cooling) of -1C/100m or 1-10C/km.

Dry Steam: Very hot steam that doesn’t occur with liquid.

Dry Tower Method: A thermal pollution treatment technique whereby heated water is pumped through tubes and the heat is released into the air (similar to the performance of an automobile radiator).

Dry-Weight Percentage: Ratio of the weight of any constituent to the oven-dry weight of the whole substance, such as plant or soil.

Drying Beds: In wastewater treatment, sludge drying beds are designed to act as dewatering beds.

Duct Diameters: Measured to calculate duct areas. Inside duct diameter is the most important measurement, but an outside measurement is often sufficient for a sheet metal duct. To measure the duct, the tape should be thrown around the duct to obtain the duct circumference, and the number should be divided by (3.142) to obtain the diameter of the duct.

Duct Velocity Measurements: May be made directly (with velometers and anemometers) or indirectly (with manometers and pitot tubes) using duct velocity pressure.

a. Air flow in industrial ventilation ducts is almost always turbulent, with a small, nonmoving boundary layer at the surface of the duct.
b. Because velocity varies with distance from the edge of the duct, a single measurement may not be sufficient. However, if the measurement is taken in a straight length of round duct, 4–6 diameters downstream ad 2–3 diameters upstream from obstructions or directional changes, then the average velocity can be estimated at 90 percent of the centerline velocity. The average velocity pressure is about 81 percent of centerline velocity pressure.
c. A more accurate method is the traverse method, which involves taking six to ten measurements on each of two or three passes across the duct, 90° or 60° opposed. Measurements are made in the center of concentric circles of equal area.
d. Density corrections (e.g., temperature) for instrument use should be made in accordance with the manufacturer’s instrument instruction manual and calculation/correction formulas.

Ductility: The ability of a metal to stretch, bend, or twist without breaking or cracking.

Ductwork: A duct system.

Due Care: A minimal level of protection in place in accordance with industry best practice.

Due Diligence: The requirement that organizations must develop and deploy a protection plan to prevent fraud, abuse, and deploy a means to detect them if they occur.

Dumps: An open location where refuse and other waste materials are disposed of in a manner that does not protect the environment, is susceptible to open burning, or is exposed to the elements, vermin and/or scavengers.

Dumpster Diving: Obtaining passwords and corporate directories by searching through discarded media.

Duplicate: A second aliquot of sample that is treated the same as the original sample in order to determine the precision of the analytical method.

Dust: 1. A dispersion of tiny solid airborne particles produced by grinding or crushing operations. 2. Various types of solid particles produced when a given type of organic or inorganic material is scraped, sawed, ground, drilled, heated, crushed, or otherwise deformed.

Duster: A well that did not encounter commercial amounts of petroleum.

Dustfall Jar: An open container used to collect large particles from the air for measurement and analysis.

Dynamics: Dynamics (kinetics in mechanics) is the mathematical and physical study of the behavior of bodies under the action of forces that produce changes of motion in them. In dynamics, certain properties are important: displacement, velocity, acceleration, momentum, kinetic energy, potential energy, work and power. Safety engineer's work with these properties to determine, for example, if rotating equipment will fly apart and cause injury to workers, or to determine the distance needed to stop a vehicle in motion.

Dynamometer: Any of various devices used in testing a motor or engine efficiency and torque.

Dyne: Unit of measurement equal to the amount of force that will cause a mass of 1 gram to accelerate at a rate of 1 cm per second per second.

E

E-10: A mixture of 10 percent ethanol and 90 percent gasoline based on volume.

E-85: A mixture of 85 percent ethanol and 15 percent gasoline based on volume.

Earth's Heat Balance: Approximately 50 percent of the solar radiation entering the atmosphere reaches earth's surface either directly or after being scattered by clouds, particulate matter or atmospheric gases. The other 50 percent is either reflected directly back, or absorbed in the atmosphere and its energy re-radiated back into space at a later time as infrared radiation. Most of the solar energy reaching the surface is absorbed, and must be returned to space to maintain **heat balance**. The energy produced within the earth's interior (from hot mantle area via convection and conduction) that reaches the earth's surface (about 1 percent of that received from the sun) must also be lost.

Reradiation of energy from the earth is accomplished by three energy transport mechanisms: radiation, conduction, and convection. **Radiation** of energy, as we've said earlier, occurs through electromagnetic radiation in the infrared region of the spectrum. The crucial importance of the radiation mechanism is that it carries energy away from earth—on a much longer wavelength than the solar energy (sunlight) that brings energy to the earth—and, in turn, works to maintain the earth's heat balance. The earth's heat balance is of particular interest to us in this text because it is susceptible to upset by human activities.

A comparatively smaller (but significant) amount of heat energy is transferred to the atmosphere by conduction from the earth's surface. **Conduction** of energy occurs through the interaction of adjacent molecules with no visible motion accompanying the transfer of heat—for example, when the whole length of a metal rod is heated when one end is held in a fire. Because air is a poor heat conductor, conduction is restricted to the layer of air in direct contact with the earth's surface. The heated air is then transferred aloft by **convection**, the movement of whole masses of air, which may be either relatively warm or cold. Convection is the mechanism by which abrupt temperature variations occur when large masses of air move across an area. Air temperature tends to be greater near the surface of the earth, and decreases gradually with altitude. A large amount of the earth's surface heat is transported to clouds in the atmosphere by conduction and convection—before being lost ultimately by radiation—and this redistribution of heat energy plays an important role in weather and climate conditions.

The earth's average surface temperature is maintained at about 15°C because of atmospheric **greenhouse effect**. Greenhouse effect occurs when the gases of the lower atmosphere transmit most of the visible portion of incident sunlight in the same way as the glass of a garden greenhouse. The warmed Earth emits radiation in the infrared region, which is selectively absorbed by the atmospheric gases whose absorption spectrum is similar to that of glass. This absorbed energy heats the atmosphere and helps maintain the earth's temperature. Without this greenhouse effect, the surface temperature would average around -18°C. Water molecules in the atmosphere perform most of the absorption of infrared energy. In addition to the key role played by water molecules, carbon dioxide, although to a lesser extent, also is essential in maintaining the heat balance. Environmentalists and others studying environmental issues are concerned that an increase in the carbon dioxide level in the atmosphere could prevent sufficient energy loss, causing damaging increases in the earth's temperature. This phenomenon, commonly known as **anthropogenic greenhouse effect**, may occur from elevated levels of carbon dioxide levels caused by increased use of fossil fuels and the reduction in carbon dioxide absorption because of destruction of the rain forest and other forest areas.

Ecological: In *environmental science*, having to do with the relationship between organisms and their environment.

Ecological Distribution: Each organism occupies only those areas that can provide for its requirements, resulting in an irregular distribution. How a particular population is distributed within a given area has considerable influence on density. Organisms in nature may be distributed in three ways, as a result of complex interactions among ecological variables.

In a random distribution, there is an equal probability of an organism occupying any point in space, and "each individual is independent of the others" (Smith 1974).

In a regular or uniform distribution, in turn, organisms are spaced more evenly; they are not distributed by chance. Animals compete with each other and effectively defend a specific territory, excluding other individuals of the same species. In regular or uniform distribution, the competition between individuals can be quite severe and antagonistic to the point where spacing generated is quite even (Odum 1983).

The most common distribution is the contagious or clumped distribution where organisms are found in groups; this may reflect the heterogeneity of the habitat. Smith (1974) points out that contagious or clumped distribution "produce aggregations, the result of response by plants and animals to habitat differences."

Organisms that exhibit a contagious or clumped distribution may develop social hierarchies in order to live together more effectively. Animals within the same species have evolved many symbolic aggressive displays that carry meanings that are not only mutually understood but also prevent injury or death within the same species. For example, in some mountainous regions, dominant male bighorn sheep force the juvenile and subordinate males out the territory during breeding season (Hickman et al. 1990). In this way, the dominant male gains control over the females and need not compete with other males.

As mentioned, distribution patterns are the result of complex interactions among ecological variables. For example, consider a study conducted by Hubbell and Johnson (1977) of five tropical bee colonies (the bees live in colonies in suitable trees) in the tropical dry forests of Costa Rica. The researchers set out to examine relationship between aggressiveness and patterns of colony distribution.

1. The researchers mapped locations of suitable nest trees. They found that the number of suitable trees was greater than number of colonies—thus nest sites were not a limiting factor. Distribution of suitable trees was random.
2. The researchers next mapped locations of bee colonies. They found that colonies sites for one species were dispersed randomly. Members of this species do not exhibit aggression toward one another. The colonies were sometimes quite close to one another. On the other hand, colony sites for the other four species were dispersed in a regular fashion. Members of all four species were aggressive to members of other colonies of the same species. They also mark their colony sites with pheromones. They also engage in ritualized battles for colony sites with conspecifics from other colonies.

Ecological Entity: In ecological risk assessment, a general term referring to a species, a group of species, an ecosystem function or characteristic, or a specific habitat or biome.

Ecological/Environmental Sustainability: Maintenance of ecosystem components and functions for future generations.

Ecological Exposure: Exposure of a non-human organism to a stressor.

Ecological Footprint: In *environmental science*, a concept used to describe the impact that a given human entity has on the biological resources of the earth.

Ecological Impact: The effect that a man-caused or natural activity has on living organism and their non-living (abiotic) environment.

Ecological Indicator: A characteristic of an ecosystem that is related to, or derived from, a measure of biotic or abiotic variable, that can provide quantitative information on ecological structure and function. An indicator can contribute to a measure of integrity and sustainability.

Ecological Integrity: A living system exhibits integrity if, when subjected to disturbance, it sustains and organizes self-correcting ability to recover toward a biomass and end-state that is normal for that system. End-states other than the pristine or naturally whole may be accepted as "normal and good."

Ecological Pyramids: 1. Three types of ecological pyramids are the pyramids of numbers, productivity, and energy. All of these pyramids are based on the fact that due to energy loss, fewer animals can be supported at each additional trophic level, which is the number of energy transfers an organism is from the rest of the pyramid indicates what happens to this energy. 2. As we proceed in the food chain from the producer to the final consumer it becomes clear that a particular community in nature often consists of several small organisms associated with a smaller and smaller number of larger organisms. A grassy field, for example, has a larger number of grass and other small plants, a smaller number of herbivores like rabbits, and an even smaller number of carnivores like fox. The practical significance of this is that we must have several more producers than consumers.

This pound-for-pound relationship, where it takes more producers than consumers, can be demonstrated graphically by building an ecological pyramid. In an ecological pyramid, the number of organisms at various trophic levels in a food chain is represented by separate levels or bars placed one above the other with a base formed by producers and the apex formed by the final consumer. The pyramid shape is formed due to a great amount of energy loss at each trophic level. The same is true if numbers are substituted by the corresponding biomass or energy. Ecologists generally use three types of ecological pyramids: pyramids of number, biomass, and energy. Obviously, there will be differences among them. Some generalizations:

1. *Energy pyramids* must always be larger at the base than at the top (because of the 2nd Law of Thermodynamics, and has to do with dissipation of energy as it moves from one trophic level to another). Simply, energy pyramids depict the decrease in the total available energy at each higher trophic level.
2. Likewise, *biomass pyramids* (in which biomass is used as an indicator of production) are usually pyramid-shaped. This is particularly true of terrestrial systems and aquatic ones dominated by large plants (marshes), in which consumption by heterotroph is low and organic matter accumulates with time. A census of the population, multiplied by the weight of an average individual in it, gives an estimate of the weight of the population. This is called the **biomass** (or standing crop). However, it is important to point out that biomass pyramids can sometimes be inverted. This is especially common in aquatic ecosystems, in which the primary producers are microscopic planktonic organisms that multiply very rapidly, have very short life spans, and heavy grazing by herbivores. At any single point in time, the amount of biomass in primary producers is less than that in larger, long-lived animals that consume primary producers.
3. *Numbers pyramids* can have various shapes (and not be pyramids at all, actually) depending on the sizes of the organisms that make up the trophic levels. In forests, the primary producers are large trees and the herbivore level usually consists of insects, so the base of the pyramid is smaller than the herbivore level above it; that is, the pyramid is inverted. In grasslands, the number of primary producers (grasses) is much larger than that of the herbivores above (large grazing animals) (Spellman 1996).

To get a better idea of how an ecological pyramid looks and how it provides its information, we need to look at an example. The example used here is the energy pyramid. According to Odum (1983), the energy pyramid is a fitting example because among the "three types of ecological pyramids, the energy pyramid gives by far the best overall picture of the functional nature of communities."

In an experiment conducted in Silver Springs, Florida, Odum (1983) measured the energy for each trophic level in terms of kilocalories. A kilocalorie is the amount of energy needed to raise 1 cubic centimeter of water 1 degree centigrade. When an energy pyramid is constructed to show Odum's findings, it takes on the typical upright form (as it must because of the second law of thermodynamics).

Simply put, according to the second law of thermodynamics, no energy transformation process is 100 percent efficient. This fact is demonstrated, for example, when a horse eats hay. The horse cannot obtain, for his own body, 100 percent of the energy available in the hay. For this reason, the energy productivity of the producers must be greater than the energy production of the primary consumers. When human beings are substituted for the horse, it is interesting to note that according to the second law of thermodynamics, only a small population could be supported. But this is not the case. Humans also feed on plant matter, which allows a larger population. Therefore, if meat supplies become scarce, we must eat more plant matter. This is the situation we see today in countries where meat is scarce. Consider this, if we all ate soybean, there would be at least enough food for 10x as many of us as compared to a world where we all eat beef (or pork, fish, chicken, etc.). Another way of looking at this. Every time we eat meat, we are taking food out of the mouths of 9 other people, who could be fed with the plant material that was fed to the animal we are eating (Spellman, 1996). Food-energy relationships are often referred to eater-eaten relationships. It's not quite that simple, of course, but you probably get the general idea.

Ecological Risk Assessment: The application of a formal framework, analytical process, or model to estimate the effects of human actions(s) on a natural resource and to interpret the significance of those effects in light of the uncertainties identified in each component of the assessment process. Such analysis includes initial hazard identification, exposure an dose-response assessments, and risk characterization.

Ecological Succession: Ecosystems can and do change. For example, if a forest is devastated by a fire, it will grow back, eventually, because of ecological succession. Ecological succession is the observed process of change (a normal occurrence in nature) in the species structure of an ecological community over time; that is, a gradual and orderly replacement of plant and animal species takes place in a particular area over time. The result of succession is evident in many places. For example, succession can be seen in an abandoned pasture. It can be seen in any lake and any pond. Succession can even be seen where weeds and grasses grow in the cracks in a tarmac, roadway, or sidewalk.

Additional specific examples of observable succession include:

1. Consider a red pine planting area where the growth of hardwood trees (including ash, popular and oak) occurs. The consequence of this hardwood tree growth is the increased shading and subsequent mortality of the sun loving red pines by the shade tolerant hardwood seedlings. The shaded forest floor conditions generated by the pines prohibit the growth of sun-loving pine seedlings and allow the growth of the hardwoods. The consequence of the growth of the hardwoods is the decline and senescence of the pine forest.
2. Consider raspberry thickets growing in the sun lit forest sections beneath the gaps in the canopy generated by wind-thrown trees. Raspberry plants require sunlight to grow and thrive. Beneath the dense shade canopy particularly of red pines but also dense stands of oak, there is not sufficient sunlight for the raspberry's survival. However, in any place in which there has been a tree fall the raspberry canes proliferate into dense thickets. Within these raspberry thickets, by the way, are dense growths of hardwood seedlings. The raspberry plants generate a protected "nursery" for these seedlings and prevent a major browser of tree seedlings (the white tail deer) from eating and destroying the trees. By providing these trees a shaded haven in which to grow the raspberry plants are setting up the future tree canopy which will extensively shade the future forest floor and consequently prevent the future growth of more raspberry plants!

Succession usually occurs in an orderly, predictable manner. It involves the entire system. The science of ecology has developed to such a point that ecologists are now able to predict several years in advance what will occur in a given ecosystem. For example, scientists know that if a burned-out forest region receives light, water, nutrients, and an influx or immigration of animals and seeds, it will eventually develop into another forest through a sequence of steps or stages.

Two types of ecological succession are recognized by ecologists: primary and secondary. The particular type that takes place depends on the condition at a particular site at the beginning of the process.

Primary succession, sometimes called bare-rock succession, occurs on surfaces such as hardened volcanic lava, bare rock, and sand dunes, where no soil exists, and where nothing has ever grown before. Obviously, in order to grow, plants need soil. Thus, soil must form on the bare rock before succession can begin. Usually this soil formation process results from weathering. Atmospheric exposure—weathering, wind, rain, and frost—forms tiny cracks and holes in rock surfaces. Water collects in the rock fissures and slowly dissolves the minerals out of the rock's surface. A pioneer soil layer is formed from the dissolved minerals and supports such plants as lichens. Lichens gradually cover the rock surface and secrete carbonic acid, which dissolves additional minerals from the rock. Eventually, the lichens are replaced by mosses. Organisms called decomposers move in and feed on dead lichen and moss. A few small animals such as mites and spiders arrive next. The result is what is known as a pioneer community. The pioneer community is defined as the first successful integration of plants, animals, and decomposers into a bare-rock community (Miller 1988).

After several years, the pioneer community builds up enough organic matter in its soil to be able to support rooted plants like herbs and shrubs. Eventually, the pioneer community is crowded out and is replaced by a different environment. This, in turn, works to thicken the upper soil layers. The progression continues through several other stages until a mature or climax ecosystem is developed, several decades later. It is interesting to note that in bare-rock succession, each stage in the complex succession pattern dooms the stage that existed before it. According to Tomera (1990), "mosses provide a habitat most inhospitable to lichens, the herbs will eventually destroy the moss community, and so on until the climax stage is reached."

Case Study—From Lava Flow to Forest: Primary Succession (USGS 1999)

Probably the best example of primary succession occurred (and is still occurring) on the Hawaiian Islands.

One of the most striking aspects of a newly formed lava flow is its barren and sterile nature. The process of colonization of new flows begins almost immediately as certain native organisms specially adapted to the harsh conditions begin to arrive from adjoining areas. A wolf spider and cricket may be the first to take up residence, consuming other invertebrates that venture onto the forbidding new environment. The succession process relies heavily on adjacent ecosystems. A steady rain of organic material, seeds, and spores slowly accumulates in cracks and pockets along with tiny fragments of the new lava surface. Some pockets of this infant soil retain enough moisture to support scattered 'ohi'a seedlings and a few hardy ferns and shrubs. Over time, the progeny of these colonizers, and additional species from nearby forests, form an open cover of vegetation, gradually changing the conditions to those more favorable to other organisms.

The accumulation of fallen leaves, bark, and dead roots is converted by soil organisms into a thin but rich organic soil. A forest can develop in wet regions in less than 150 years.

On Hawaiian lava flows, primary succession proceeds rapidly on wet windward slopes, but more slowly in dry areas. The influence of moisture can be seen on the Kona side, where the same flow can support a forest along the Belt Highway but be nearly barren near the dry coast. Except for the newer flows and disturbed areas, the windward surfaces of Kilauea are heavily forested, but the leeward slope is barren or sparsely vegetated.

All the undisturbed flows on Kilauea, Mauna Loa, and Hualaiai volcanoes are young enough to be in some degree of primary succession, and the patterns and relative age of lava flows are reflected in the maturity of vegetation. Only a few of the newest flows on the dry upper slopes of dormant Mauna Kea are young enough to reflect primary succession. Extinct Kohala volcano is too old to find such flows, and vegetation differences reflect rainfall amounts and disturbance.

On wetter slopes of Hualaiai and Mauna Loa, younger flows stand out against a more uniform, older background, as the surfaces are recovered by lava at rates of only 20 to 40 percent a century. Small and more active, Kilauea renews about 90 percent of its surface in the same time period, and the resulting pattern is a patchwork of flows and vegetated remnants (kipuka). The many younger flows rely on the older kipuka to provide sources of plants and animals.

The native forest ecosystems have adapted to the overpowering nature of volcanic eruptions by being able to quickly recolonize from the many kipuka around new flows. However, the added losses due to forest clearing and alien invasion provide additional threats to which the native biota is not adapted. If too many of the native forest areas are cleared or taken over by introduced organisms, natural succession may not be able to provide a replacement native ecosystem on the younger flows. The continuing primary succession process may be already partially interrupted in low Puna, where so much of the native forest has been cleared for development and where colonizers from nearby areas are mostly introduced organisms.

Secondary succession is the most common type of succession. Secondary succession occurs in an area where the natural vegetation has been removed or destroyed but the soil is not destroyed. For example, succession that occurs in abandoned farm fields, known as old field succession, illustrates secondary succession. An example of secondary succession can be seen in the Piedmont region of North Carolina. Early settlers of the area cleared away the native oak-hickory forests and cultivated the land. In the ensuing years, the soil became depleted of nutrients, reducing the soil's fertility. As a result, farming ceased in the region a few generations later, and the fields were abandoned. Some 150 to 200 years after abandonment, the climax oak-hickory forest was restored.

Ecological Toxicology: The branch of toxicology that addresses the effect of toxic substances, not only on the human population, but also the environment in general, including air, soil, surface water, and groundwater.

Ecology: Ecology can be defined in various and numerous ways. For example, ecology, or ecological science, is commonly defined in the literature as the scientific study of the distribution and abundance of living organisms and how the distribution and abundance are affected by interactions between the organisms and their environment. The term ecology was coined in 1866 by the German biologist Haeckel and it loosely means "the study of the household [of nature]". Odum (1983) explains that the word "ecology" is derived from the Greek oikos, meaning home. Ecology then means the study of organisms at home. It means the study of an organism at its home. Ecology is the study of the relation of an organism or a group of organisms to their environment. In a broader sense, ecology is the study of the relation of organisms or groups to their environment.

✔ **Important Point:** No ecosystem can be studied in isolation. If we were to describe ourselves, our histories, and what made us the way we are, we could not leave the world around us out of our description! So it is with streams, for example: they are directly tied in with the world around them. They take their chemistry from the rocks and dirt beneath them as well as for a great distance around them (Spellman 1996).

Charles Darwin explained ecology in a famous passage in the *Origin*, a passage that helped establish the science of ecology. A "web of complex relations" binds all living things in any region, Darwin writes. Adding or subtracting even a single species causes waves of change that race through the web, "onwards in ever-increasing circles of complexity." The simple act of adding cats to an English village would reduce the number of field mice. Killing mice would benefit the bumblebees, whose nest and honeycombs the mice often devour. Increasing the number of bumblebees would benefit the heartsease and red clover, which are fertilized almost exclusively by bumblebees. So adding cats to the village could end by adding flowers. For Darwin the whole of the Galapagos archipelago argues this fundamental lesson. The volcanoes are much more diverse in their ecology than their biology. The contrast suggests that in the struggle for existence, species are shaped at least as much by the local flora and fauna as by the local soil and climate.

"Why else would the plants and animals differ radically among islands that have the same geological nature, the same height, and climate" (Darwin, 1998).

Probably the best way to understand ecology—to get a really good "feel" for it—or to get to the heart of what ecology is all about is to read the following by Rachel Carson (1962):

> "We poison the caddis flies in a stream and the salmon runs dwindle and die. We poison the gnats in a lake and the poison travels from link to link of the food chain and soon the birds of the lake margins become victims. We spray our elms and the following springs are silent of robin song, not because we sprayed the robins directly but because the poison traveled, step by step, through the now familiar elm leaf-earthworm-robin cycle. These are matters of record, observable, part of the visible world around us. They reflect the web of life—or death—that scientists know as ecology."

As Rachel Carson points out, what we do to any part of our environment has an impact upon other parts. In other words, there is an interrelationship between the parts that make up our environment. Probably the best way to state this interrelationship is to define ecology definitively—that is, to define it as it is used in this text: "Ecology is the science that deals with the specific interactions that exist between organisms and their living and nonliving environment" (Tomera 1989).

When environment was mentioned in the proceeding, it (the environment) includes everything important to the organism in its surroundings. The organism's environment can be divided into four parts:

1. Habitat and distribution—its place to live
2. Other organisms—whether friendly or hostile
3. Food
4. Weather—light, moisture, temperature, soil, etc.

There are four major subdivisions of ecology:

- Behavioral Ecology
- Population Ecology (Autecology)
- Community Ecology (Synecology)
- Ecosystem Ecology

Behavioral ecology is the study of the ecological and evolutionary basis for animal behavior. *Population ecology* (or Autecology) is the study of the individual organism or a species. It emphasizes life history, adaptations and behavior. It is the study of communities, ecosystems, and biosphere. An example of autecology would be when biologists spend their entire lifetime studying the ecology of the salmon. *Community ecology* (or Synecology), on the other hand, is the study of groups of organisms associated together as a unit and deals with the environmental problems caused by mankind. For example, the effect of discharging phosphorous-laden effluent into a stream involves several organisms. The activities of human beings have become a major component of many natural areas. As a result, it is important to realize that the study of ecology must involve people. *Ecosystem ecology* is the study of how energy flow and matter interact with biotic elements of ecosystems (Odum, 1971).

✔ **Important Point:** Ecology is generally categorized according to complexity; the primary kinds of organism under study (plant, animal, insect ecology); the biomes principally studied (forest, desert, benthic, grassland, etc.); the climatic or geographic area (e.g., artic or tropics); and/or the spatial scale (macro or micro) under consideration.

Economic Poisons: Chemicals used to control pests and to defoliate cash crops such as cotton.

Ecosphere: The "bio-bubble" that contains life on earth, in surface waters, and in the air.

Ecosystem: A contraction of "ecological" and "system," ecosystem is a term introduced by Tansley to denote an area that includes all organisms therein and their physical environment. Specifically, an ecosystem is defined as the geographic area including all the living organisms, their physical surroundings, and the natural cycles that sustain them. All of these elements are interconnected (USFWS 2007). Simply, the ecosystem is the major ecological unit in nature. Elements of an ecosystem may include flora, fauna, lower life forms, water and soil (Ecosystem 2007). "There is a constant interchange of the most various kinds within each system, not only between the organisms but between the organic and the inorganic" (Tansley 1935). Living organisms and their nonliving environment are inseparably interrelated and interact upon each other to create a self-regulating and self-maintaining system. To create a self-regulating and self-maintaining system, ecosystems are homeostatic, i.e., they resist any change through natural controls. These natural controls are important in ecology. This is especially the case since it is people through their complex activities who tend to disrupt natural controls.

Tansley regarded the ecosystem as not only the organism complex, but also the whole complex of physical factors forming what we call the environment. It was first applied to levels of biological organization represented by units such community and the biome. Odum (1952) and Evans (1956) expanded the extent of the concept to include other levels of organization (USDA, 1982).

✔ **Important Point**: According to the *Concise Oxford Dictionary of Ecology* (1994), "Natural" is commonly defined as being "present in or produced by nature . . . with relatively little modification by humans."

✔ **Important Point:** Modern usage of the term ecosystem derives from the work done by Raymond Lindeman. Lindeman's central concepts were that of functional organization and ecological energy efficiency ratios. This approach is connected to ecological energetics and might also be thought of as environmental rationalism. It was subsequently applied by H.T. Odum in founding the transdiscipline known as **systems ecology** (Lindeman, 1942).

As stated earlier, an ecosystem encompasses both the living and nonliving factors in a particular environment. The living or biotic part of the ecosystem is formed by two components: autotrophic and heterotrophic. The autotrophic (self-nourishing) component does not require food from its environment but can manufacture food from inorganic substances. For example, some autotrophic components (plants) manufacture needed energy through photosynthesis. Heterotrophic components, on the other hand, depend upon autotrophic components for food (Porteous 1992).

The non-living or abiotic part of the ecosystem is formed by three components: inorganic substances, organic compounds (link biotic and abiotic parts), and climate regime.

An ecosystem is a cyclic mechanism in which biotic and abiotic materials are constantly exchanged through biogeochemical cycles. Biogeochemical cycles are defined as follows: *bio* refers to living organisms and *geo* to water, air, rocks or solids. *Chemical* is concerned with the chemical composition of the earth. Biogeochemical cycles are driven by energy, directly or indirectly from the sun.

As stated earlier, an ecosystem is a cyclic mechanism. From a functional viewpoint, an ecosystem can be analyzed in terms of several factors. The factors important in this study include: biogeochemical cycles, energy, and food chains; these factors are discussed in detail later.

Individual ecosystems consist of physical, chemical and biological components. As mentioned, the physical and chemical components are known as abiotic (not living environment) factors that influence living organisms in both terrestrial and aquatic ecosystems. The abiotic factors are:

For Terrestrial Ecosystems
- Sunlight
- Temperature
- Precipitation
- Wind
- Latitude
- Altitude
- Fire frequency
- Soil

For Aquatic Ecosystems
- Light penetration
- Water currents
- Dissolved nutrient concentrations
- Suspended solids

The biotic (living environment) factors making up an ecosystem include the producers, consumers and decomposers.

Abiotic and biotic factors combine to make up the following types of terrestrial and aquatic ecosystems:

- Estuaries
- Swamps and marshes
- Tropical rain forest
- Temperate forest
- Northern coniferous forest (taiga)
- Savanna
- Agricultural land
- Woodland and shrubland
- Temperate grassland
- Lake and streams
- Continental shelf
- Open ocean
- Tundra (arctic and alpine)
- Desert scrub
- Extreme desert

Ecosystem Structure: Attributes related to the instantaneous physical state of an ecosystem; examples include species population density, species richness or evenness, and standing crop biomass.

Ecotone: A habitat created by juxtaposition of distinctly different habitats; and edge habitat; or an ecological zone or boundary where two or more ecosystems meet.

Effective Dose Equivalent (EDE): The dose equivalent from both external and internal irradiation. The effective dose is expressed in the units of rem.

Effective Half-Life: The half-life is the length of time required for one-half of a radioactive substance to disintegrate. The formula depicted below is used when the industrial hygienist is interested in determining how much radiation is left in a worker's stomach after a period of time. Effective half-life is a combination of radiological and biological half-lives and is expressed as:

$$T_{eff} = \frac{(T_b)(T_r)}{T_b + T_r}$$

where:

T_b = biological half-life
T_r = radiological half-life

It is important to point out that T_{eff} will always be shorter than either T_b or T_r. T_b may be modified by diet and physical activity.

Efficiency: A percentage obtained by dividing the actual power or energy by the theoretical power or energy.

Stated differently, it is the ratio of the useful energy output of a machine or other energy converting plant to the energy input. It represents how well the hydropower plant converts the energy of the water into electrical energy.

Effluent: Liquid discharge of a sewage or manure treatment process.

Effluent Filter: A removable, cleanable device inserted into the outlet piping of the septic tank designed to trap excess solids due to tank upsets that would otherwise be transported to the subsurface wastewater infiltration system or other downstream treatment components.

Effluent Guidelines: Technical EPA documents which set effluent limitations for given industries and pollutants.

Effluent Limitations: NPDES regulations define effluent limitations as follows: Any restriction imposed by the Director on quantities, discharge rates, and concentrations of pollutants which are discharged from point sources into waters of the U.S., the contiguous zone, or the ocean 940 CFR 122.2).

Effluent Limitations Guideline (ELG): An ELG is a technical EPA document that sets effluent limits for a given industry and its pollutants [http://www.epa.gov/OCEPAterms/].

Effluent Standard: Designated limit in the amount of any constituent within an effluent.

Eight (8)-Hour Time-Weighted Average (TWA) Exposure Limit: The time-weighted average concentration in the employee's breathing zone which shall not be exceeded in any eight-hour work shift of a forty-hour workweek.

Ejector: A device used to disperse a chemical solution into water being treated.

Elastic Limit: The maximum intensity of stress to which a material may be subjected and return to its original shape upon the removal of stress.

Elastic Tissue: Type of connective tissue containing elastic fibers.

Electric Power Sector: An energy-consuming sector that consist of electricity only and combined heat and power (CHP) plants whose primary business is to sell electrical, or electricity and heat, to the public—i.e., North American Industry Classification System 22 plants.

Electric Shock: Physical stimulation that occurs when electrical current passes through the body.

Electrical Grounding: Precautionary measures designed into an electrical installation to eliminate dangerous voltages in and around the installation, and to operate protective devices in case of current leakage from energized conductors to their enclosures.

Electrical Hazard: A dangerous condition such that contact or equipment failure can result in electric shock, are flash burn, thermal burn, or blast (NFPA 70E).

Electrical Power, Energy, and Heat: Electrical power (P) is measured in watts. One watt is equal to 1 joule/second. One kilowatt is equal to 1,000 watts, or 1.34 horsepower. One horsepower is equal to 746 watts. One joule of 10^7 ergs of work is done when 1 coulomb (the practical unit of electrical quantity representing a certain number of electrons) is transferred through a potential difference of 1 volt. When 1 coulomb per second is transferred through a potential difference of 1 volt, the power is equal to 1 joule per second, or 1 watt. Since 1 coulomb per second gives a current of 1 ampere, 1 watt is the power developed by 1 ampere in flowing through a potential difference of 1 volt.

In summary:

Joules = coulombs × volts
Joules/sec or watts = coulombs/se × volts
= amps × volts
Watts delivered to a circuit = amps × volts × E
Watts used in heating a resistance = $(\text{amps})^2 \times \text{ohms} = I^2R$
(since $E = IR$, $E = I \times Ir = I^2R$)

A practical unit of electrical energy is the watt-second or Joule.

Electrical energy equals electrical multiplied by time
Energy in Joules or watt-sec = power in watts × time in secs
= E × t = I2R
Energy in kilowatt-hours = power in kilowatts × time in hours

Heat is measured in calories. One calorie equals 4.2 Joules; and 1 Joule equals 1/4.2 calories or 0.24 cal. Thus the heat in calories developed in a conductor of resistance R W ohms when using a current of 1 amp is:

Heat energy in calories = 0.24 × heat energy in joules
= $0.24 \times I^2Rt$

Electrical Resistance Heating Remediation: Is an in situ environmental remediation method that uses the flow of alternating current electricity to heat soil and groundwater and evaporate contaminants.

Electrical Safety:

1. Keep electrical equipment away from lab sinks and running water. In addition, wet floors should not only be mopped to prevent a slip hazard but also to prevent electrical shock. A rubber mat provides some protection against electrical shock, but should not be depended on as a substitute for proper grounding and bonding of electrical equipment and maintaining floors in a dry condition.
2. Check electrical cords for fraying; never allow them to dangle over sinks. Report damaged cords to the electricians immediately, and label the equipment (tag it out) so that it will not be used.
3. Any electrical equipment that must be near a sink must be secured in place and isolated from splash or spray.
4. Outlets on the backsplash of a sink must be equipped with a ground-fault circuit interrupter (GFCI). Rubber mats should be placed in front of sinks that have electrical outlets on the backsplash.
5. Do not handle electrical equipment with wet hands. Keep areas surrounding sinks dry. Do not touch an electrical device and the sink, faucet, or water at the same time. Do not reach into a sink to retrieve an electrical item that has dropped in. Either unplug the item or cut off the circuit breaker (safest) and then unplug, before retrieving. Label such equipment for evaluation by the electrician before using it again.
6. Equipment that generates or uses large amounts of current or magnetic fields should only be operated by properly trained individuals, following the manufacturer's recommendations. Always unplug equipment when cleaning or servicing.
7. All electrical equipment should use a three-prong or other properly grounded connector. Do not use two-to-three prong adapters without ascertaining that a proper ground has been established (check with an electrician). Determine the location and how to use circuit breakers or fuse boards to cut off the power to equipment in an emergency.

Note: Servicing of electrical equipment should be left to qualified personnel only. Disconnect the equipment, tag it out, and notify the supervisor.

If contact with a live electrical circuit has taken place, the first step should be to cut off the current at the circuit breaker box. If this is not possible, separate the victim from the electrical source using a non-conductive material such as a lab coat, wooden chair, or rubber hose. Make sure that you do not become involved in the circuit (avoid water spills or making contact with grounded objects such as water faucets or other electrical equipment). If victims are unconscious, attempt to arouse them by gentle shaking. If breathing has stopped or a pulse cannot be felt, apply cardiopulmonary resuscitation (CPR) following approved methods. Send someone to call for medical help.

Electricity: Electricity has helped make modern society possible. It not only provides light for employees to work during non-daylight hours, but also powers the machines they use to produce society's products. Today, we would have difficulty imagining ourselves without electricity; it is indispensable to our modern way of life.

For the safety and health professional, electricity and electrical circuits and components are areas of major concern. The primary concern, of course, is to ensure that workers do not become part of an electrical circuit (conductors of electricity), and thus become shocked or electrocuted. A secondary (but just as important) concern is the prevention of fires caused by faulty electrical components and/or wiring. No other ignition source comes close to causing the number of industrial fires that electricity has caused.

Three basic concepts are important to an understanding of electricity: voltage, current, and resistance.

We use a common analogy to help us visualize the flow of electrical energy through a wire or conductor: water flowing through a pipe. Again, the following three factors must be present in every electric circuit. Voltage (V), (also known as electromotive force—emf) measured in volts, can be visualized as the pressure (the pump) of the water in the pipe. Current (I)—electron flow—measured in amperes, is the total amount of water flowing past a point per unit of time. Resistance (R), measured in ohms, is the friction or any other impediment that tends to retard the flow of the water. Resistance in an electrical conductor is proportional to its length, and to the resistivity of the material of which it is made, and inversely proportional to its cross sectional area (i.e., smaller wire = more resistance; larger wire = equals less resistance; smaller water piper = more resistance; larger water pipe = less resistance).

In regards to electrical shock, it is not the voltage in an electrical circuit that shocks, kills, causes fire or arc-blasts. Voltage (like the water pump) does not flow; instead, the current (like water) flows—and the current causes electrocutions and ignites fires. In general, the greater the current and the longer it is able to flow through the body, the greater will be the injury.

How much current is needed to be fatal? Experience shows that as little as 100 milliamps (Ma) of 60 Hertz (Hz) alternating (AC) current can be fatal. Note that this level is well below those levels often found in average household electrical circuits, indicating that severe electrical injuries can arise from very ordinary electrical sources. In the industrial setting, however, where much higher energy sources are commonly found, the potential hazards increase dramatically. Electricity, like water, always follows the path of least resistance. Thus, if the human body has low resistance relative to some other material, electricity will use the body as its path to flow. Human body resistance is lowered anytime it is wet from water or sweat or when the body part touched by electricity has broken skin, allowing electron flow easy access.

Electrocardiogram (ECG): A recording of the electrical activity of the heart.

Electrodialysis: A process that uses electrical current applied to permeable membranes to remove minerals from water. Often used to desalinize salty or brackish water.

Electrolyte: Substance that separates into free ions when dissolved in water is called an electrolyte. The resulting solution is able to conduct electric current (a common use is in wet cell batteries).

Electrolytic Recovery Technique: Used primarily for recovery of metals from process streams, to clean process waters, or to treat wastewaters prior to discharge; based on the oxidation-reduction reaction where electrode surfaces are used to collect the metals from the waste stream.

Electromagnetic Geophysical Methods: Ways to measure subsurface conductivity via low-frequency electromagnetic induction.

Electron: A component of an atom; travels in a distant orbit around a nucleus.

Electron Transport System: In metabolic transfer, a series of electron carriers that operate together to transfer electrons from donors such as NADH and $FADH_2$ to acceptors such as oxygen.

Electronic Nose: Device that detects a select number of individual chemical compounds to measure an odor.

Electronic Particle Counter: Device that reports the number of dust particles per volume of air that a filter collects in and near animal facilities.

Electronic Sensor: Device that measures gas concentrations.

Electrostatic Precipitator (ESP): This is a particle control device that uses electrical forces to move the particles out of the flowing gas stream and onto collector plates. ESPs are usually used to remove small particles from moving gas streams at high collection efficiencies. Widely used in power plants for removing fly ash from the gases prior to discharge, an electrostatic precipitator applies electrical force to separate particles from the gas stream. A high voltage drop is established between electrodes, and particles passing through the resulting electrical field acquire a charge. The charged particles are attracted to and collected on an oppositely charged plate, and the cleaned gas glows through the device. Periodically, the plates are cleaned by rapping to shake off the layer of dust that accumulates, and the dust is collected in hoppers at the bottom of the device. Although electrostatic precipitators have the advantages of low operating costs, capability for operation an high temperature applications (to 1300°F), low pressure drop—and extremely high particulate (coarse and fine) collection efficiencies can be attained, they have the disadvantages of high capital costs and space requirements. The removal efficiencies for ESPs are highly variable; however, for very small particles alone the removal efficiency is about 99 percent. Typical ESP applications include use in industrial and utility boilers, cement plants, steel mills, petroleum refineries, municipal waste incinerators, hazardous waste incinerators, Kraft pulp and paper mills, and lead, zinc, and copper smelters.

Element: Any of more than hundred fundamental substances that consist of atoms of only one kind and that constitute all matter.

Eligible Costs: The construction costs for wastewater treatment works upon which EPA grants are based.

Ellipsoid, Height: The distance of a point above the ellipsoid measured perpendicular to the surface of the ellipsoid.

EMAP Data: Environmental monitoring data collected under the auspices of the Environmental monitoring and assessment Program. All EMAP data share the common attribute of being of known quality, having been collected in the context of explicit data quality objectives (DQOs) and a consistent quality assurance program.

Emergency and Hazardous Chemical Inventory: An annual report by facilities having one of more extremely hazardous substances or hazardous chemical above certain weight limits.

Emergency (Chemical): A situation created by an accidental release or spill of hazardous chemicals that poses a threat to the safety of workers, residents, the environment, or property.

Emergency Exemption: Provision in FIFRA under which EPA can grant temporary exemption to a state or another federal agency to allow the use of a pesticide product not registered for that particular use. Such actions involve unanticipated and/or severe pest probes where there is not time or interest by a manufacturer to register the product for that use.

Emergency Removal Action: Steps taken to remove contaminated materials that pose “imminent threats” to local residents (e.g., removal of leaking drums or the excavation of explosive waste.) Then state record of such removals.

Emergency Response: 1. The response made by firefighters, police, health care personnel, and/or other emergency service workers upon notification of a fire, chemical spill, explosion, or other incident in which human life and/or property may be in jeopardy. 2. Relates primarily to OSHA’s requirement under 29 CFR 1910.120 for chemical, industrial, storage, and waste sites to have a written Emergency Response Plan for any covered chemical release or spill to the environment that could jeopardize the good health and well-being of any worker. The EPA also requires an Emergency Response Plan for facilities handling, producing, or using covered chemicals in its Risk Management Plan requirements. Contingencies for fire, natural disasters, terrorist attacks, and medical emergencies should also be included in emergency response plans.

Emergency Response Values: Concentrations of chemicals, published by various groups, defining acceptable levels for short-term exposures in emergencies.

Emergency Suspension: Suspension of a pesticide product registration due to an imminent hazard. The action immediately halts distribution, sale, and sometimes actual use of the pesticide involved.

Emerging Pollution (contaminants); PPCPs: Are any synthetic or naturally occurring chemical or any microorganism that is not commonly monitored in the environment but has the potential to enter the environment and cause known or suspected adviser ecological and/or human health effects. PPCP—Pharmaceuticals and Personal Care Products comprise a very broad, diverse collection of thousands of chemical substances, including prescription and overt-the-counter therapeutic drugs, fragrances, cosmetics, sunscreen agents, diagnostic agents, nutrapharmaceuticals, biopharmaceuticsl, and many others.

Emission: Pollution discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, or aircraft exhausts.

Emissions: Anthropogenic releases of gases to the atmosphere. In the context of global climate change, they consist of radiatively important greenhouse gases (e.g., the release of carbon dioxide during fuel combustion).

Emission Cap: A limit designed to prevent projected growth in emissions from existing and future stationary sources from eroding any mandated reductions. Generally, such provisions require that any emission growth from facilities under the restrictions be offset by equivalent reductions at other facilities under the same cap.

Emission Factor: The relationship between the amount of pollution produced and the amount of raw material processed. For example, an emission factor for a blast furnace making iron would be the number of pounds of particulates per ton of raw materials.

Emission Flux: Rate of mass emission per unit of area (e.g., tones per hour per hectare), typically from an area such as a waste lagoon or field.

Emission Rate: Rate of mass emissions (e.g., tons per hour).

Emission Standards: The maximum amount of a specific pollutant permitted to be legally discharged from a particular source in a given environment.

Emissions Inventory: List of all applicable regulated pollutants and their expected annual emissions. In the case of a cattle feedlot, the emissions inventory has generally been limited to emissions from flaker cyclones, hay grinding, grain unloading, and feed loading.

Emissions Trading: The creation of surplus emission reductions at certain stacks, vents or similar emissions sources and the use of the surplus to meet or redefine pollution requirements applicable to other emission sources. This allows one source to increase emissions when another source reduces them, maintaining an overall constant emission level. Facilities that reduce emissions substantially may “bank” their “credits” or sell them to other facilities or industries.

Emissivity: The relative power of a surface to reradiate solar radiation back into space in the form of heat, or long-wave infrared radiation.

Emphysema: A disease of the lungs characterized by air-filled expansions in lung tissues.

Employee Exposure: Exposure to various airborne contaminants that employees could be exposed to if not wearing respiratory protection.

Employee Involvement: OSHA trend of safety standard implementation within an organization whereby employees are required to provide input in the planning and implementation stages of the program.

Emulsifier: A chemical that aids in suspending one liquid in another. Usually an organic chemical in an aqueous solution.

Emulsion: A suspension, each in the other, or two or more unlike liquids that usually do not dissolve in each other. Droplets of one liquid suspended in a different liquid such as water-in-oil.

Encapsulation: 1. The treatment of asbestos-containing material (ACM) with a liquid that covers the surface with a protective coating or embeds fibers in an adhesive matrix to prevent their release into the air. 2. In *renewable energy, photovoltaics*, a method by which photovoltaic cells are protected from the environment, typically by being laminated between a glass superstrate and a ethylene vinyl acetate substrate.

Enclosure: Putting an airtight, impermeable, permanent barrier around asbestos-containing materials to prevent the release of asbestos fibers into the air.

End-of-the-Pipe: Technologies such as scrubbers on smokestacks and catalytic convertors on automobile tailpipes that reduce emissions of pollutants after they have formed.

End-Use Project: A pesticide formulation for field or other end use. The label has instructions for use or application to control pests or regulated plant growth. The term excludes products used to formulate other pesticide products.

Endangered Species: Animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (human-caused) or other natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.

Endangerment Assessment: A study to determine the nature and extent of contamination at a site on the National Priorities List and the risk posed to public health or the environment. EPA or the state conducts the study when a legal action is to be taken to direct potentially responsible parties to clean up a site or pay for it. An endangerment assessment supplements a remedial investigation.

Endemic: 1. Present in a community or among a group of people; usually refers to a disease prevailing continually in a region. 2. The continuing prevalence of a disease, as distinguished from an epidemic.

Endergonic: A reaction in which energy is absorbed.

Endo (prefix): Within, inside of, internal. The endometrium is the lining membrane of the uterus.

Endocrine: Secreting without the means of a duct or tube. The term is applied to certain glands that produce secretions that enter the bloodstream of the lymph directly and are then carried to the particular gland or tissue whose function they regulate.

Endoscopic: A medical procedure that uses an instrument endoscope to examine visually the interior of a bodily canal or a hollow organ such as the colon, bladder, or stomach.

Endothermic: Characterized by or formed with absorption of heat.

Endotoxin: A toxin that is part of the wall of a microorganism and is released when that organism dies.

Endrin: A pesticide toxic to freshwater and marine aquatic life that produces adverse health effects in domestic water supplies.

Energy: The capacity for doing work; the ability to do work, to move matter from place to place, or to change matter from one form to another. Energy is degraded from a higher to a lower state. Potential energy (PE) is energy deriving from position; thus a stretched spring has elastic PE, and an object raised to a height above the earth's surface, or the water in an elevated reservoir, has gravitational PE. A lump of coal and a tank of oil, together with oxygen needed for their combustion, have chemical energy. Other sorts of energy include electrical and nuclear energy, light, and sound. Moving bodies possess kinetic energy (KE). Energy can be converted from one form to another, but the total quantity stays the same (in accordance with the conservation of energy principle). For example, as an orange falls, it loses gravitational PE, but gains KE.

Energy Budget: A quantitative description of the energy exchange (a "balance sheet") for a given physical or ecological system including radiation, conduction, convection, latent heat, and sources and sinks of energy.

Energy Cascading: In *energy science*, the use of the residual heat in exhaust, liquids or steam from one process to provide heating, cooling or pressure another process; e.g., the use of exhaust from a gas turbine to power a waste heat boiler.

Energy Crops: In *renewable energy biomass*, crops grown specifically for their fuel value. They include food crops such as corn and sugarcane, and nonfood crops such as poplar trees and switchgrass. Currently, low energy crops are under development: short-rotation woody crops, which are fast-growing hardwood trees harvested in five to eight years, and herbaceous energy crops, such as perennial grasses, which are harvested annually after taking two to three years to reach full productivity.

Energy Density: The intensity of electromagnetic radiaton per unit area per pulse expressed in joules per square centimeter.

Energy Flow: The transfer of energy from its source to some other point. There are two types of energy flows: wanted (controlled—able to do work) and unwanted (uncontrolled—able to do harm).

Energy Isolating Device: A mechanical device that physically prevents the transmission or release of energy, including (but not limited to) the following: A manually operated electrical circuit breaker, a disconnect switch, a manually operated switch by which the conductors of a circuit can be disconnected from all ungrounded supply conductors, and in addition, in which no pole can be operated independently; a line valve; a block; and any similar device used to block or isolate energy. Push buttons, selector switches and other control circuit type devices are not energy isolating devices.

Energy Management System: A control system capable of monitoring environmental and system loads and adjusting HVAC operations accordingly in order to conserve energy while maintaining comfort.

Units, Standards of Measurement & Conversion (Energy and Miscellanious)

An engineering handbook that does not include units and conversions is like a book without a table of contents or index. For example, converting units from grams to slugs, centistokes to square feet per second, or pounds per million gallons to milligrams per liter can be accomplished automatically, right away, if you have a mind containing a library of facts and figures and conversions and data and all kinds of stuff. However, if you are normal, there are times when even the most adept, confident, competent, and brilliant engineer or engineer want-to-be must refer to some reference to find some facts, even if these be their own name and address. I always hand out a printed copy of units and conversion in my college environmental classes. Most students welcome the handout; however, I have had a few who shunned it—at first. They stated they knew how to convert units and could do it from memory. My reply? "Well, now that means you know how convert abamperes to statamperes, right?" Oh my! My, my, my! The look on their faces was worth hundreds, thousands…no, it was totally priceless: They wore that mask of total confusion and unknowing. I loved it… still do. Students who do not know everything are my kind of students; they are teachable. Thus, because not many of us are human computers with digital memories, I have included units, standards of measurement and conversions in this handbook. Moreover, because this is the age of energy consumption, renewable energy production, and hydraulic fracturing to capture more energy, I have included energy conversion calculations within. By the way, can you tell me (or can anyone) the difference, in gallons, between a barrel of U.S liquid and a barrel of petroleum? Don't know? Don't fear, if you use this chapter, you will know the difference.

—Frank R. Spellman (2002)

Units of Measurement: The Basics: A basic knowledge of units of measurement and how to use them and convert them is essential. Environmental engineers should be familiar both with the U.S. Customary System (USCS) or English System and the International System of Units (SI). Some of the important units are summarized in the Table; these are a few of the basic SI and USCS units of measurement that will be encountered in practice.

In the study of environmental engineering math operations (and in actual practice), it is quite common to encounter both extremely large quantities and extremely small ones. The concentrations of some toxic substance may be measured in parts per million or billion or trillion (ppm or ppb or ppt), for example.

✔ **Key Point:** PPM may be roughly described as an amount contained in a full shot glass in the bottom of a standard-sized swimming pool—the full shot glass is 1 ppm relative to the rest of the water contained in the pool.

Commonly Used Units

Quantity	*SI Units*	*USCS Units*
Length	meter	feet (ft)
Mass	kilogram	pound (lb)
Temperature	Celsius	Fahrenheit (F)
Area	square meter	square foot (ft^2)
Volume	cubic meter	cubic foot (ft^3)
Energy	kilojoule	British thermal unit (Btu)
Power	watt	Btu/hr
Velocity	meter/second	mile/hour (mi/hr)

To describe quantities that may take on such large or small values, it is useful to have a system of prefixes that accompanies the units. Some of the more important prefixes are present in the following Table.

Common Prefixes

Quantity	*Prefix*	*Symbol*
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	µ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10	deca	da
10^{2}	hecto	h
10^{3}	kilo	k
10^{3}	mega	M

CONVERSION FACTORS

The following conversion factors are used extensively in water/wastewater operations and are commonly needed to solve problems on licensure examinations; the environmental engineer should keep them accessible for all plant operators.

- 7.48 gallons per ft^3
- 3.785 liters per gallon
- 454 grams per pound
- 1,000 mL per liter
- 1,000 mg per gram
- 1 ft^3/sec (cfs) = 0.6465 MGD

✔ **Key Point:** Density (also called specific weight) is mass per unit volume, and may be registered as lb/cu ft, lb/gal, grams/mL, grams/cu meter. If we take a fixed volume container, fill it with a fluid, and weigh it, we can determine density of the fluid (after subtracting the weight of the container).

- 8.34 pounds per gallon (water)—(density = 8.34 lb/gal)
- one milliliter of water weighs 1 gram—(density = 1 gram/mL)
- 62.4 pounds per ft^3 (water)—(density = 8.34 lb/gal)
- 8.34 lb/gal = mg/L (converts dosage in mg/L into lb/day/MGD)
- Example: 1 mg/L × 10 MGD × 8.3 = 83.4 lb/day
- 1 psi = 2.31 feet of water (head)
- 1 foot head = 0.433 psi
- °F = 9/5(°C + 32)
- °C = 5/9(°F – 32)
- average water usage: 100 gallons/capita/day (gpcd)
- persons per single family residence: 3.7

MKS System (SI UNITS)

The *mks system* (so named because it uses the meter, kilogram and second as base units) is comprised of *SI units*. All other units are derived from the base units, which are listed in the Table. This is a fully consistent system; there is only one recognized unit for each variable (physical quantity).

Did You Know?

U.S. environmental engineers find that identifying certain quantities used in the United States can be confusing. For example, at the beginning of this chapter the question was asked if you knew how many gallons are contained in a barrel of U.S. liquid as compared to a barrel of petroleum. Along with answering this question and to clear the air on other quantities, several are listed below:

• atmosphere	standard atmosphere
• barrel	31.5 gallons (U.S., liquid)
• barrel	42 gallons (petroleum)
• Btu	tradition (thermochemical) value
• calories	thermochemical
• gallons	U.S., liquid
• horsepower	U.S. or mechanical
• ounces	avoirdupois
• pints	U.S., liquid
• pounds	avoirdupois
• quarts	U.S., liquid
• tons	short tons of 2000 pounds

Table SI Base Units

Quantity	*Name*	*Symbol*
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Did You Know?

An abampere, in electricity, is a centimeter-gram-second unit of electromagnetic current, equivalent to 10 amperes. A statampere is the electric unit of current equal to the current produced by an electromotive force of one statvolt acting through a resistance of one statohm. An abampere is multiplied by 2.99793×10^{10} to obtain a statampere.

Energy Pyramid: Energy pyramids depict the decrease in the total available energy at each higher trophic level. They must always be larger at the base than at the top (because of the 2nd Law of Thermodynamics, and has to do with dissipation of energy as it moves from one trophic level to another).

Energy Recovery: Obtaining energy from waste through a variety of processes (e.g., combustion).

Energy Source: Any source of electrical, mechanical, hydraulic, pneumatic, chemical, thermal, or other energy.

Enforceable Requirements: Conditions or limitations in permits issued under the Clean Water Act Section 402 or 404 that, if violated, could result in the issuances of a compliance order or initiation of a civil or criminal action under federal or applicable state laws. If a permit has not bee issued, the term includes any requirement which, ith the Regional Administrator's judgment, would be included in the permit when issued. Where no permit applies, the term includes any requirement which the EPA determines is necessary for the best practical waste treatment technology to meet applicable criteria.

Enforcement: EPA, state, or local legal actions to obtain compliance with environmental laws, rules, regulations or agreements and/or obtain penalties or criminal sanctions for violations. Enforcement procedures may vary, depending on the requirements of different environmental laws and related implementing regulations. Under CERCLA, for example, EPA will seek to require potentially responsible parties to cleanup a Superfund site, or pay for the cleanup, whereas under the Clean Air Act the Agency may invoke sanctions against cities failing to meet ambient air quality standards that could prevent certain types of construction or federal funding. In other situations, if investigations by EPA and state agencies uncover willful violations, criminal trials and penalties are sought.

Enforcement Decision Document (EDD): A document that provides an explanation to the public of EPA's selection of the cleanup alternative at enforcement sites on the National Priorities List. Similar to a record of Decision.

Engineered Safety Features: Systems, components, or structures that prevent and/or mitigate the consequences of potential accidents.

Engineering: The application of scientific principles to the design and construction of structures, machines, apparatus, manufacturing processes, and power generation and utilization, for the purpose of satisfying human needs. Safety engineering is concerned with control of environment and humankind's interface with it, especially safety interaction with machines, hazardous materials, and radiation.

Engineering Controls: 1. Workplace exposure to toxic materials can be reduced or controlled by a variety of individual control methods, or by a combination of methods. Various control methods available to safety engineers are broken down into three categories: Engineering controls, administrative controls, and personal protective equipment. 2. Methods of controlling employee exposures by modifying the source or reducing the quantity of contaminants released into the workplace environment. Stated differently, engineering controls are methods of environmental control whereby the hazard is "engineered out", either by initial design specifications, or by applying methods of substitution (e.g., replacing toxic chlorine used in disinfection processes with relatively non-toxic sodium hypochlorite). Engineering control may entail isolation methods. For example, a diesel generator that, when operating, produces noise levels in excess of 120 decibels (dBA) could be controlled by enclosing it inside a soundproofed enclosure—effectively isolating the noise hazard. Another example of hazard isolation can be seen in the use of tightly closed enclosures that isolate an abrasive blasting operation. This method of isolation is typically used in conjunction with local exhaust ventilation. Ventilation is one of the most widely used and effective engineering controls—crucial in controlling workplace atmospheric hazards.

Engulfment: In confined space entry and excavations a person may be captured by a liquid or granular material; engulfment can cause death by constriction, aspiration and asphyxiation.

Enhanced Geothermal Systems (EGS): Engineered reservoirs that can extract economic amounts of that from geothermal resources. Rock fracturing, water injection, and water circulation technologies to sweep heat from the unproductive areas of existing geothermal fields or new fields lacking sufficient production capacity.

Enhanced Inspection and Maintenance (I&M): An improved automobile inspection and maintenance program—aimed art educing automobile emissions—that contains, at a minimum, more vehicle types and model years, tighter inspection, and better management practices. It may also include annual computerized or centralized inspections, under-the-hood inspection—for signs of tampering with pollution control equipment—and increased repair wavier cost.

Enhanced Security Requirements (DOT HM-232): In the aftermath of 9/11 there are two strategies that are critical to managing transportation security risks. The first is to develop and implement security plans. The second is to assure that employees who handle and transport hazardous materials are trained to recognize and react to potential security problems. USDOT has established new security requirements that make use of these two strategies for hazardous materials transported in commerce. In this section post 9/11 security enhancements, as mandated and addressed in HM-232 (49 CFR Part 397), are discussed.

Security Plans

Persons responsible for transportation of hazardous materials must develop and implement a security plan if they offer for transportation or transport the following types or quantities of hazardous materials:

- A hazardous material in an amount that must be placarded in accordance with the Hazardous Materials Regulations
- A hazardous material in a bulk packaging having a capacity equal to or greater than 13,248 L (3,500 gallons) for liquids or gases or more than 13.24 cubic meters (468 cubic feet) for solids; or
- A select agent or toxin regulated by the Centers for Disease Control and Prevention under 4 CFR part 73.

At a minimum, the security plan must include the following elements:

- Personnel security
- Unauthorized access
- En route security

The security plan must be in writing and must be retained for as long as it remains in effect. The security plan must be revised as necessary to reflect changing circumstances.

✔ **Important Point**: Many materials that are classified as hazardous materials are essential products to industry, but potentially deadly weapons in the hands of a terrorist.

Training

Persons responsible for transportation of hazardous materials must provide training to their employees who are responsible for implementing the security plan. This training should cover the following topics:

- Company security objectives
- Specific security procedures
- Employee responsibilities
- Actions to take in the event of a security breach
- Organizational security structure

In addition, all hazmat employees—that is, employees who directly affect hazardous materials transportation safety-must receive training that provides an awareness of the security risks associated with hazardous materials transportation and methods to enhance transportation security. This training should also include a component that covers how to recognize and respond to possible security threats.

✔ **Important Point**: Some mixtures containing hazardous materials can cause a powerful explosion if detonated or ignited.

Developing a Security Plan

The following guidance should assist the responsible person for the transportation of hazardous materials in developing a security plan appropriate to his/her industry and operations.

Even if not covered by the security plan requirements in the Hazardous Materials Regulations, the responsible person may want to review his/her current security program and make any necessary adjustments to improve it.

✔ **Important Point**: One easy way to increase security of hazardous materials in transportation is to lock all doors of transport vehicles.

Begin with a Security Assessment

To develop a security plan, the responsible person should begin with a security assessment. List the materials handled and identify those with the potential for use as a weapon or target of opportunity. Then, review current activities and operations from a transportation security perspective. Ask, **“What if? What are we doing now? What could go wrong? What can we do differently?”** The responsible person can use a security risk assessment model to identify security risks and develop appropriate measures to reduce or eliminate those risks. The Risk Management Self-Evaluation Framework Security Template found on DOT’s hazmat safety homepage (http://hazmat.dot.gv) utilizes the following steps:

- Scoping—determine the scope of operations that should be subject to security risk management. Identify the types of hazardous materials handled and the modes of shipment used.
- Knowledge of operations—collect detailed information about your transportation operations: (1) quantities of material transported; (2) baseline security programs; (3) current security procedures; and (4) related safety programs and procedures.
- Assessment—analyze potential security threats and identify security risk control points. Risk control points are points in the transportation process where the responsible person can make an impact by improving procedures or operations.
- Strategy—rank or group security risks, prioritize opportunities for security risk reduction, and decide

on preventative reactions. Create a written document summarizing decisions. This written document is the security plan.

- Action—implement the security plan.
- Verification—monitor implementation of the security plan.
- Evaluation—determine if goals are being met and compare the strategy and results with others in the field.

✔ **Important Point**: With the use of commonplace equipment like scanners and color printers, a driver's license, certifications, passports, and other types of personal identification can be forged.

Suggested Security Measures

DOT requires shippers and transporters, including agricultural producers, who ship or transport certain hazardous materials in quantities that require placards to develop and implement a transportation security plan. The following are specific security measures that might be considered for inclusion in the security plan.

As mentioned, at a minimum, a security plan must include the following elements: **personnel security**, **unauthorized access**, and **en route security**.

Personnel Security

Be aware of the possibility that someone hired may pose a potential security risk. Establish a process to confirm the information provided by applicants on application forms or resumes, including checking with former and current employers, and personal references provided by job applicants. Such confirmation must be consistent with applicable Federal and State laws and requirements concerning employment practices and individual privacy.

✔ **Important Point**: A careful employee background check and verification of information provided on an employment application can be an effective deterrent to the inside threat.

Employees, however, can be one of the most critical assets as the endeavor is made to improve the security of shipping or transportation operations. Under the new DOT security requirements, the responsible person must ensure that employees are familiar with the company security plan and are properly trained in its implementation. Training should include company security objectives, specific security procedures, employee responsibilities, and organizational security structure. In addition, consider taking one or more of the following actions:

- Encourage employees to report suspicious incidents or events.
- Implement routine security inspections.
- Convene regular employee/management meetings on security measures and awareness.
- Communicate with staff using an internal communication system to provide information on facts, trends, and other security issues. Because Internet communications may be accessed by others, consider alternative methods for communicating sensitive information.

✔ **Important Point**: When questioned about hazardous materials transportation it is important to know the person asking and that he or she has a need to know.

Unauthorized Access

Access to hazardous materials in transportation and to the facility should be another security concern. Consider utilizing one or more of the following security measures to prevent unauthorized access:

- Establish partnerships with local law enforcement officials, emergency responders, and other public safety agencies with jurisdiction over your facility. Through such relations, you can exchange information about threats, trends, and unsuccessful security programs.
- Request a review of your facility and security program by local law enforcement and fire safety officials.
- Restrict the availability of information related to your facility and the materials you handle. Encourage authorities in possession of information about our facility to limit disclosure of that information to a need-to-know basis.
- Add security guards and increase off-hour patrols by private security personnel. Requires that law enforcement personnel increase off-hour patrols.
- Check the adequacy of locks and other protective equipment. Consider equipping access gates with timed closure devices. Conduct frequent inspections.
- Install additional lights, alarm systems, or surveillance cameras.
- Restrict access to a single entry or gate.
- Place limits on visitor access, especially when the Homeland Security Alert System raises its threat level; require visitors to register and show photo identification, and have someone accompany visitors at all times.
- Require employees to display identification cards or badges.
- Conduct security spot checks of personnel and vehicles.
- Upgrade security procedures for handling pick-ups and deliveries at your facilities. Verify all paperwork and require pick-ups and deliveries be handled only by appointment with known vendors. Require that vendors call before a delivery and provide the driver's

name and vehicle number. Accept packages and deliveries only at the facility front gate.

- Secure hazardous materials in locked buildings or fenced areas. Have a sign-out system for keys.
- Secure valves, manways, and other fixtures on transportation equipment when not in use. Lock all vehicle and delivery trailer doors when not in use. Secure all rail, truck, and intermodal containers when stored at your location.
- Use tamper-resistant or tamper-evident seals and locks on cargo compartment openings.
- Periodically inventory the quantity of hazardous materials you have on site in order to recognize if a theft has occurred.
- Keep records of security incidents. Review records to identify trends and potential vulnerabilities.
- Report any suspicious incidents or individuals to your local Federal Bureau of Investigation (FBI) office and to local law enforcement officials.

En Route Security

Shippers and carriers should work together to assure the security of hazardous materials shipments en route from origin to destination. Shippers should assess the security of transportation modes of combinations of modes available for transporting specific materials and select the most appropriate method of transportation to ensure their efficient and secure movement.

Know your carrier and have a system of qualifying the carriers used to transport hazardous materials. Consider implementing one or more of the following measures:

- Use carrier safety ratings, assessments, safety surveys, or audits, and ask the carrier to provide information on security measures it has implemented.
- Verify the carrier has an appropriate employee hiring and review process, including background checks, and an ongoing security training program.
- Verify the identity of the carrier and/or driver prior to loading a hazardous material.
- Ask the driver for photo identification and a commercial drivers license for comparison with information provided by the carrier.
- Ask the driver to tell you the name of the consignee and the destination for the material and confirm with your records before releasing shipments.
- Identify preferred and alternative routing, including acceptable deviations.
- Strive to minimize product exposures to communities or populated areas, including downtown areas; avoid tunnels and bridges where possible; and expedite transportation of the shipment to its final destination.
- Minimize stops en route; if you must stop, select locations with adequate lighting on well-traveled roads, and check your vehicle after each stop to make sure nothing has been tampered with.
- Consider using two drivers or driver relays to minimize stops during the trip. Avoid layovers, particularly for high hazard materials.
- Shippers and rail carriers should cooperate to assure that security of rail cars stored temporarily on leased tracks.
- If materials must be stored during transportation, make sure they are stored in secure facilities.
- Train drivers in how to avoid high jacking or stolen cargo—keep vehicles locked when parked and avoid casual conversation with strangers about cargoes and routes.
- Consider whether a guard or escort for a specific shipment of hazardous material is appropriate.
- Consider using advanced technology to track or protect shipments en route to their destinations. For example, you may wish to install tractor and trailer anti-theft devices or use satellite tracking or surveillance systems. As an alternative, consider frequent checks with drivers by cell phone to ensure everything is in order.
- Install tamper-proof seals on all valves and package or container openings.
- Establish a communication system with transport vehicles and operators, including a crisis communication system with primary and back-up means of communication among the shipper, carrier, and law enforcement and emergency response officials.
- Implement a system for a customer to alert the shipper if a hazardous materials shipment is not received when expected.
- When products are delivered, check the carrier's identity with shipping documents provided by the shipper.
- Get to know your customers and their hazardous materials programs. If you suspect you have shipped or delivered a hazardous material to someone who may intend to use it for a criminal purpose, notify your local FBI office or local law enforcement officials.
- Report any suspicious incidents or individuals to you local FBI office and to local law enforcement officials.

Additional Information

Up-to-date information is a key element of any security plan. You should consider methods to:

- Gather as much data as you can about your own operations and those of other businesses with similar product lines and transportation patterns.
- Develop a communications network to share best practices and lessons learned.
- Share information on security incidents to determine if there is a pattern of activities that, when considered

in isolation are not significant, but when taken as a whole generated concern.

- Revise your security plan as necessary to take into account changing circumstances and new information.

Role of Placards in Hazmat Safety

As mentioned earlier, placards are a source of information identifying the type of hazard the hazardous material being shipped poses. They are key component of an international system of hazard communication that also includes shipping paper, package marking and labeling requirements. The primary function of placards is to provide initial warning information in the event of an incident involving a shipment of hazardous materials. The prominent display of the diamond-shaped placard is intended to immediately warn responders, handlers, and bystanders that hazards are present and reduce the change of someone inadvertently entering an incident site.

In addition to their emergency response function, placards also alert transport workers to the presence of a hazardous material in a specific shipment, assuring that the shipment is handled safely and in conformance with regulatory requirements. Placards are part of an internationally harmonized hazard communication system. Placarding requirements are also integrated into state and local requirements. For example, they are frequently used to control the movement of certain hazard material through tunnels, over bridges and over certain routes.

As mentioned, following the events of 9/11, the USDOT has taken steps to reduce vulnerabilities of hazardous materials in transportation through security enhancing initiatives directed at reducing their potential use in a terrorist event. As part of this effort, the DOT evaluated exiting safety regulations to ascertain whether they detracted from efforts to enhance security. While it is agreed that existing safety regulations generally enhance security, some have called into question the hazardous materials placarding requirements. They have argued that placards, which are important for communicating the present of hazardous materials, also might aid a terrorist in identifying hazardous materials in transportation and have suggested that placards should be removed and that an alternative to placards should be provided.

In response to placarding concerns, the DOT conducted a review of the use of placards on shipments of hazardous materials from the perspective of both safety and security. To ensure an informed review, DOT sponsored two workshops with participants with expertise in security, hazmat shipping, public safety and emergency response, and relevant alternative communication technologies. The workshops took into account professional experiences as well as other research, most notably findings from a related study conducted by the National Academy of Sciences (NAS). Alternatives to the current U.S. placarding system that would improve the security of shipments of hazardous materials, without compromising or degrading safety, were evaluated.

The results of the review are summarized as follows:

- **Placards are critical sources of hazard information**. Placards are an integral part of an internationally harmonized system of communicating the hazards of hazardous materials in transportation and play a critical role in communicating the presence of hazardous materials to emergency responders in the event of a hazardous materials incident, to transport workers and to regulatory enforcement personnel.
- **Placards provide information about hazards, but not necessarily about commodities.** Placards could not be relied on as a single source of information for ascertaining the presence of hazardous materials in sufficient quantity for carrying out a significant terrorist attack as placards may also be found on transport units containing only residues of hazardous materials. Placards depict a hazard type. There is frequently a wide range of substances posing the same type of hazard with the lower hazard materials posing a lesser security threat, yet all of these substances may be identified by the same placard.
- **Effective emergency response is a critical component of security**. Effective emergency response plays a critical role in combating terrorism by reducing its appeal as an effective means or warfare. In that placards reduce or eliminate the disruptive effects of terrorism through effective emergency response they also enhance security.
- **Enhancing security through alternative means is more appropriate than replacing placarding.** This study evaluated both operation procedures and technological alternatives to placards. These alternatives are largely considered as enhancements to the security of hazardous materials not as replacements for placards except on a limited scale for extremely high-risk materials.
- **The Department of Transportation is currently working to enhance hazmat security.** The DOT and industry have taken considerable steps to enhance the security of hazardous materials in transportation. Some of DOT's steps include the publication of security advisories identifying measures industry should take; the proposed development and implementation of security plans through the formal rulemaking process; extensive outreach activities on security, including security sensitivity visits to motor carriers; and solicitation of public comments on the feasibility of specific security enhancements that include technological and operational measures. DOT has also developed new programs to improve security awareness, such as a CD based basic awareness security training program that has been widely

disseminated. On the technology side, the Department has initiated an operation evaluation of cutting-edge communication and tracking technology, electronic seals and biometric identification. The regulated industries are also taking steps to implement voluntary security measures that include developing company specific security plans, issuing security guidelines, maintaining continual contact between drivers and company dispatchers, evaluating routes from a security perspective and enhancing the overall level of security awareness among their hazardous materials employees.

This study concludes that the existing placarding system should be retained; and as DOT continues to develop a comprehensive security program for hazardous materials transportation, it should continue to review the use of operational procedures and technological developments as security enhancements and as alternatives to placards in specific high risk situations as well as for broad application. In considering potential changes to its placarding requirements as a result of its continuing review, DOT will have to take into account the considerable impacts on cost, training and international trade that changes to placarding requirements could have.

Enrichment: The addition of nutrients (e.g., nitrogen, phosphorus, carbon compounds) from sewage effluent or agricultural runoff to surface water, greatly increases the growth potential for algae and other aquatic plants.

Enrichment Ratio: ratio of pollutant concentration in the runoff or sediment to its concentration in the soil or soil water, respectively.

Enthalpy: A thermodynamic property of a substance, defined as the sum of its internal energy plus the pressure of the substance times its volume, divided by the mechanical equivalent of heat. The total heat content of air; the sum of enthalpies of dry air and water vapor, per unit weight of dry air; measured in Btu per pound (or calories per kilogram).

Entrain: To trap bubbles in water either mechanically through turbulence or chemically through a reaction.

Entropy: A measure of the disorder of a system.

Environment: All the surroundings of an organisms, including other living things, climate and soil, etc. In other words, the conditions for development or growth.

Environmental Assessment: An environmental analysis prepared pursuant to the National Environmental Policy Act to determine whether a federal action would significantly affect the environment and thus require a more detailed environmental impact statement.

Environmental Audit: An independent assessment of the current status of a party's compliance with applicable environmental requirements or of a party's environmental compliance polices, practices, and controls.

Environmental Degradation: All the limiting factors that act together to regulate the maximum allowable size or carrying capacity of a population.

Environmental/Ecological Risk: The potential for adverse effects on living organisms associated with pollution of the environment by effluents, emissions, wastes, or accidental chemical releases; energy use; or the depletion of natural resources.

Environmental Equity/Justice: Equal protection from environmental hazards for individuals, groups, or communities regardless of race, ethnicity, or economic status. This applies to the development, implementation, and enforcement of environmental laws, regulations, and policies, and implies that no population of people should be forced to shoulder a disproportionate share of the negative environmental impacts of pollution or environmental hazard due to a lack of political or economic strength levels.

Environmental Exposure: Human exposure to pollutants originating from facility emissions. Threshold levels are not necessarily surpassed, but low-level chronic pollutant exposure is one of the most common forms of environmental exposure.

Environmental Factors: Factors that influence volatilization of hydrocarbon compounds from soils. Environmental factors include temperature, wind, evaporation, and precipitation.

Environmental Fate: The destiny of a chemical or biological pollutant after release into the environment.

Environmental Fate Data: Data that characterize a pesticide's fate in the ecosystem, considering factors that foster its degradation (light, water, microbes), pathways and resultant products.

Environmental Heat: Produced by external sources. Gas or electric heating systems produce environmental heat, as do sources of electricity and a number of industrial processes.

Environmental Impact Statement: A document created from a study of the expected environmental effects of a new development or installation.

Environmental Indicator: A measurement, statistic or value that provides a proximate gauge or evidence of the effects of environmental management programs or of the state or condition of the environment.

Environmental Justice: The fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development and enforcement of environmental laws, regulations, and polices.

Environmental Laboratory Medical Emergency: Along with providing a written plan, emergency equipment, and worker training for chemical/hazardous materials incidents in the environmental laboratory, it is also important to include medical response planning and training. The lab's medical response plan should be integrated with the emergency action plan or procedures.

In addition to having some type of medical response plan it is also important that the chemical industry workplace establish emergency first-aid stations. These first-aid stations should be stocked with enough medical supplies to provide general first aid for minor cuts, sprains, and abrasions. In addition to standard first aid supplies, these first-aid stations should contain stretchers, burn kits, ice, emergency eyewash, and fire extinguishing blankets. Emergency medical phone numbers should be posted throughout the laboratory at, near, or on each phone.

As with all types of emergency response, training and regulatory compliance are the key elements. One thing is certain, when hazardous materials/chemicals are involved with any type of emergency response, the responders must be trained to know how to prevent spread of the spill and how to protect themselves from contamination. In addition, key chemical industry workplace personnel should be trained in standard first aid—all workers should be trained in CPR. Finally, in order to ensure good first aid and emergency medical practices, the employer must ensure compliance with OSHA's 29 CFR 1910.151 (Medical Services and First Aid).

Environmental Lien: A charge, security, or encumbrance on a property's title to secure payment of cost or debt arising from response actions, cleanup, or other remediation of hazardous substances or petroleum products.

Environmental Management System (EMS): The part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes, and resources for developing, integrating, achieving, reviewing, and maintaining environmental policy; a continuing cycle of planning, implementing, evaluating, and improving processes and actions undertaken to achieve environmental goals.

Environmental Media: Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental Media and Transport Mechanism: Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to point where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

Environmental Medium: A major environmental category that surrounds or contacts humans, animals, plants, and other organisms (e.g. surface water, ground water, soil or air) and through which chemicals or pollutants move.

Environmental Monitoring for Public Access and Community Tracking: Joint EPA, NOAA, and USGS program to provide timely and effective communication of environmental data and information through improved and updated technology solutions tat support timely environmental monitoring reporting, interpreting, and use of the information for the benefit of the public.

Environmental Performance: Measurable results of the environmental management system, related to an organization's control of its environmental aspects, based on its environmental policy, objectives, and targets.

Environmental Protection Agency (EPA): The government agency that leads the nation's environmental science, research, education and assessment efforts.

Environmental Protection Standard: A specified set of rules or conditions concerned with delineation of procedures; definition of terms; specification of performance, design, or operations; or measurements that define the quantity of emissions, discharges, or releases to the environment and the quality of the environment.

Environmental Radioactivity: The study of radioactive material in the human environment.

Environmental Response Team: EPA experts located in Edison, N.J., and Cincinnati, OH, who an provide around-the-clock technical assistance to EPA regional offices and states during all types of hazardous waste site emergencies and spills of hazardous substances.

Environmental Science: The study of the human impact on the physical and biological environment of an organism. In its broadest sense, it also encompasses the social and cultural aspects of the environment.

Environmental Sensitivity: The relative susceptibility to adverse impacts of a water resource or other environments that may receive wastewater discharges.

Environmental Site Assessment: The process of determining whether contamination is present on a parcel of real property.

Environmental Sustainability: Long-term maintenance of ecosystem components and functions for future generations.

Environmental Tobacco Smoke (ETS): Mixture of smoke from the burning end of a cigarette, pipe, or cigar and smoke exhaled by the smoker.

Enzymes: Proteinaceous substances that catalyze microbiological reactions such as decay or fermentation. They are not used up in the process but speed it up greatly. They can promote a wide range of reactions, but a particular enzyme can usually only promote a reaction on a specific substrate.

Epiclastic: Formed from the fragments or particles broken away (by weathering and erosion) from pre-existing rocks to form an altogether new rock in a new place.

Epidemic: A disease occurring suddenly in humans in a community, region or country in numbers clearly in access of normal.

Epidemiological Theory: This theory holds that the models used for studying and determining epidemiological relationships can also be used to study causal relationships between environmental factors and accidents or diseases.

Epidemiological Triangle: As mentioned, Dr. John Snow was truly a pioneer; he delved into the unknown where his curiosity was his torch and common sense his road map to discovery and the truth. As pointed out earlier, Dr. Snow's detective work in determining causal factors related to the 1854 London cholera outbreak (and his eventual saving of countless numbers of lives of Londoners and others) did follow the tenets of what we call the scientific method—the scientist's toolbox—but it is important to point out that modern Epidemiology has taken the six step scientist's toolbox and augmented and refined it somewhat. Today Epidemiologists use the Epidemiologic Triangle along with the standard scientific method. The Epidemiological Triangle is the traditional model of infectious disease causation. Simply, by using the triangle, Epidemiologists have added a few more important tools to the scientists' toolbox. The triangle has three major components: an external agent, a susceptible host, and an environment that brings the host and agent together. The triangle also includes time. In this model, the environment influences the agent, the host, and the route of transmission of the agent from the source to the host.

Agent—"What"

Agent originally referred to an infectious (pathogenic) microorganism—virus, bacteria (such as *Streptococcus* and *Staphylococcus*), fungi (mold and mushrooms) and protozoa (a type of parasite such as *Giardia* and *Cryptosporida*). Simply, the agent is cause of the disease. Most people call agents "germs." Disease agents must be present for disease to occur. That is, they are necessary but not always sufficient to cause disease. When studying the epidemiology of most infectious diseases, the agent is an organism too small to be seen with the naked eye. This is why the germ theory of disease was not formulated before von Leeuwenhoek refined the microscope—the microbes were simply too small to be seen by the naked eye.

Science, scientific principles, practices, and methodologies that are continually being added to scientists' toolboxes have brought us a long way forward in our in constant battle against infectious disease. We have a long way to go, of course. Until we conquer, heart disease, cancer, diabetes, MS, HIV, Alzheimer's, Parkinson's and many other dreaded diseases we have only scratched the surface in our on-going battle against disease.

In our on-going battle against infectious disease, we have had our breakthroughs in medical science and research that make all of our lives better. The 1950's cure for polio is probably the most memorable and relatively current example of a medical advance that has reduced much suffering and pain, and no doubt has saved countless lives.

It is interesting to note that even the most scientific illiterate individual usually sits up and takes notice when some astonishingly new medical finding that will either save lives or make life easier to live is announced. Interest is short-term, of course, but it is there initially because the discovery has direct and readily visible impact on the individual.

There are a number of scientific facts and occurrences present in our daily lives, however, that very few notice. Newspapers and other media outlets do not provide large swaths of print or broadcast time to science, unless there is some significant finding or cure for a deadly disease found, for example. Beyond the significant and attention-grabbing headlines there are several mundane science facts available to us all that are generally ignored; they simply do not have that "reach out and grab you" quality that a new hit song, television show or movie might have.

The point is that when we discuss a topic such as the one we are discussing now, that is the epidemiological triangle and its three factors, agent, environment, and host, most people don't have a clue or an interest in any of them—it's the old "science is for scientists only syndrome."

Of course our mission in this text is to explain science in the simplest way possible and, at the same time, point out why science is important to us all. Whether we want to admit it or not we all need some background in science to survive and to live life to the fullest, or at least to try to live better. The good news is we do not need to be scientists to understand and appreciate science. Instead, we simply need to be aware of the world around us and its impact on us and our impact on it.

Therefore, when we mention, discuss and describe the epidemiological triangle and its individual members it has importance to all us in our daily lives. In order to gain better understanding of the term agent and how it impacts our daily existence, we have included two sidebars relevant to this discussion. In the sidebars we discuss the disease-causing agents *Giardia lamblia* (Giardia) and *Cryptosporida* (Crypto). If you have ever hiked in the mountains or woods along various trails in our National Parks or other areas, you are probably familiar with Giardia or at least its effects. If you have lived in certain parts of the United States when water treatment operations failed or were inadequate, you might be familiar with Crypto. However, as we found out on a recent hiking trip on various trails in Zion National Park, Utah many fellow hikers did not hesitate to stop at a hillside spring and indulge in what appeared to be mountain-fresh spring-fed water as it tricked down and through the rocks. Whenever we stumbled across hikers who were about to drink from these water sources, we warned them "don't drink the water!"

Epidemiology: Defined as the study of the incidence and prevalence of disease in large populations. The source and cause of disease is also identified. The animal studies discussed earlier are controlled experiments. Instead of using controlled experiments, epidemiology is based on findings from observations in the real world. Because it is not considered ethical to use humans as experimental animals, data from controlled experiments are not available.

Estimating the toxicity of chemicals in humans can be done using two basic approaches: (1) observations are made on humans directly through epidemiology, or (2) data from controlled animal studies are extrapolated to humans. The former of these approaches is the most desirable because extrapolation, which involves uncertainty, is not necessary.

Due to all of the confounding factors among different individuals, it is very difficult to conduct and interpret results of epidemiology studies. Unlike lab animals, humans all lead different lives and have a wide variety of genetics, medical histories, and other factors.

This makes it very difficult to identify an exposed group of individuals and a control group for comparison and to minimize all other differences between the groups.

This approach is even more difficult for identifying chemical-based sources of effects because the incidence rate for toxic effects is typically very low. This low incidence rate means that the background incidence rate (i.e., the frequency at which an adverse effect occurs without influence by chemicals) might be high enough to mask toxic effects unless a very large population is affected. For example, assume the incidence rate of toxicity for exposure to 1 part per million of a chemical in drinking water is 1 in 10,000 based on lab animal studies.

If this chemical contaminated a drinking water supply that served five hundred people, this incidence rate corresponds to 1/100th of one case would occur. In other words, it is quite possible that no adverse effects would be seen because the population was too small. This does not mean that the chemical is not toxic at this concentration, but that the effects cannot be differentiated from the background. However, if the chemical contaminated a reservoir that served a city of 100,000, then several cases should appear if the incidence rate in humans is similar to that seen in animals.

Even in this situation, only ten cases might be expected. The background incidence might be 1 in 20,000, so five cases would be expected. Proving a link between chemical exposure and the additional five cases of this effect seen in this example would be extremely difficult due to the variability in the human population. Additionally, factors such as the latency period between the exposure and the development of cancer, the high background rate of some cancers (e.g., lung), and the inexact knowledge of exposure by individuals, further complicate the process.

Epidemiological studies targeted at quantitatively linking chemicals and specific toxic effects typically are either (1) episodic or (2) retrospective. Episodic studies are those that evaluate isolated cases of toxicity (typically cancer) and attempt to link these effects with specific environmental factors (e.g., a chemical).

Episodic studies include those that involve cancer "clusters." One such cluster involving the chlorinated solvent TCE was popularized in a book (*A Civil Action*) and a movie of the same name. Twelve cases of leukemia developed in children living within a one-half mile radius in a small town in Massachusetts. The incidence rate was more than seven times higher than the national average. TCE was identified in the groundwater used for the drinking supply in that area of the town. Therefore, epidemiological evidence suggested a link between the TCE and the leukemias. However, such a link was not proven in court. In part, this was due to the very small sample size for the study, which was only a small portion of the population's 35,000 people.

Retrospective studies review the history and habits of targeted populations with specific effects in an effort to identify a cause of the effects. These are the most typical types of epidemiological studies conducted in toxicology. Such studies have led to identifying the links between leukemia and benzene, lung cancer and smoking, mesothelioma and asbestos, etc.

In these studies, two groups are typically compared. One group has specific toxic effects and exposure to the substance under evaluation. The other group has not toxic effects and was not exposed to the substance. All other differences between the two groups are minimized as much as possible. For example, both groups should be similar in regard to sex, age, medical history, and smoking habits.

Episode (Pollution): An air pollution incident in a given area caused by a concentration of atmospheric pollutants under meteorological conditions that may result in a significant increase in illnesses or deaths. May also describe water pollution events or hazardous material spills.

Equal areas: A map projection is equal area if every art, as well as the whole, has the same area as the corresponding part on the Earth, at the same reduced scale. No flat map can be both equal area and conformal.

Equilibrium: In relation to radiation, the state at which the radioactivity of consecutive elements within a radioactive series is neither increasing nor decreasing.

Equipotential line: A contour line on the water table or potentiometric surface; a line along which the pressure head of ground water in an aquifer is the same. Fluid flow is normal to these lines in the direction of decreasing fluid potential.

Equivalent Method: Any method of sampling and analyzing for air pollution which has been demonstrated to the EPA Administrator's satisfaction to be, under specific conditions, an acceptable alternative to normally used reference methods.

Ergonomics: Private sector employers spend about $60 billion each year on workers' compensation claims associated with musculoskeletal disorders, which involve illnesses and injuries linked to repetitive stress or sustained exertion on the body. The Occupational Safety and Health Administration (OSHA) has tried to develop a workplace standard that would require employers to reduce ergonomic hazards in the workplace. A draft standard that OSHA circulated for comment in 1995 generated stiff opposition from many employers because they believed that it required an unreasonable level of effort to address ergonomic issues. Since then, Congress has limited OSHA's ability to issue a proposed or final ergonomic standard. GAO (General Accounting Office) found that employers can reduce the costs and injuries associated with ergonomic hazards, thereby improving employees' health and morale as well as productivity and product quality, through simple, flexible approaches that are neither costly nor complicated. Effective ergonomics programs share certain core elements: Management commitment, employee involvement, identification of problem jobs, development of solutions, training and education of employees, and appropriate medical management. OSHA may wish to consider a framework for a worksite ergonomics program that gives employers the flexibility to introduce site-specific efforts and the discretion to determine the appropriate level of effort to make, as long as the effort effectively addresses the hazards.

Erosion: Wearing away of the land surface by water, wind, ice, or other geologic agents and by such processes as gravitational creep.

ERPG: Emergency Response Planning Guidelines developed by the American Industrial Hygiene Association (AIHA).

ERPG-1: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.

ERPG-2: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hours without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.

ERPG-3: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hours without experiencing or developing life-threatening health effects.

Erythema: Redness of the skin.

Erythrocyte: Red blood cell.

Escherichia Coli (E. Coli): One of the species of bacteria in the intestinal tract of warm-blooded animals. Its presence is considered indicative of fecal contamination.

Escrow Passwords: Passwords recorded and stored in a secure location (like a safe) and used by emergency personnel when privileged personnel are unavailable.

Established Treatment Technologies: Technologies for which cost and performance data are readily available.

Ester: Chemical compounds derived by reaction an oxoacid (one containing an oxo group, X=O) with a hydroxyl compound such as an alcohol or phenol.

Estimated Environmental Concentration: The estimated pesticide concentration in an ecosystem.

Estuary: A place where fresh and salt water mix, such as a bay, salt marsh, or where a river enters an ocean.

Ethanol (also known as Ethyl Alcohol or Grain Alcohol, CH3-CH2OH): An alternative automotive fuel derived from grain and corn; usually blended with gasoline to from gasohol. A clear, colorless flammable oxygenated hydrocarbon with a boiling point of 173.5 degrees Fahrenheit in the anhydrous state. However it readily forms a binary azetrope with water, with a boiling point of 172.67 degrees Fahrenheit at a composition of 95.57 percent by weight ethanol. It is used in the United States as a gasoline octane enhancer and oxygenate (maximum 10 percent concentration). Ethanol can be used in higher concentrations (E85) in vehicles designed for its use. Ethanol is typically produced chemically from ethylene, or biologically from fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues from crops or wood. The lower heating value, equal to 76,000 Btu per gallon, is assumed for estimates in this text.

Ethylene: A simple organic gas that is a major hormone in trees and other plants and may also serve as a pheromone.

Ethylene Dibromide (EDB): A chemical used as an agricultural fumigant and in certain industrial processes. Extremely toxic and found to be a carcinogen in laboratory animals, EDB has been banned for most agricultural uses in the Untied States.

Etiology: The study or knowledge of the causes of disease.

Eucaryotic: An organism characterized by a cellular organization that includes a well-defined nuclear membrane.

Euphoria: A disproportionate feeling of well-being.

Eutrophic: A term applied to water that has a concentration of nutrients optimal, or nearly so, for plant or animal growth. In general, nitrogen and phosphorus compounds contribute to eutrophic conditions in coastal and inland fresh waters, respectively.

Eutrophication: A natural aging process in which lakes receive inputs of plant nutrients as a result of natural erosion and runoff from the surrounding land basin. Through natural succession (i.e., the process by which biological communities replace each other in a relatively predictable sequence), eutrophication cause a lake ecosystem to turn into a bog and eventually to a terrestrial ecosystem. Eutrophication has received great amount of publicity later. In recent years, humans have accelerated the eutrophication of many surface waters by the addition of wastes containing nutrients. This sewage, agricultural runoff, mining, industrial wastes, urban runoff, leaching from cleared land, and landfills.

Evacuated Tube: In a solar thermal collector, an absorber tube, which is contained in an evacuated glass cylinder, through which collector fluids flows.

Evaporation: The process of liquid water becoming water vapor, including vaporization fro water surfaces, land surfaces, and snow fields, but not from leaf surfaces.

Evaporation Ponds: Areas where sewage sludge is dumped and dried.

Evaporative Cooling: Takes place when sweat evaporates from the skin. High humidity reduces the rate of evaporation and thus reduces the effectiveness of the body's primary cooling mechanism.

Evaporative Emissions: The evaporative emission of fuel from internal combustion systems caused by diurnal loses, hot soak, and running losses.

Evapotranspiration: *Evaporation* of water is a major factor in hydrologic systems. Evaporation is a function of temperature, wind velocity, and relative humidity. Evaporation (or vaporization) is, as the name implies, the formation of vapor. Dissolved constituents such as salts remain behind when water evaporates. Evaporation of the surface water of oceans provides most of the water vapor. It should be pointed out, however, that water can also vaporize through plants, especially from leaf surfaces. This process is called *evapotranspiration*. Plant transpiration is pretty much an invisible process—since the water is evaporating from the leaf surfaces, you don't just go out and see the leaves "breathe". During a growing season, a leaf will transpire many times more water than its own weight. A large oak tree can transpire 40,000 gallons (151,000 liters) per year (USGS, 2006).

USGS (2006) points out that the amount of water that plants transpire varies greatly geographically and over time. There are a number of factors that determine transpiration rates:

- **Temperature**: transpiration rates go up as the temperature goes up, especially during he growing season, when the air is warmer due to stronger sunlight and warmer air masses.

- **Relative humidity**: As the relative humidity of the air surrounding the plant rises the transpiration rate falls. It is easier for water to evaporate into dryer air than into more saturated air.
- **Wind and air movement**: Increased movement of the air around a plant will result in a higher transpiration rate.
- **Soil-moisture availability**: When moisture is lacking, plants can begin to senesce (i.e., premature ageing, which can result in leaf loss) and transpire less water.
- **Type of plant**: Plants transpire water at different rates. Some plants which grow in arid regions, such as cacti and succulents, conserve precious water by transpiring less water than other plants.

✔ **Interesting Point**: It may surprise you that ice can also vaporize without melting first. However, this *sublimation* process is slower than vaporization of liquid water.

Evaporation rates are measured with evaporation pans. These evaporation pans provide data that indicate the atmospheric evaporative demand of an area and can be used to estimate (1) the rates of evaporation from ponds, lakes, and reservoirs, and (2) evapotranspiration rates. It is important to note that several factors affect the rate of pan evaporation. These factors include the type of pan, type of pan environment, method of operating the pan, exchange of heat between pan and ground, solar radiation, air temperature, wind, and temperature of the water surface (Jones, 1992).

Evase (pronounced eh-va-say): A cone-shaped exhaust stack that recaptures static pressure from velocity pressure.

Event: An observable occurrence in a system or network.

Excavation[1]: 1. The physical removal of soil to construct a burial site for contaminants (landfill) and/or contaminated soil by mechanical means. 2. Because the fatality rate for excavation work is 112 percent higher than the rate for general construction work, OSHA places significant emphasis on requirements to perform all manner of excavation in a safe manner. OSHA requirements for proper excavations are covered in its Construction Standard, 29 CFR 1926.650-.652, Subpart P. The subpart P standards apply to all open excavations (including trenches) made in the earth's surface. In some situations, it requires the use of written designs (approved by a registered professional engineer) for sloping, benching, and support systems.

There are six explanatory appendixes to Subpart that should be consulted by employers engaged in excavation work. The include illustrations, tables, and diagrams. They cover the following subjects:

Appendix A	Soil classification
Appendix B	Sloping and benching
Appendix C	Timber shoring for trenches
Appendix D	Aluminum hydraulic shorting for trenches
Appendix E	Alternatives to timber shoring
Appendix F	Selection of protective systems

The Subpart P standards went into effect in 1990. They constitute a total revision of the OSHA trenching and excavation standards that had been in effect for the previous eighteen years.

Section 1926.651 has specific requirements for excavations that need to be reviewed for further details. Daily inspections of excavations must be made by a competent person to make sure that cave-ins, failure of protective systems, or hazardous atmospheres are not found. If the competent person discovers there are indications that could result in a possible cave-in, exposed employees must be removed from the hazardous area until the necessary precautions have been taken.

Exceedance: Violation of the pollutant levels permitted by environmental protection standards.

Exchange Capacity: The abundance of sites (within the soil sample) which have the pot6ential for being actively engaged in ion adsorption.

Exclusion: In the asbestos program, one of several situations that permit a Local Education Agency (LEA) to delete one or more of the items required by the Asbestos Hazard Emergency Response Act (AHERA); e.g., records of previous asbestos sample collection and analysis may be used by the accredited inspector in the lieu of AHERA bulk sampling.

Exclusionary Ordinance: Zoning that excludes classes of persons or businesses from a particular neighborhood or area.

Exempt Solvent: Specific organic compounds not subject to requirements of regulation because thy are deemed by EPA to be of negligible photochemical reactivity.

Exempted Aquifer: Underground bodies of water defined in the Underground Injection Control program as aquifers that are potential sources of drinking water though

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[1] From Government Institute's *Occupational Safety and Health Simplified for the Construction Industry*, 2007. Lanham, Maryland.

not being used as such, and thus exempted from regulations barring underground injection activities.

Exemption: A state (with primacy) may exempt a public water system from a requirement involving a Maximum Contaminant Level (MCL), treatment technique, or both, if the system cannot comply due to compelling economic or other factors, or because the system was in operation before the requirements or MCL was instituted; and the exemption will not create a public health risk.

Exergonic: Releasing energy.

Exergy: In thermodynamics, exergy is the maximum useful work possible during a process that brings the system into equilibrium with a heat reservoir.

Exfoliation: The process by which concentric scales, plates, or shells or rock, from less than centimeter to several meters in thickness, are stripped from the bare surface of a large rock mass.

Exhaust Hood: Device that encloses, captures, receives emitted contaminants and exhausts them to the atmosphere.

Exhaust Stack: A device on the end of a ventilation system that disperses exhaust contaminants for dilution by the atmosphere.

Exothermic Reaction: A chemical reaction that gives off heat.

Experimental Use Permit: Obtained by manufacturers for testing new pesticides or uses thereof whenever they conduct experimental field studies to support registration on ten acres or more of land or one acre or more of water.

Explosive Limits: The amounts of vapor in the air that form explosive mixtures limits are expressed as lower and upper limits and give the range of vapor concentrations in air that will explode if an ignition source is present.

Explosive Range: The range between the LEL and UEL is the “explosive range.” If a source of ignition such as a spark, flame, or static electricity is present, an explosion may occur. This may also be referred to as “flammable range” (LFL and UFL).

Exposure: 1. Contact with a chemical, biological, or physical hazard. 2. A threat action whereby sensitive data is directly released to an unauthorized entity.

Exposure Assessment: IIdentifying the pathways by which toxicants may reach individuals, estimating how much of a chemical an individual is likely to be exposed to, and estimating the number like to be exposed.

Exposure Ceiling: The concentration level of a given substance that should not be exceeded at any point during an exposure period.

Exposure Concentration: The concentration of a chemical or other pollutant representing a health threat in a given environment.

Exposure-Dose Reconstruction: A method of estimating the amount of people’s past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure Duration: The amount of exposure to a chemical depends in part on the exposure route. In addition, the length of time over which exposure occurs will affect the total amount to which someone might be exposed. Duration is classified as:

- Acute
- Subchronic
- Chronic

Acute Duration

Acute exposure involves single episodes, or otherwise very short periods, such as a week or less.

The infamous Bhopal air pollution incident involved acute exposure duration. The releases occurred, people inhaled the chemicals, and the chemicals dispersed in the atmosphere or settled to the ground. These types of durations typically only lead to toxic effects if exposure occurs to relatively high concentrations of a chemical. An example of an acute duration would be exposure to poison oak or poison ivy while hiking. The exposure is essentially instantaneous, although the effects may last for a week or more if someone is allergic to the toxins in the plant.

Spills requiring emergency response also involve acute durations. The spill occurs, is contained, and is cleaned up in a matter of hours. Those near the spill may have acute exposures to the spilled chemicals. The emergency-response team, however, might have acute and subchronic or chronic exposure because they may deal with spills involving this chemical over several years. Therefore, the duration of exposure can differ for different people exposed to the same chemicals under the same conditions.

Subchronic Duration

This represents a length of time between acute and chronic durations. This duration can extend from more than a week to less than 7 years for humans. Students in chemistry lab will have subchronic exposure over their college years to typical solvents used in the labs (e.g., methanol, chloroform). A typical emergency-response technician working at the same job for 5 years could have subchronic exposure durations to commonly spilled chemicals (e.g., gasoline).

Chronic Duration

These are the long-term exposure durations that typically lead to the highest overall exposures.

Chronic exposure duration is typically defined as one spanning at least 10 percent of a lifetime.

For humans, this is considered seven or more years. Although daily exposure might be low, the total exposure over a lifetime might be very much greater than higher exposures over shorter time periods. There are numerous examples for this type of duration. Someone who does dry cleaning for a living will have chronic exposures to trichloroethylene (TCE), a cleaning solvent that has anesthetic effects and might cause cancer. We all receive chronic exposures to gasoline vapors during refueling, and to smog through breathing. Smokers are chronically exposed to nicotine, cadmium, and other toxic chemicals contained in the tobacco and additives to cigarettes. Casino workers may have chronic exposure to second-hand smoke from those patrons smoking at their tables. Careers in the chemical or environmental industry can lead to occupational exposure to chemicals over a career. Someone living directly downwind of a smelter for many years will have chronic exposures to released chemicals from the stacks.

In toxicology and risk assessment, chronic exposure is of primary interest because these types of exposures are the ones that are most relevant for the typical person. However, relevant toxicology data for chronic exposures is often lacking.

Exposure Frequency: The duration of exposure alone does not indicate the amount of chemical someone might have been exposed to. In addition to duration, the frequency of exposure over that time period will impact the level of exposure. Chronic exposure may be insignificant if someone is only exposed for 5 days each year. We are exposed to smog daily over a chronic time period. Although eating tuna containing mercury may also be of chronic duration, the frequency at which we eat tuna is much less than our exposure to smog. Therefore, our overall exposure to mercury from tuna fish should be much less than our exposure to chemicals in smog.

Recently, much interest has been focused on the toxicity of diesel exhaust, especially as a possible cancer-causing mixture. Does this mean that we should avoid following behind buses, diesel trucks, or cares? Likely our activity patterns lead to only infrequent exposures to diesel exhaust, even though the exposure may persist over many years. Therefore, it is unlikely that these very brief exposure episodes, on the order of a minute or two daily, will lead to toxic effects.

The combination of exposure routes, duration, and frequency will govern the amount of chemical to which someone might be exposed, which will have an impact on the likelihood of receiving toxic levels. This can be expressed by the following relationship:

Exposure Level = (Sum of exposure routes) X Exposure duration X Exposure frequency

It is important to note that these exposure levels do not equal doses, which govern the toxic responses from chemical exposure. It is not until the chemicals are actually absorbed into the body that someone receives a chemical dose.

Exposure Investigation: The collection and analysis of site-specific information and biologic tests (when appropriate) to determine a whether people have been exposed.

Exposure Indicator: A characteristic of the environment measured to provide evidence of the occurrence or magnitude of a response indicator's exposure to a chemical or biological stress.

Exposure Level: The amount (concentration) of a chemical at the absorptive surfaces of an organism.

Exposure Pathways: Consist of two categories: (1) direct human exposure pathways; and (2) environmental exposure pathways. Both of these categories are further subdivided into primary and secondary exposure pathways. Primary pathways are those which directly affect site operations and personnel (skin contact during soil sampling, for example). Secondary exposure pathways occur as a minor component during site operations and exhibit significant decreases with time as treatment progresses (for example, wind blown dust).

Exposure Registry: A system of ongoing followup of people who have had documented environmental exposures.

Exposure Route: The way a chemical or pollutant enters an organism after contact; i.e., by ingestion, inhalation, or dermal absorption.

Exposure-Response Relationship: The relationship between exposure level and the incidence of adverse effects.

External Radiation Protection: Three mechanisms for external radiation protection include time, distance, and shielding. A shorter time in a radiation field means less dose. From a point source, dose rate is reduced by the square of the distance and expressed by the inverse square law:

$$I_1(d_1)^2 = I_2(d_2)^2$$

where:

I_1 = dose rate or radiation intensity at distance d_1
I_2 = dose rate or radiation intensity at distance d_2

Radiation is reduced exponentially by thickness of shielding material.

Externality: A cost or benefit not accounted for in the price of goods and services. Often "externality" refers to the cost of pollution and other environmental impacts.

Extinction (Behavior): The conditioning phenomenon in which a previously learned response to a cue is reduced when the cue is presented in the absence of the previously paired aversive or appetitive (i.e., desiring gratification) stimulus.

Extinction Coefficient: A measure of the rate of reduction of transmitted light through a substance.

Extraction Procedure (EP Toxic): A standardized laboratory test used to test for toxicity; replaced in 1990 by Toxicity Characteristics Leaching Procedure (TCLP).

Extraction Well: Used to lower the water table, creating a hydraulic gradient that draws a plume of contamination to the well so that the contaminant can be extracted.

Extremely Hazardous Substance: An EPA term for those chemicals that must be reported to the appropriate authorities if released above the threshold reporting quantity.

Extremity: Means hand, elbow, and arm below the elbow, foot, knee, or leg below the knee.

Eye Toxins: Chemicals that produce symptoms of conjunctivitis and corneal damage.

Eyewash Fountains/Showers/Requirements: With regard to emergency eyewash equipment, OSHA makes the requirement clear in the following:

General Industry:
"Where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use" (29 CFR 1910.151(c).

Construction Industry:
"Where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided with the work area for immediate emergency use" (29 CFR 1926.50(g).

As can be seen from the above statements, the OSHA regulation regarding emergency equipment is quite vague, in that it does not define what constitutes "suitable facilities" for drenching the eyes or body. In order to provide additional guidance to employers, the American National Standards Institute (ANSI) has promulgated a voluntary standard covering emergency eye wash and shower equipment. This standard—ANSI Z358.1—is intended to serve as a guideline for the proper design, performance, installation, use and maintenance of emergency equipment.

In regard to the distance to travel for workers who might need the use of emergency eyewash fountains, it may surprise you to know that there are no "fixed" standards on the maximum acceptable distance of travel to reach an eyewash station. However, the National Safety Council has recommended that the travel distance should be no more than 25 feet or that the station take no longer than 15 seconds to reach. It is interesting to note that, in contrast to the National Safety Council's recommendation, (and as mentioned earlier) the American National Standard Institute (ANSI) in its Z358.1-2004 standard "recommends":

Eyewash and Shower Units

- Accessibility of emergency showers and/or eyewash stations within 10 seconds or less (travel time). Appendix B of ANSI Z358.1-2004 states that an average person covers a distance of approximately 55 feet in 10 seconds, when walking at a normal pace.
- The eyewash and/or shower unit must be on the same level as the operation in question. The climbing of stairs to reach the unit in an emergency is not allowed.

Did You Know?

29 CFR 1926.50(g) applies in all construction situations except, battery handling is addressed in 29 CFR 1926.441(a)(6) which states:

1. *"Facilities for quick drenching of the eyes and body shall be provided within 25 feet (7.62 meters) of battery handling areas."*

- ANSI recommends that unit be immediately adjacent to the hazard when the pH of the hazardous substance is less than or equal to 1 or equal to or greater than 12.
- The location of the unit must be well lit, highly visible, and marked with a highly visible sign.
- The unit must be operable at all times, with provisions to prevent unauthorized shutoff of the water lines to the unit.
- A sewer connection or drain is not required, unless a special hazard is posed by the water.
- Units are to be installed in accordance with the manufacturer's instructions.

Eyewash Units Only

- Eyewash units must be installed so that its nozzles are 33 – 45 inches (83.8 – 1143 cm) from the floor.
- Eyewash units must provide a minimum of 0.4 gallons per minute (1.5 liters per minute) or a potable water or commercial flush for 15 minutes. Eyewash fountains/stations should provide flow at 25 psi or less. This eyewash pressurized-flow should be presented to the eyes in such a manner as to flood both eyes with aerated potable water. If the installed unit is intended to cover the entire face, then 3 gallons per minute is required according to ANSI 358.1.
- Eyewash units must provide a pressure-reduced divergent flow of flushing fluid.
- Eyewash units must be flushed weekly to remove any bacterial contamination (Acanthamoeba), and to verify proper operation. Plumed units must be flushed for 3 minutes minimum.
- Where contamination can occur, nozzles must be protected from contaminants by covers (or caps) that do not require an extra step for removal beyond the activation of the unit.
- Self-contained and portable eyewash unit smut provide 0.4 gallons per minute (1.5 liters per minute) for 15 minutes (6 gallon capacity).
- Portable eyewash units should be used only where fixed installation is not feasible.
- In self-contained and portable eyewash units, the flushing fluid must be replaced after any use. In addition, it must be replaced at the intervals recommended by the manufacturer.
- Squeeze bottles are not acceptable eyewash units on their own. They cannot supply the required amount of water to adequately flush the eyes, and their use does not keep the both hands free to hold the eyelids open.
- They can only be used as an interim protective measure, in conjunction with an approved eyewash facility, where installation difficulties are an issue.
- In the General Requirements for Dipping and Coating Operations standard (29 CFR 1910.124), drench hoses are allowed in lieu of an eyewash and shower at open-surface tanks containing hazardous liquids. The device must supply clean water provided by a ¾ inch diameter, 48 inch or longer, hose with a quick opening valve. Pressure should not exceed 25 psi.
- Many faucet-mounted eyewash devices do not meet ANSI construction requirements.
- If use is planned, ANSI-approved faucet-mounted eyewash must meet all requirements for plumbed eyewash units. This includes requirements for installation height, water temperature, unobstructed access, travel time, labeling, etc. Because of the need for immediate use, the water temperature at the sink must immediately meet temperature requirements at all times.

Showers Only

- In many installations, emergency eyewash stations are combined with emergency showers to form one compact unit. Whether this is the case or not, the emergency shower is, like the eyewash station, standard safety equipment that must be installed in chemical industrial work areas for immediate first aid treatment of chemical splashes. The facility's safety showers must have a quick-opening valve that will allow for drenching the victim immediately and must be large enough to accommodate more that one person if necessary; the quick-opening valve must be closed manually.
- Showers must provide a minimum of 20 gallons per minute (75.7 liters per minute) flow of flushing fluid in a dispersed pattern.
- Weekly checks of the shower must be conducted to flush the lines and to verify proper operation.
- Overhead showers should be mounted at a head height of 82-96 inches (208.3-243.8 cm)
- The valve actuator for the shower must be located less than or equal to 69 inches (or 173.3 cm) above the floor or platform.
- Along with properly locating the safety shower, it is important to ensure that the water supply feeding the shower is adequate. The water supply should be able to provide up to 30 gallons per minute. The temperature of the water supply to the safety shower is also important, but even more so than the temperature of eyewash station water. This is the case because the water from the deluge shower covers more of the body's surface area.
- The safety shower should be easy to operate and should remain on until it is deliberately turned off.
- Some caution must be used when locating these shower stations. Obviously, it would not be wise to install a deluge shower next to an electrical power panel. Another point to keep in mind is that portable electrical equipment should not be moved near safety showers.

Whatever style, type, or model of eyewash/deluge shower station chosen for use in the chemical industry, the main requirement is that the unit operate in the easiest manner possible. When a victim's eyes are contaminated with chemical, the last thing this victim should have to worry about is how to activate a complicated eyewash station. Training requirements for emergency and shower units include:

- Employees are to be trained on the location and proper use of emergency eyewashes and showers.
- The training must address the holding open of the eyelids, and the rolling of the eyeballs, to facilitate the flushing over the entire surface of the eye.
- If squeeze bottles are provided for use as an interim protective measure, the training must address proper use in conjunction with the provided emergency eyewash.

The chemical industry workplace can have all the safety equipment that it could possibly contain but if the workers are not properly trained on the use of the equipment, what good is it? Remember, any training conducted must be documented. If training is not documented, it did not occur; this is certainly the view that OSHA and the courts will take.

Again, these ANSI specifications are recommendations only. When it comes right down to it, common sense should dictate where the lab's eyewash fountains are to be placed. Remember, the effectiveness of any eyewash station is dependent on its accessibility. Placing eyewash stations on the other side of doorways is not making them accessible. No one should have to open a door or doors to reach an eyewash fountain. No one who is blinded and in pain from chemical exposure should have to "feel" their way to a remote eyewash/deluge shower station. Depending on the size of the industrial facility, eyewash stations should be located along a normal path of egress; for example, in a facility's main corridor. When in doubt as to where an eyewash fountain should be located the following standard rule of thumb on the topic may be of assistance.

RULE OF THUMB: **The maximum time to reach an eyewash fountain should be determined by the potential effect of the chemical**.

This thumb rule makes sense when you consider that if chemical workers routinely work with very strong acids, then emergency eyewash should be located within arm's reach, at their elbow, or no more than 10 ft in all directions.

Another point to keep in mind if you are planning on installing an eyewash station/fountain outdoors is the weather. Experience has shown that it is not unusual for a safety auditor to audit an industrial facility and find an outdoor eyewash/shower station that is inoperative because the pipes are frozen or broken from freezing. It is important to ensure that outdoor stations are piped in such a manner that will ensure they are protected from the elements. Water at temperatures 60° to 70° F temperature range (normal tap water temperatures) should be used for emergency eyewash stations.

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Fabric Filter: A cloth device that catches dust particles from industrial emissions.

Face Protection: Under OSHA's 29 CFR 1910.133 all workers who could be exposed to hazards of any type that could cause damage to the face must be provided with and required to wear face protection equipment.

Face Shield: A supplementary protective device worn to shield the wearer's face from certain hazards. Face shields are secondary protectors only and must be worn with safety glasses or goggles.

Face Velocity: Average air velocity into an exhaust system measured at the opening into the hood or booth.

Facilities Plans: Plans and studies related to the construction of treatment works necessary to comply with the Clean Water Act or RCRA. A facilities plan investigates needs and provides information on the cost-effectiveness of alternatives, a recommended plan, an environmental assessment of the recommendations, and descriptions of the treatment works, costs, and a competition schedule.

Facility Emergency Coordinator: Representative of a facility covered by environmental law (e.g., a chemical plant) who participates in the emergency reporting process with the Local Emergency Planning Committee (LEPC).

Facultative Bacteria: Bacteria that can grow in the presence, as well as in the absence, of oxygen.

Facultative Lagoons/Ponds: Used frequently to treat municipal and industrial wastewater in the United States. These earthen lagoons/ponds are usually 1.2 to 2.4 m (4 to 8 feet) in depth and are not mechanically mixed or aerated. The layer of water near the surface contains dissolved oxygen due to atmospheric reaeration and algal respiration, a condition that supports aerobic and facultative organisms. The bottom layer of the lagoon includes sludge deposits and supports anaerobic organism. The intermediate anoxic layer, termed the facultative zone, ranges from aerobic near the top to anaerobic at the bottom. These layers may persist for long periods due to temperature-induced water-density variations. Inversions can occur in the spring and fall when the surface water layer may have higher density than lower layers due to temperature fluctuations. This higher density water sinks during these unstable periods, create turbidity, and produces objectionable odors.

Facultative Organisms: An organism, usually a bacterium, that makes ATP by aerobic respiration if oxygen is present but is also capable of witching to fermentation. In contrast, obligate anaerobes die in presence of oxygen.

Failure Mode and Effects Analysis (FMEA): Is both a system safety and reliability analysis used to identify critical failure modes that seriously affect the safe and successful life of the system or failure modes that could prevent a system from accomplishing its intended mission. This technique permits system change to reduce the severity of failure effects. FMEA is organized around the basic question "What if?" The areas covered and the questions asked move logically from cause to effect.

1. Component—What individual components make up the system?
2. Failure Mode—What could go wrong with each component in the system?
3. System Causes—What would cause component failure or malfunction?
4. System Effects—What would be the effect of such a failure on the system and how would this failure affect other components in the system?

5. Severity Index—Consequences are often placed into one of four reliability categories:
    1 Catastrophic—may cause multiple injuries, fatalities, or loss of a facility.
    2 Critical—may cause severe injury, severe occupational illness, or major property damage.
    3 Marginal—may cause minor injury or minor occupational illness resulting in lost workday(s) or minor property damage.
    4 Negligible—probably would not affect the safety and health of personnel but is still in violation of a safety or health standard.
6. Probability Index—How likely is the event to occur under the circumstances described and given the required precursor events? These probabilities are based on such factors as accident experience, test results from component manufacturers, comparison with similar equipment, or engineering data. Probability categories, which may be developed by individual companies or analysts, are sometimes classified as:
    1 probable (likely to occur immediately or within a short period of time).
    2 reasonably probable (probably will occur in time).
    3 remote (possible to occur in time).
    4 extremely remote (unlikely to occur).
7. Action or Modification—After the failure modes, causes and effects, severity, and probability have been established, the system must be modified to prevent or control the failure.

The severity index, probability index, and a third index relating to personnel exposure maybe used to determine the overall risk. A review of the above steps makes the objectives of FMEA clear. FMEA is intended to rank failures by risk (severity and probability) so that potentially serious hazards can be corrected.

Fair Labor Standards Act: Prescribes standards for the basic minimum wage and overtime pay, affects most private and public employment.

Fairway (or Trend): The area along which the play has been proven, and more fields could be found.

Fall Arresting System: A system consisting of a body harness, a lanyard or lifeline, and an arresting mechanism with built-in shock absorber, designed for use by workers performing tasks in locations from which falls would be injurious or fatal, or where other kinds of protection are not practical.

Fall Protection: Fall protection is the series of steps taken to cause reasonable elimination or control of the injurious effects of an unintentional fall while accessing or working.

> . . . Fall hazard distance begins and is measured from the level of a workstation on which a worker must initially step and where a fall hazard exists. It ends with the greatest distance of possible continuous fall, including steps, openings, projections, roofs, and direction of fall (interior or exterior). Protection is required to keep workers from striking objects and to avoid pendulum swing, crushing and foreseeable impact with any part of the body to which injury could occur.
>
> The object of elevated fall protection is to convert the hazard to a slip or minor fall at the very worst—a fall from which hopefully no injury occurs.
>
> —J. L. Ellis, *Introduction to Fall Protection*, p. xvi, 1988.

Because injuries received from falls in the workplace are such a common occurrence—in a typical year, more than 10,000 workers will lose their lives in falls—safety engineers not only need to be aware of fall hazards, but also of the need to institute a Fall Protection Safety Program (Kohr, 1989). We know that falls can be serious—just how frequent and serious are accidents/incidents related to falls?

Let's look at a few telling facts about falls in the workplace. The National Safety Council's annual report typically "predicts" 1,400 or more deaths, and more than 400,000 disabling injuries each year from falls. Falls are the leading cause of disabling injuries in the United States, accounting for close to 18 percent of all workers' compensation claims. A 1984 Bureau of Labor Statistics 24-state survey reported 60 percent of elevated falls were under 10 feet and 50 percent of those were under 5 feet (Pater, 1985).

According to Kohr, the primary causes of falls are:

1. A foreign object on the walking surface;
2. A design flaw in the walking surface;
3. Slippery surfaces; and
4. An individual's impaired physical condition.

As you might imagine, that the construction industry (42 percent of all injuries resulting from falls) has the largest percentage of fall-related injuries. A NSC Accident Facts publication (1984 and 1985) reported that 70 percent of reported falls were from scaffolds, 14 percent from roofs, and another 14 percent were from barrels, boxes, equipment, or furniture. Eisma (1990) reports that 85 percent of falls from elevation resulted in lost workdays—and 20 percent resulted in death. In a more recent report provided by the Bureau of Labor Statistics (1996), falls caused 600 or 10 percent of workplace deaths in 1994, along with more than 370,000 injuries. In the same year, slips and trips caused more than 70,000, or 18 percent of all occupational injuries.

Obviously, as the above data clearly indicates, falls are a problem that the safety engineer must continually face.

In this chapter, we discuss fall protection and the steps the safety engineer should take to lessen their impact.

Fall Protection: Defining the Problem

When attempting to install a Fall Protection Safety Program in any organization, safety engineers must first define their needs (what the organization requires). The actual needs of any type of fall protection program are going to be driven mainly by the type of work the organization does. Obviously, if the company is involved in construction, the needs are rather straightforward, because much of the work conducted will include the necessity of doing elevated work. However, this might also be the case for various trades as well, such as carpentry, for example. Public utility and transportation work might also require elevated work. The factor that may surprise you is the large percentage of falls from elevation that occur in the manufacturing industry.

To define the problem associated with all types of falls, let's examine what falls are all about. None of us have a problem understanding what a fall from a high-rise construction project involves—it is simply a fall from elevation. However, in the workplace, worker injuries result from falls of types other than falling from elevations. Falls in the workplace also include slips, trips, and stair falls, as well as elevated falls. Slips and trips are falls on the same level. Stair falls are falls on one or more levels. Elevated falls are from one level to another. In the following sections, each of these types of falls is discussed in greater detail—but first we discuss the physical factors at work in causing a fall. Remember that the safety engineer must address and work to reduce or eliminate all types of falls.

Physical Factors at Work in a Fall

The safety engineer is a student and practitioner of science. In a moment of humor, workers sometimes say, "The bigger they are, the harder they fall" and "It's not the fall that's so bad, it's the sudden stop when you hit the ground." Though this is often the common view, many would-be practitioners in the safety field are often surprised to find out that science not only plays a role in falls, but that slips, trips, and falls actually involve three well-known laws of science: friction, momentum, and gravity.

Friction is the resistance between things, such as between workshoes and the workplace-walking surface. Without friction, workers are likely to slip and fall. Probably the best example of this phenomenon is a slip on ice. On icy surfaces, shoes can't grip the surface normally, causing a loss of traction and a fall.

Momentum (in physics) is the product of the mass of a body and its linear velocity. Simply put, momentum is affected by speed and size of the moving object. Momentum is best understood if we translate the humorous sayings above to: "The more you weigh and the faster you move, the harder you fall if you slip or trip."

Gravity is (on the earth) the force of attraction between any object in the earth's gravitational field and the earth itself. Simply put, gravity is the force that pulls you to the ground once a fall is in process. If someone loses balance and begins to fall, they are going to hit the ground. The human body is equipped with mechanisms that work to prevent falls (sense of balance and center of gravity). These mechanisms include the eyes, ears, and muscles, which all work to keep the human body close to its natural center of balance. However, if this center of balance shifts too far, a fall will occur if balance can't be restored to normal.

Because gravity obviously has the same effect on all of us here on Earth, it has always been surprising to us to discover how such a well-known (but often ignored) basic law of science is so often and conveniently ignored by various industries. For example, we commonly (even in this day and age) come face to face with company owners or workplace foremen who ignore the laws of gravity and require their workers to perform "daring" (and extremely dangerous) feats in the workplace. The worker (who needs the job and the security it provides) is led to believe that gravity is something that is not important to them, but only important in movies about space travel, perhaps. Obviously, this is a dangerous mindset and practice that the company safety engineer must not tolerate.

Slips: Falls on the Same Level

In its simplest form, a slip is a loss of balance caused by too little friction between the feet and the surfaces walked or worked on. The more technical explanation refers to a slip resulting in a sliding motion, when the friction between the feet (shoe sole surface) and the surface is too little. This slip (loss of traction), in turn, often leads to a loss of balance. The result is a fall.

Slips can be caused by a number of design factors and work practices, individually or in combination. Factors involved include footwear, floor surfaces, personal characteristics, and the work task.

Footwear is an important consideration in the prevention of a slip-fall. Not only is the condition of the footwear important in fall prevention, but also the composition, shape, and style. For industrial applications, the organizational safety professional should ensure that only approved safety shoes are worn. Safety shoes should not only be designed to include toe protection; they should also include slip resistant soles.

For floor surfaces, design, installation, composition and condition, gradient, modifications by protective coatings and cleaning/waxing agents, and illumination are all-important elements that must be taken into consideration in providing safe floor surfaces in the workplace. Common solutions used to make floor surfaces slip-resistant include grooving, gritting, matting, and grating.

Personal characteristics (physical make-up or disabilities, age, physical health, emotional state, agility, and attentiveness) are also factors important to consider in making walking and working surfaces slip-resistant for workers.

Work task design also plays an important role in causing and/or preventing slip-falls.

Slips can also be the result of work practices—work practices that cause walking surfaces to be constantly wet, from spills, or wet or slippery from weather hazards like snow and ice. Workplace supervisors and workers (and the safety engineer) must follow safe work practices and exercise vigilance to ensure such conditions do not occur, or are remediated as quickly as possible when they do. This type of problem is much more common than we might realize. How often have workers spilled oil or some other slippery chemical on the workplace floor, then just walked away from the spill—leaving this common slip hazard for another worker to step in, slip on and fall? The common workplace safe work practice and housekeeping rule should be to clean up spills right away. Another unsafe work practice that commonly leads to slip-falls is when the worker is in a hurry, rushing to finish whatever he or she is attempting to accomplish, and simply not paying attention to the conditions of the area around them.

Trips: Falls on the Same Level

Have you ever considered what happens when a worker trips? If you are a safety engineer, you should. Trips normally occur whenever a worker's foot contacts an object that causes him or her to lose balance. However, you do not always have to come into contact with an object to trip. Too much friction between the foot or footwear and the walking surface may cause trips.

Like slips, trips commonly occur when the worker is rushing, hurrying to complete whatever he or she is doing. The problem with hurrying is, of course, is that the victim's attention is usually focused on anything but possible trip hazards.

Another common factor that leads to a trip is the practice of carrying objects that are too large for the worker to adequately see the walking surface in front of him or her.

Lighting also plays a critical role in preventing trips. Inadequate lighting fixtures, burned-out bulbs, and lights that are turned off all increase the opportunity for trips to occur.

Again, as in the prevention of slips, housekeeping plays an important role in prevention. Good workplace housekeeping practices include keeping passageways clean and uncluttered; arranging equipment so that it doesn't interfere with walkways or pedestrian traffic; keeping working areas clear of extension or power tool cords; eliminating loose footing on stairs, steps, and floors; and properly storing gangplanks and ramps.

Stair Falls: Falls on One or More Levels

One of the first things any conscientious safety engineer should do when first hired (and should continue throughout his or her tenure) is to become completely familiar with the applicable literature that describes workplace hazards, their frequency of occurrence, and the recommended hazard control methods.

For falls from stairs, the best publication we know is the one provided by the Department of Labor, Bureau of Labor Statistics titled *Injuries Resulting From Falls on Stairs* (Bulletin 2214), August 1984. This particular booklet is excellent because it not only provides statistical data, but also is an eye-opener on the way many of the injuries occur (causal factors). For example, it is widely known and accepted that stairs are a high-risk area. It is also accepted that a loss of balance can occur from a slip or trip while a worker (or any person) is traveling up or down a stairway. However, for the safety engineer the question becomes why: Why are stairs so hazardous? What are the causal factors? Bulletin 2214 comes in handy in trying to answer questions like these. For example, Bulletin 2214 points out that the vast majority of falls on stairs occur when traveling down the stairs, not holding the handrail. This is an important point for two reasons: (1) The safety engineer can focus training on this important point; and (2) the safety engineer can ensure that handrails are not only in place in all stairways, but are also in good repair.

Loss of traction is the common cause of the highest number of stairway slipping and falling accidents. Again, this is where good housekeeping practices come into play. Many of the stairway slipping and falling accidents happen because of water or other liquid on steps. Along with improper housekeeping practices, stairs can also become hazardous whenever they are improperly designed, installed, and/or neglected. Safe work practices should also be considered. A work practice that allows the worker to carry or reach for large or heavy objects while climbing stairs is not a good work practice.

Elevated Falls: Falls from One Level to Another

When workers are working from elevated scaffolds, ladders, platforms, and other surfaces, the risk of serious injury from an elevated fall is increased exponentially whenever the worker has a loss of balance resulting from a slip or trip. Unfortunately, in our experience, often the practice of various supervisors and companies requires workers to perform work from elevated areas to use some type of device (handrail or hand-line), which they are supposed to grab onto to break their fall. In our judgment (and the judgment of most experienced safety professionals), this is not fall protection. These types of jerry-rigged devices are not acceptable substitutes for guardrails, appropriate midrails, and toeboards. OSHA requires guardrails to be 42” nominal, midrails 21” and toeboards 4”.

Ellis (1988) makes a good point in that “unlike many workplace hazards, few, if any, ‘near-miss’ incidents help people learn to appreciate the seriousness of elevated falls” (28). When you consider that losing one’s balance from an elevation of 10 to 200 feet or more usually leaves little chance to avoid serious or fatal injury, Ellis’ statement makes a lot of sense.

Fall Protection Measures

Just about anyone can talk about the hazards and dangers inherent in slips, trips, and falls from elevation. Under 29 CFR Subpart M, Fall Protection, 1926.501, employers must assess the workplace to determine if the walking or working surfaces on which employees are to work have the strength and structural integrity to safely support workers. Accordingly, the real goal should be on how to prevent slips, trips, and falls from elevation from occurring in the first place. This is the safety engineer’s goal.

Earlier we highlighted the major components that make up a good fall protection program. After determining that workers may be required to perform elevated work, the safety engineer responsible for the safety of such workers needs to develop a fall protection program. Even if a particular company does not require workers to work from elevated locations, remember that every workplace still has slip and trip hazards to guard against. The need for a company fall protection program may still be necessary.

Along with installing a company fall protection program, we have three other important recommendations: (1) planning before beginning any elevated work (e.g., a Scaffold Safety Program); (2) establishing a written policy and developing rules; and (3) a written safe work practice designed to prevent falls.

Planning is all about thinking through the job at hand. For example, if exterior-refurbishing work is to be accomplished on a chemical storage tank that is 80 feet in height, erecting scaffolding is probably required. Properly erecting scaffolding takes both planning, and a great deal of skill. (NOTE: Recall the 1996 BLS report pointed out that 70 percent of falls from elevation are from scaffolds). If scaffolding is to be used, the organization responsible for erecting the scaffolding should have a Scaffold Safety Program (see listing in this text).

False Positive: Positive result of a test for a disease or illicit drug use when the subject does not have the disease and/or had not used illicit drugs.

False Rejects: When an authentication system fails to recognize a valid user.

Fan Curve: A curve relating pressure and volume flow rate of a given fan at a fixed fan speed (rpm).

Fan Laws: Relationships that describe theoretical, mutual performance changes in pressure, flow rate, rpm of the fan, horsepower, density of air, fan size, and sound power.

FAO: Food and Agriculture Organization of the United Nations leads international efforts to defeat hunger. FAO serves both developed and developing countries and acts as a natural forum where all nations meet as equals to negotiate agreements and debate policy.

Farad: In *electricity*, a basic unit of capacitance; equivalent to the capacitance of a capacity in which a charge of 1 coulomb produces a change of 1 volt in the potential difference between its terminals.

Faraday’s Law of Electromagnetic Induction: A basic law of electromagnetism relating to the operating principles of transformers, inductors, and many types of electrical motors and generators. The law states that: The induced electromagnetic force or EMF in any closed circuit is equal to the time rate of change of the magnetic flux through the circuit.

Fast Pyrolysis: Thermal conversion of biomass by rapid heating to 450-600 degrees Celsius in the absence of oxygen.

Fatigue Strength: The property of a material to resist various kinds of rapidly alternating stresses.

Fault: Fracture or a zone of fractures in rock along which there has been displacement of the sides relative to one another parallel to the fracture.

Fault Line Attacks: Attacks that use weaknesses between interfaces of systems to exploit gaps in coverage.

Fault Tolerance: A design method that ensures continued systems operation in the event of individual failures by providing redundant system elements.

Fault Tree Analysis (FTA): Postulates the possible failure of a system and then identifies component states that contribute to the failure. It reasons backwards from the undesired event to identify all of the ways in which such an event could occur and, in dosing so, identifies the contributory causes. The lowest levels of a fault tree involve individual components or processes and their failure modes. This level of the analysis generally corresponds to the starting point in Failure Modes and Effect Analysis (FMEA).

FTA uses Boolean logic and algebra to represent and quantify the interactions between events. The primary Boolean operators are AND and OR gates. With an AND gate, the output of the gate, the event that is at the top of the symbol, occurs only if all of the conditions below the gate, and feeding into the gate, coexist. With the OR gate, the output event occurs if any one of the input evens occur.

When the probabilities of initial events or conditions are known, the probabilities of succeeding events can be determined through the application of Boolean algebra. For an AND gate, the probability of the output event is the intersection of the Boolean probabilities, or the product of the probabilities of the input events, or:

Probability (output) = (Prob Input 1) × (Prob Input 2) × (Prob Input 3)

For an OR gate, the probability of the output event is the sum of the "union" of the Boolean probabilities, or the sum of the probabilities of the input events minus all of the products.
Probability (output) = (Prob Input 1) + (Prob Input 2) + (Prob Input 3)

-[(Prob Input 1) × (Prob Input 2) + (Prob Input 2) × (Prob Input 3) + (Prob Input 1) × (Prob Input 1) × (Prob Input 3) + (Prob Input 1) × (Prob Input 2) × (Prob Input 3)]

Where the probabilities of the input events are small (less than 0.1, for example), the probability of the output event for an OR gate can be estimated by the sum of the probabilities of the input events or:

Probability (output) = (Prob Input 1) + (Prob Input 2) + (Prob Input 3)

FDA: U.S. Food and Drug Administration, the government agency responsible for protecting the public health by assuring the safety, efficacy, and security of human and veterinary drugs, biological products, medical devices, our nation's food supply, cosmetics, and products that emit radiation. FDA is one of thirteen major operating components of the Department of Health and Human Services.

Feasibility Study: 1. Analysis of the practicability of a proposal; e.g., a description and analysis of potential cleanup alternatives for a site such as one on the National Priorities list. The feasibility study usually recommends selection of a cost-effective alternative. It usually starts as soon as the remedial investigation is underway, together, they are commonly referred to as the "RI/FS". 2. A small-scale investigation of a problem to ascertain whether a proposed research approach is likely to provide useful data.

Fecal Coliform Bacteria: *Much of the information in this section is from USEPA* Test Methods for Escherichia coli and Enterococci in Water by the Membrane Filter Procedure *(Method #1103.1). EPA 600/4-85-076, 1985 and* USEPA Bacteriological Ambient Water Quality Criteria for Marine and Fresh Recreational Waters. EPA 440/5-84-002. *Cincinnati, OH: Environmental Protection Agency, Office of Research and Development, 1986.*

Fecal coliform bacteria are non-disease-causing organisms which are found in the intestinal tract of all warm blooded animals. Each discharge of body wastes contains large amounts of these organisms. The presence of fecal coliform bacteria in a stream or lake indicates the presence of human or animal wastes. The number of fecal coliform bacteria present is a good indicator of the amount of pollution present in the water.

EPA's November 2001 Total Coliform Rule 816-F-01-035 specifies the following:

1. The purpose of the Total Coliform Rule is to improve public health protection by reducing fecal pathogens to minimal levels through control of total coliform bacteria, including fecal coliforms and Escherichia coli (E. coli).
2. Establishes a maximum contaminant level (MCL) based on the presence or absence of total coliforms, modifies monitoring requirements including testing for fecal coliforms or E. coli, requires use of a sample siting plan, and also requires sanitary surveys for systems collecting fewer than five samples per month.
3. The Total Coliform Rule applies to all public water systems.
4. Implementation of the Total Coliform Rule has resulted in reduction in risk of illness from disease causing organisms associated with sewage or animal wastes. Disease symptoms may include diarrhea, cramps, nausea, and possibly jaundice, and associated headaches and fatigue.

Fecal coliforms are used as indicators of possible sewage contamination, because they are commonly found in human and animal feces. Although they are not generally harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, and protozoans that also live in human and animal digestive systems. Their presence in streams suggests that pathogenic microorganisms might also be present, and that swimming in and/or eating shellfish from the waters might present a health risk. Since testing directly for the presence of a large variety of pathogens is difficult, time-consuming, and expensive, water is usually tested for coliforms and fecal streptococci instead. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff.

In addition to the possible health risks associated with the presence of elevated levels of fecal bacteria, they can also cause cloudy water, unpleasant odors, and an increased oxygen demand.

Note: In addition to the most commonly tested fecal bacteria indicators, total coliforms, fecal coliforms, and E. coli, fecal streptococci and enterococci are also commonly used as bacteria indicators.

Fecal coliforms are widespread in nature. All members of the total coliform group can occur in human feces, but some can also be present in animal manure, soil, and submerged wood, and in other places outside the human body. The usefulness of total coliforms as an indicator of fecal contamination depends on the extent to which the bacteria species found are fecal and human in origin. For recreational waters, total coliforms are no longer recommended as an indicator. For drinking water, total coliforms are still the standard test, because their presence indicates contamination of a water supply by an outside source.

Fecal coliforms, a subset of total coliform bacteria, are more fecal-specific in origin. However, even this group contains a genus, Klebsiella, with species that are not necessarily fecal in origin. Klebsiella are commonly associated with textile and pulp and paper mill wastes. If these sources discharge to a local stream, consideration should be given to monitoring more fecal and human-specific bacteria. For recreational waters, this group was the primary bacteria indicator until relatively recently, when USEPA began recommending E. coli and enterococci as better indicators of health risk from water contact. Fecal coliforms are still being used in many areas as indicator bacteria.

Federal Clean Air Act Amendments (CAAA): Statutory basis for federal regulation of air pollution, revised and reauthorized every five years.

Federal Food, Drug, and Cosmetic Act: This Act established the federal FDA, whose primary purpose is to protect the interest of the public by ensuring that foods, drugs, and cosmetics are safe, effective, and properly labeled. It established testing requirements for new drugs, which had to be proven safe for their intended use prior to marketing. It also required testing to be proven safe for their intended use prior to marketing. It also required testing all food additives for toxicity. Some chemicals are not considered food additives, and are not subject to the testing requirement of additives.

In 1958, the Delaney Clause was added to this Act. The Delaney Clause states that any substance that causes cancer in animals or humans cannot be used in food in any quantity.

This Clause was first used to prohibit the use of saccharin in food because the additive was shown to cause cancer in mice.

One reason why toxicity tests are required under these and other regulations is so that standardized testing methods and procedures (known as good lab practices or GLP) will be followed for using chemicals in the marketplace. This ensures that the chemicals will be adequately tested, the methods used will be scientifically defensible, and the results will provide useful information regarding the toxicity of a chemical under its intended use to humans.

This standardized protocol also prevents fraudulent experiments that are intended to demonstrate that a chemical is safe when it in fact is not.

It is not possible to prove a chemical is safe, because this means proving that the chemical cannot cause toxicity. This is like trying to prove a negative. For example, you might be pretty sure that it has never rained in a certain part of a desert over the last 100 years because of direct measurements, but this is insufficient to say that it will never rain in that location.

However, it is possible to show that a chemical does not cause toxic effects within the testing guidelines defined in the Act. This should indicate that the chemical is likely to be safe for its intended use.

The primary objective of toxicity testing is to minimize the potential harm to humans from chemical use. The specific objectives typically include:

- Identifying the target organ, target organs, or target system for the chemical
- Establishing if the effects are reversible or permanent
- Determining the most sensitive method for detecting the toxic effect
- Determining the mechanism of toxic action

Lab animal testing is still a common method for gathering toxicity information relative to these overall objectives. Although *in vitro* tests are becoming more prevalent in the scientific community, there is still uncertainty related to how tests on cells or tissues in a lab will translate to whole organisms exposed to the chemical in the environment.

Recent information regarding reproductive effects that can occur at concentrations below those previously shown to cause toxicity based on lab studies (e.g., endocrine disruptors) also indicates that, for some information, animal testing provides the only reliable and accurate method for toxicity testing.

Federal Hazardous Materials Statutes: Hazardous materials are controlled under ten federal statutes. Each statute provides protection from hazardous materials in different situations:

Clean Water Act (CWA)	Water
Clean Air Act (CAA)	Air
Safe Drinking Water Act (SDWA)	Ground Water
Toxic Substances Control Act (TSCA)	Products
Occupational Safety & Health Act (OSHA)	The Workplace
Resource Conservation & Recovery Act (RCRA)	Solid Waste
Emergency Planning and Community Right to Know Act (EPCRA)	Public Domain
Oil Pollution Act (OPA)	Oil Spills
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	Dump Sites
Hazardous Materials Transportation Act (HMTA)	Transportation

Obviously, the Hazardous Materials Transportation Act (HMTA), as amended by Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA) is the focus of this text, because, of course, Hazardous Materials Transportation Regulations are mandated by HMTA of 1975 (PL93-633).

✔ **Important Point:** The intent of DOT's hazardous materials regulations is to protect transportation personnel and equipment from materials with dangerous properties. To further promote safety within the transportation industry, these regulations are periodically revised and amended. Until 1988, they were highly complex in both content and organization. Then proposals were made to simplify them to produce consistent modal and regional transportation requirements. To the extent possible, the discussion in this text follows these simplified proposals.

✔ **Important Point**: Presently, more than 32,000 commodities are regulated as hazardous materials, ranging from everyday substances such as kerosene to firecrackers and highly explosive or toxic chemicals. Some are products that we use in our homes in limited (usually diluted) quantities (drain cleaners using sodium hydroxide or caustic, for example). All these materials demand care in handling and transportation.

Today, thanks to massive media exposure, we are routinely informed of Hazmat incidents, though, nation-wide, they occur more often than some people might expect. The fact is, the highly publicized incidents involving Hazmats have led to increasing public concern about the safe shipment of these materials. Safe transportation of Hazmats is not a given; it requires the coordinated efforts of both shipper and carrier. It requires planning and careful management with attention to detail. The transportation community and public authorities recognize the need for contingency plans (emergency response) to deal with the situation when things go wrong. One thing is certain, in transportation incidents involving Hazmats, the Hazmats always make what goes wrong even nastier to deal with—and the consequences more difficult and dangerous to live with.

✔ **Important Point**: The Hazardous Materials Transportation Regulations cover transportation of hazardous materials by rail, car, aircraft, vessel, and motor, and cover, in particular: hazardous substances, hazardous waste and flammable cryogenic liquids. The regulation enforcement program is administered by the Research and Special Programs Administration (RSPA) of the DOT.

Federal Implementation Plan: Under current law, a federally implemented plan to achieve attainment of air quality standards, used with a state is unable to develop an adequate plan.

Federal Insecticide, Fungicide, and Rodenticides Act (FIFRA): This Act was originally enacted in 1947, but was revised in 1972 based on passage of the Environmental Pesticide Control Act. This Act covers all pesticides, not just the three types listed in the title of the Act. Under this Act, the manufacturer of a new pesticide must conduct a battery of toxicology tests to obtain registration for a specific use. If this specific use changes, additional testing must be conducted to evaluate toxicity of the chemical for this different use. For example, if a pesticide is approved only for use on cantelopes, more tests are required before it can be used on other crops like watermelons.

Pesticides are classified into two categories by this Act:

1. those registered for general use (e.g., household), which are considered of relatively low hazard,
2. those registered for restricted use (e.g., application on a specific crop by a certified pesticide applicator), which are considered of higher toxicity.

Federal Motor Carrier Safety Regulations (FMCSR): This headword addresses the HMR requirements for the acceptance and transportation of hazardous materials by private, common and/or contract "for-hire" motor carriers in 49 CFR Part 177, "Carriage by Highway," are in addition to those requirements contained in Parts 171, 172, 173, 178 and 180 of the HMR. Additionally, this section addresses applicable requirements of the FMCSA in 49 CFR Parts 390-397.

General Requirements

You may not offer or accept a hazardous material for transportation in commerce unless:

- You are registered, if required, and;
- You have properly classed, described, packaged, marked, and labeled the hazardous material and;
- The hazardous material is in proper condition for shipment.

Motor carrier and offeror/shipper responsibilities frequently overlap. When a carrier performs a shipper function, the carrier is responsible for performing that function in accordance with the 49 CFR.

✔ **Important Point**: Both carriers and shippers are responsible for ensuring their employees are properly trained as required by the HMR.

As mentioned previously, a "hazmat employee" is anyone employed by a hazmat employer who, during the course of employment, directly affects hazmat transportation safety including an owner-operator of a motor vehicle that transports hazardous materials in commerce.

Except as provided in 172.704(c)(1), before any hazmat employee performs a function subject to the HMR, that person must be provided initial training in the performance of that function. Each hazmat employee must be periodically retrained at least every three years.

The driver training regulations in Part 177 illustrate how the Federal Motor Carrier Safety Regulations can be closely linked to related rules in the HMR. Section 177.816 mandates training in the requirements found in the FMCSR Parts 390-397. Section 177.816(a)(2) requires training in areas such as vehicle controls and equipment, including emergency equipment. The exact equipment required is found in FMCSR Part 393.

Section 177.816 requires additional training for operators of cargo tanks or vehicles with portable tanks, as well as other training that may be satisfied by the appropriate state commercial driver's license, known as a CDL, required in Part 383. But remember, recurrent hazardous materials transportation training is required every three years, regardless of the length of time your CDL is valid.

The HRM differ from the FMCSR, that the HMR are specifically intended to cover transportation of hazardous materials, whether within a state or between states. The FMCSR regulate general safety requirements for motor vehicles, including hazardous materials safety. Within the FMCSR, the regulations in Parts 390-399 apply to interstate transportation—that is, between states—and not intrastate transportation, which stays entirely within a single state. The other regulations from the FMCSR we touch on cover both interstate and intrastate transportation, like the HMR.

When determining which FMCSR regulations apply, it is also important to verify state regulations. The differences in regulations are important. The FMCSR on drug and alcohol testing and CDL cover both interstate and intrastate transport, and FMCSR insurance regulations in some cases apply to intrastate as well as interstate transport. State, not Federal, regulations cover hours of service and qualification of drivers, except as note above, in strictly intrastate transport.

✔ **Important Point**: USDOT representatives are authorized to conduct unannounced inspections of all motor carrier records, equipment, packaging, and containers that may affect the safe transportation of hazardous materials. Unlike state and local police, they have the right of entry without probable case or prior notification.

Many state statutes and municipal ordinances prohibit carriers from transporting hazardous materials on restricted highways and through public tunnels. Motor carriers have to obey those laws as well as Federal regulations unless an exemption has been authorized. The HMR do not nullify or supersede these state statutes and municipal ordinances, regardless of the kind or quantity of hazardous materials. Section 177.810, within the HMR, requires compliance with local ordinances regarding public tunnels, and Section 397.3, within the FMCSR, requires compliance with state and local laws unless they are in disagreement with specific Federal requirements.

Part 397 of the FMCSR covers driving and parking rules, including attendance and surveillance of parked vehicles and routing regulations for both radioactive and non-radioactive hazardous materials. The requirements for routing non-radioactive hazardous material shipments by motor vehicle are in Part 397, Subpart C, within the FMCST. Routing requirements for radioactive hazardous materials are found in Subpart D.

Shipping Papers

As mentioned earlier, unless excepted, you must have a shipping paper that is prepared in accordance with sections 172.200, 172.201, 172.202, and 172.203 for each hazardous material shipment. The carrier must retain shipping papers for one year for hazardous materials, and three years for hazardous wastes.

An initial motor carrier may not accept a hazardous material unless the shipping paper includes a properly completed shipper's certification. However, you do not need a shipper's certification for:

- Shipments transported entirely by the shipper as a private motor carrier, unless reshipped or transferred from one carrier to another;
- Bulk shipments transported in a cargo tank supplied by the motor carrier (since the carrier, not the shipper, provides the packaging);

- Return of an empty tank car previously containing a hazardous material that has not been cleaned or purged.

When you offer a freight container or transport vehicle to a rail carrier, the shipping paper must contain the description of the freight container or transport vehicle, and the kind of placard affixed to the freight container or transport vehicle.

It is the responsibility of every motor carrier and driver to make sure that the shipping papers are readily available and accessible in case of an accident or inspection. In order to do this, shipping papers for hazmats must be clearly distinguished from all other shipping papers. This can be accomplished by tabbing the hazmat shipping papers, placing them on top of the stack of papers, or keeping them separate but still readily accessible.

When you are at the motor vehicle's controls, the shipping paper must be within your immediate reach, even while you are restrained by a lap belt. The shipping papers must be readily visible to a person entering the driver's compartment, or in a holder mounted on the inside of the driver's door.

When you are not at the motor vehicle's controls, the shipping paper must either be placed in the holder mounted to the inside of the driver's door, or placed on the driver's seat.

✔ **Important Point**: Marking and placarding requirements are found in Subparts D & F of Part 72 of the 49 CFR. Except in an emergency, a transport vehicle containing a hazardous material may not be moved unless it displays all required marking and placards. An improperly placarded or marked transport vehicle may be moved in an emergency, only if:

- escorted by a state or local government representative;
- the motor carrier has permission from the USDOT; or
- movement of the transport vehicle is necessary to protect life or property.

Leaking Cargo

You must handle broken or leaking containers in transmit by the safest practice available. You may repair these packages if safe to do so. You may place a broken or leaking package in a salvage drum in accordance with section 173.3(c) and transport it to its destination, or return it to the shipper. To see the complete requirements for handling disabled vehicles and broken or leaking packages, review section 177.854 in the HMR.

When a leak in a cargo tank makes further transportation unsafe:

- Remove the cargo tank from the traveled portion of the highway, and;
- Use every means to safely dispose of the leaking material by preventing its spread over a wide area, and preventing the contamination of streams and sewers;
- All sources of ignition are forbidden.

✔ **Important Point**: Hazardous materials must be loaded, blocked, braced, and unloaded in accordance with the prescribed safeguards found in Section 177.834(a-o).

You may move leaking cargo tanks only to the nearest place where the contents can be disposed of safely. You must use all available means to prevent leakage or spillage on the highway.

✔ **Important Point**: Special requirements for the loading and unloading of motor vehicles are contained in 49 CFR 177.835-177.842. There are specific loading and unloading requirements for materials in hazard classes 1 through 8. Additional attendance requirements are found in 49 CFR 397.5.

FMCSR—Specific Requirements

Specific requirements for Class 1—Explosive Materials include:

- You must turn off the vehicle engine during loading and unloading;
- The cargo area interior must be free of projections, such as bolts, screws or nails that could damage a package or container;
- The tailgate must be closed;
- The cargo must remain within the body of the vehicle;
- The trailer must have a tight floor and the inside surfaces in contact with the load must be lined with non-metallic or non-ferrous materials;
- are one of the most transported materials. They are also among the most cited materials in transport violations.

- Part 177 includes special requirements for cargo tank motor vehicles that transport Class 3—(flammable liquid) materials. You must bond and ground a cargo tank if the cargo tank is loaded through an open filling hole. You do not have to ground and bond the cargo tank if it is loaded or unloaded through a vapor tight connection into a stationary tank, provided the metallic connection is in contact with the filling hole.
- Section 177.839 provides special requirements for storage batteries containing electrolyte if loaded with other cargo. You must load such a storage battery so other cargo does not fall onto or against it. You must adequately protect and insulate battery terminals against short circuits. Section 177.839 also regulates

the loading of Nitric Acid. You must not load any packaging of nitric acid of 50 percent or greater concentration above any packaging containing any other kind of material.

- cylinder containing compressed gas must be protected from movement or ejection from the motor vehicle. You must:
  - ○ securely restrain it in an upright or horizontal position,
  - ○ load it into a rack attached to the motor vehicle, or
  - ○ pack it in a box or crate.
- Part 177 provides special requirements for packages labeled “TOXIC” or “POISON”. You may not transport packages labeled “TOXIC,” “POISON,” or “POISON INHALATION HAZARD” in the same motor vehicle with foodstuff, feed or edible material unless the package is overpacked in a metal drum as provided in section 173.259(c) of the HMR, or loaded in a closed unit load device and the foodstuff, feed, or edible material is loaded in another closed unit load device.
- You may not transport a package labeled “TOXIC,” “POISON”’ “TOXIC GAS,” “POISON GAS,” or “POISON-INHALATION HAZARD” in the driver’s compartment of the sleeper berth of a motor vehicle.
- When you load Class 4 (flammable solid) or Class 5 (oxidizing) materials in a motor vehicle, you must make certain they are contained in the body of the vehicle and covered either by the body of the vehicle, by a tarpaulin, or by other means. If the vehicle has a tailboard or tailgate, you must close and secure it. If the material is likely to become hazardous to transport when wet, take precautions to keep it dry, both during loading and during transport. If there is a spontaneous heating/combustion hazard associated with the material, make sure the lading is sufficiently ventilated to provide reasonable assurance against fire. When loading nitrates, make sure the vehicle is swept clean and is free of projections that might injure the bag. Do not load ammonium nitrate with organic coating in an all-metal vehicle, unless the metal is aluminum, or in the case of a closed vehicle, aluminum alloy. Do not load more than 100 pounds of smokeless powder for small arms, Division 4.1, in a single vehicle. Finally, for division 4.2 (Pyrophoric liquid) cylinders, load with all valves and safety relief devices in the vapor space, and secure the cylinders against shifting in transit.
- Transport Index, known as TI, is derived from the radiation reading one meter from the package containing radioactive material. The number of radioactive material packages in a storage location or transported in a motor vehicle is limited so that the total transport index number does not exceed 50. The TI is placed on the label of a package to designate the degree of control to be exercised by the carrier during transportation. The total TI is the sum of the TI on the labels of individual packages and overpacks. The TI is used to determine the minimum separation distance in meters or feet to the nearest undeveloped film, passengers, employees and animals, in continuously occupied areas in various stages of transportation. The limitation that the total transport index number may not exceed 50, does not apply to exclusive use shipments, meaning motor vehicles used only to transport that material or commodity by a single shipper. “Exclusive use” and “transport index” are defined in 173.403 of the HMR.

✔ **Important Point**: No group of “RADIOACTIVE YELLOW-II” or “RADIOACTIVE YELLOW-III” Labeled packages may have a total TI of more than 50 in any single storage location. Each group of packages must be handled and stowed no closer than 6 meters (20 feet) to any other such group, measured edge to edge.

- Each motor vehicle used to transport radioactive materials under exclusive use conditions must be checked for radiation contamination after each use. The examination must be performed with radiation detection instruments. A motor vehicle may not be returned to service until the radiation dose rate meets acceptably low levels. The requirements applicable to radioactive surface contamination of a motor vehicle under exclusive use do not apply to any vehicle used solely for transporting Class 7 (radioactive) materials under the conditions and limitations specified in Section 177.843(b).
- Vehicles used solely for transporting Class 7 (radioactive) materials must be stenciled with the words ”For Radioactive Materials Use Only.” The stencil lettering must be at least three (3) inches high in a conspicuous place on both sides of the vehicle exterior. Also, these vehicles must be kept closed “at all times” except when being loaded or unloaded.

Compatibility

Certain hazardous materials must be separated in a manner that, in the event of leakage from packages, commingling would not occur. The segregation and separation chart of hazardous materials supplies to materials in one or more hazard Class I packages which require labels, in a compartment within a multi-compartmented cargo tank, or in a portable tank loaded in a transport vehicle or freight container. The “Segregation Table for Hazardous Materials” found in Section 177.848 shows the segregation requirements for hazard classes and divisions. A hazard class or division that is not shown is not restricted. For example, hazard Class 9 is not restricted.

✔ **Important Point**: A blank space in the table also indicates that no restrictions apply. Additional instructions for using the table are found in 177.848(e).

Spill Reporting
Despite all safety efforts, incidents do occur. When hazardous materials are involved in a transportation incident, a report may be required. Reporting requirements are the responsibility of the carrier. For certain incidents, you must notify either the National Response Center (NRC) or, for infectious substances, the Centers for Disease Control (CDC), s soon as practical but not later than twelve hours after the incident occurs. For any such incident, you must also follow up with a written Hazardous Materials Incident Report within thirty days of discovering any unintentional discharge of hazardous waste, as well as under certain other conditions (see 171.16). But unless a requirement listed in 171.15 applies, you do not need to notify the NRC or CDC by phone.

You must notify the NRC as soon as practical in the event of fire, breakage, spillage, or suspected radioactive contamination from a radioactive material. You must also notify the shipper in such a case as soon as practical.

You must report a large release of a marine pollutant, by phone, as soon as possible, to the NRC. This requirement applies to a release of over 400 kilograms of a solid, and to the release of over 450 liters of a liquid.

Hazmat incidents that result in any of the following require notification as soon as possible to the National Response Center or the Center for Disease Control, if applicable, when due to the hazardous materials:

- death or injury requiring hospitalization,
- change in the operational flight pattern or routine of an aircraft,
- the shutdown of major facility or transportation artery for ore than on hour,
- an evacuation of the general public that lasts more than one hour, or
- situation that, in your judgment, requires notification, even if none of the above conditions are met—for example, a continuing danger to life, although no death has yet occurred.

✔ **Important Point**: You may sometimes transport hazmats on motor vehicles carrying passengers for hire. Certain conditions and limitations apply, however, to this type of hazmat transportation. You may not transport hazardous materials, including explosives, on motor vehicles carrying passengers for hire where other practicable means of transport is available, except: small arms ammunitions; emergency shipments of drugs, chemicals, and hospital supplies; and the accompanying munitions of war of the armed forces of the United States. The specific limitations and conditions relating to these shipments can be found in 49 CFR 177.870(b).

Federal Motor Vehicle Control Program: All federal actions aimed at controlling pollution from motor vehicles by such efforts as establishing and enforcing tailpipe and evaporative emission stands for new vehicles, testing methods development, and guidance to states operating inspection and maintenance programs. Federally designated area that is required to meet and maintain federal ambient air quality standards. May include nearby locations in the same state or nearby states that share common air pollution problems.

Federal Operating Permit (FOP): Operating permit obtained under the auspices of the Clean Air Act, outlining the maximum emissions rates and abatement measures required of all sources under the permit's purview.

Federal Water Pollution Control Act (Otherwise known as the Clean Water Act): Concerned with controlling and regulating the amount of municipal and industrial pollution fed into the nation's water bodies.

Feedlot: An animal feeding operation where beef cattle are finished to slaughter weight; it consists of fenced earthen or concrete paddocks with cattle having little or no access to pasture.

Feller-buncher: In *biomass*, a self-propelled machine that cuts trees with giant shears near ground level and then stack the trees into piles to await skidding.

Fen: In *earth science*, a type of wetland that accumulates peat deposits. Fans are less acidic that gobs, deriving most of their water from groundwater rich in calcium and magnesium.

Fences: A fence is a physical barrier that can be set up around the perimeter of an asset. Fences often consist of individual pieces (such as individual pickets in a wooden fence, or individual sections of a wrought iron fence) that are fastened together. Individual sections of the fence are fastened together using posts, which are sunk into the ground to provide stability and strength for the sections of the fence hung between them. Gates are installed between individual sections of the fence to allow access inside the fenced area.

Many fences are used as decorative architectural features to separate physical spaces for each other. They may also be used to physically mark the location of a boundary (such as a fence installed along a properly line). However, a fence can also serve as an effective means for physically delaying intruders from gaining access to an energy sector asset. For example, many utilities install fences around their primary facilities, around remote pump stations, or around hazardous petrochemical materials storage areas or sensitive areas within a facility. Access to the area can be controlled through security at gates or doors through the fence (for example, by posting a guard at the gate or by locking it). In order to gain access to the asset, unauthorized persons could either have to go around or through the fence.

Fences are often compared with walls when determining the appropriate system for perimeter security. While both fences and walls can provide adequate perimeter security, fences are often easier and less expensive to install than walls. However, they do not usually provide the same physical strength that walls do. In addition, many types of fences have gaps between he individual pieces that make up the fence (i.e., the spaces between chain links in a chain link fence or the space between pickets in a picket fence). Thus, many types of fences allow the interior of the fenced area to be seen. This may allow intruders to gather important information about the locations or defenses of vulnerable areas within the facility.

There are numerous types of materials used to construct fences, including chain link iron, aluminum, wood, or wire. Some types of fences, such as split rails or pickets, may not be appropriate for security purposes because they are traditionally low fences, and they are not physically strong. Potential intruders may be able to easily defeat these fences either by jumping or climbing over them or by breaking through them. For example, the rails in a split fence may be able to be broken easily.

Important security attributes of a fence include the height to which it can be constructed, the strength of the material comprising the fence, the method and strength of attaching the individual sections of the fence together at the posts and the fence's ability to restrict the view of the assets inside the fence. Additional considerations should include the ease of installing the fence and the ease of removing and reusing sections of the fence. The table 34 provides a comparison of the important security and usability features of various fence types.

Comparison of Different Fence Types

Specifications	*Chain Link*	*Iron*	*Wire (Wirewall)*	*Wood*
Height limitations	12′	12′	12′	8′
Strength	Medium	High	High	Low
Installation Requirements	Low	High	High	Low
Ability to Remove/ Reuse	Low	High	Low	High
Ability to Replace/ Repair	Medium	High	Low	High

Source: USEPA, 2005.

Some fences can include additional measures to delay, or even detect, potential intruders. Such measures may include the addition of barbed wire, razor wire, or other deterrents at the top of the fence. Barbed wire is sometimes employed at the base of fences as well. This can impede a would-be intruder's progress in even reaching the fence. Fences may also be fitted with security cameras to provide visual surveillance of the perimeter. Finally, some facilities have installed motion sensors along their fences to detect movement on the fence. Several manufacturers have combined these multiple perimeter security features into one product and offer alarms, and other security features.

The correct implementation of a fence can make it a much more effective security measure. Security experts recommend the following when a facility constructs a fence:

- The fence should be at least 7–9 feet high.
- Any outriggers, such as barbed wire, that are affixed on top of the fence should be angled out and away from the facility, and not in towards the facility. This will make climbing the fence more difficult, and will prevent ladders from being placed against the fence.
- Other types of hardware can increase the security of the fence. This can include installing concertina wire along the fence (this can be done in front of the fence or at the top of the fence), or adding intrusion sensors, camera, or other hardware to the fence.
- All undergrowth should be cleared for several feet (typically 6 feet) on both sides of the fence. This will allow for a clearer view of the fence by any patrols in the area.
- Any trees with limbs or branches hanging over the fence should be trimmed so that intruders cannot use them to go over the fence. Also, it should be noted that fallen trees can damage fences, and so management of trees around the fence can be important. This can be especially important in areas where fence goes through a remote area.
- Fences that do not block the view from outside the fence to inside the fence allow patrols to see inside the fence without having to enter the facility.
- "No Trespassing" signs posted along fence can be a valuable tool in prosecuting any intruders who claim that the fence was broken and that they did not enter through the fence illegally. Adding signs that highlight the local ordinances against trespassing can further persuade simple troublemakers for illegally jumping/climbing the fence. Electrical substation and other electrical component installations should have clearly visible signage warning of HIGH VOLTAGE and the dangers of electrical shock.

Fenestration: In *HVAC and solar daylighting*, the whole-building design approach will determine what type of fenestration products—windows, doors, and skylights—should be used. Basically, you want to select products with characteristics that accommodate your building's climate, which includes insulating, daylighting, heating and cooling, and natural ventilation needs.

Fermentation: 1. The decomposition of organic substances by microorganisms and/or enzymes. The process is usually accompanied by the evolution of heat and gas, and can be aerobic or anaerobic. 2. Conversion of carbon-containing compounds by micro-organisms for production of fuels and chemicals such as alcohols, acids, or energy-rich gases.

Ferric Chloride: An industrial scale commodity chemical compound, with the formula $FeCl_3$. Is commonly used as a coagulant. in wastewater treatment and drinking water production.

Ferric Coagulation: This type of coagulant is a metal salt which reacts with alkalinity in water to produce an insoluble metal hydroxide floc which incorporates the colloidal particles. This fine particulate is then flocculated to produce settleable solids.

Ferric Hydroxide: A brown powder, insoluble in water; used as arsenic poisoning antidote, in pigments and in pharmaceutical preparations.

Ferric Iron (Fe^{3+}): Iron containing materials or compounds.

Ferric Sulfate: A yellow, water-soluble, rhombohedral crystal, decomposing when heated; used as a chemical intermediate, disinfectant, soil conditioner, pigment, and analytical reagent, and in medicine.

Ferrous Iron: A compound of iron that is soluble in water and which will impart a clear green color.

Ferrous Metals: Magnetic metals derived from iron or steel; products made from ferrous metals include appliances, furniture, containers, and packaging like steel drums and barrels. Recyclable products include processing tin/steel cans, strapping, and metals from appliances into new products.

Fertilizer: Substance that adds essential nutrients to the soil and makes the land or soil capable of producing more vegetation or crops.

Fertilizer Value: Potential worth of the plant nutrients in the wastes and available to plants when applied to soil. It is the cost of obtaining the same nutrients commercially.

Fetch: In *environmental science*, 1. the straight line distance across a body of water subject to wind forces. 2. the distance that wind passes over water.

Fiber: In asbestos management, a particulate form of asbestos, five micrometers or longer, with a length to diameter ratio of at least 3 to 1.

Fiber Products: Products derived from fibers of herbaceous sand wood plant material. Examples include pulp, composition board products, and wood chips for export.

Fiber and Synthetic Rope Sling Safety:

1. Do not attempt to lift loads that exceed the rated load capacity of the rope.
2. Fiber rope slings should have a diameter of curvature meeting at least minimum OSHA or manufacturer's specifications.
3. Natural fiber and synthetic fiber rope slings, except for wet frozen slings, may be used in a temperature range from minimum 20°F to plus 180°F without decreasing the work load limit. For operations outside this temperature range, and for wet frozen ropes, the sling manufacturer's recommendations should be followed.
4. Spliced fiber rope slings should not be used unless they have been spliced in accordance with the requirements of the manufacturer.
5. Natural and synthetic fiber rope slings should be immediately removed from service if any of the following conditions are present:
   —Abnormal wear
   —Powdered fibers between strands
   —Broken or cut fibers
   —Variations in the size or roundness of strands
   —Discoloration or rotting
   —Distortion of hardware in the sling.
6. Only fiber rope slings made from new rope should be used. Law prohibits use of repaired or reconditioned fiber rope slings.
7. When synthetic web slings are used, certain precautions should be taken:
   —Nylon web slings must not be used where fumes, vapors, sprays, mists, acids, or phenolics are present.
   —Polyester and polypropylene web slings must not be used where fumes, vapors, sprays, mists, or liquid forms of caustics are present.
   —Web slings with aluminum fittings must not be used where fumes, vapors, sprays, mists, or liquid forms of caustics are present.
   —Synthetic web slings of polyester and nylon must not be used at temperatures in excess of 180°F; slings of polypropylene must not be used at temperatures in excess of 200°F.

—Synthetic web slings must be immediately removed from service if any of the following problems exist: acid or caustic burns, melting or charring of any part of the sling surface, snags, punctures, tears or cuts, broken or worn stitches, or distortion of fittings.

8. Sling legs should not be kinked.
9. Slings should be securely attached to their loads.
10. All employees must keep clear of loads about to be lifted, and of suspended loads.

Fiber Rope: Ropes used in rigging (for slings) are usually divided into two main classes: fiber rope slings and wire rope slings. Fiber ropes are further divided into natural and synthetic fibers, depending on their construction. Many types of slings have been designed to serve many different purposes. Slings normally have a fixed length. They may be made from various materials and have the form of rope, belts, mesh, or fabric.

Natural fiber ropes and slings are usually made from manila, sisal, or henequen fibers. Most natural fiber ropes and slings used in industry today are made from manila fibers, because of its superior breaking strength, consistency between grades, excellent wear properties in both fresh and salt water atmospheres, and elasticity. The main advantages of natural fiber ropes are their price, and their ability to form or bend around angles of the object being lifted. The disadvantages of using natural fiber ropes are susceptibility to cuts and abrasions, their reduced capability or inability to be used to lift materials at elevated temperatures, and that hot or humid conditions may reduce their service life. Fiber ropes should never be used in atmospheres where they may come in contact with acids and caustics, since these substances will degrade the fibers.

Safe working loads of various sizes and classifications natural fiber ropes can be determined from tables in the 1926.251 OSHA Standard.

Synthetic fiber rope slings are made from synthetic fibers (such as nylon, polyester, polypropylene, polyethylene, or a combination of these) to obtain the desired properties. Synthetic fiber ropes have many of the same qualities as natural fiber rope slings, but are in much wider use throughout the industry because they can be engineered to fit a particular operation. Synthetic fiber ropes have many advantages, including increased strength and elasticity over natural fiber rope. Synthetic fiber rope also stands up better to shock loading, and has better resistance to abrasion than natural fiber rope. One of the key advantages of synthetic fiber rope is that it does not swell when wet. It is also more resistant to acids, caustics, alcohol-based solvents, bleaching solutions and their atmospheres. As with the use of natural fiber rope, synthetic fiber rope also has some disadvantages, including damage from excessive heat (they can melt), from alkalis, susceptibility to abrasion damage, and the real possibility for worker injury if sudden breakage under load occurs. They also cost more than natural ones.

Fibrosis: An increase in fibrous tissue situated within but not restricted to or characteristic of a particular organ or tissue.

FID: Flame ionization detector.

Field (Moisture) Capacity: Moisture content of a soil, expressed as a percentage of the ovendry weight, after the gravitational, or fee, water has drained away.

Field Sniffer: Trained panelist who determines odor intensity in the field.

FIFRA Pesticide Ingredient: An ingredient of a pesticide that must be registered with EPA under the Federal Insecticide, Fungicide, and Rodenticide Act. Products making pesticide claims must register under FIFRA and may be subject to labeling and use requirement.

Filamentous Organisms: In *wastewater treatment*, filamentous organisms (bacteria, fungi, etc.) occur whenever the environment of the activated sludge favors their predominance. They are normally present in small amounts and provide the basic framework for floc formation. When the environmental conditions (i.e., pH, nutrient levels, DO, etc.) favor their development, they become the predominant organisms. When this occurs, they restrict settling, and the condition known as "bulking" occurs.

File Transfer Protocol (FTP): A TCP/IP protocol specifying the transfer of text or binary files across the network.

Fill: Man-made deposits of natural soils or rock products and waste materials.

Filling: Depositing dirt, mud or other materials into aquatic areas to create more dry land, usually for agricultural or commercial development purposes, often with ruinous ecological consequences.

Filter Flies: In *wastewater trickling filter operations*, the trickling filter and surrounding area become populated with large numbers of very small flying insects (psychoda moths).

Causal Factors:

- Poor housekeeping
- Insufficient recirculation
- Intermittent wet and dry conditions
- Warm weather

Corrective Actions (note that corrective actions for filter fly problems revolve around the need to disrupt the fly's life cycle (seven to ten days in warm weather).

- Increase recirculation rate to obtain a hydraulic loading of at least 200 gpd/ft^2. At this rate, filter fly larvae are normally flushed out of the filter.
- Clean filter walls and remove weeds, brush, and shrubbery around the filter. This removes some of the area for fly breeding.
- Dose the filter periodically with low chlorine concentrations (less than 1 mg/l). This normally destroys larvae.
- Dry the filter media for several hours.
- Flood the filter for twenty-four hours.
- Spray area around the filter with insecticide. Do not use insecticide directly on the media, because of the chance of carryover and unknown effects on the slime populations.

Filter Press: In *wastewater dewatering operations*, an ideal dewatering operation would capture all of the biosolids at minimum cost and the resultant dry biosolids solids or cake would be capable of being handled without causing unnecessary problems. Process reliability, ease of operation, and compatibility with the plant environment would also be optimized.

Pressure Filtration Calculations
In *pressure filtration*, the liquid is forced through the filter media by a positive pressure. Several types of presses are available, but the most commonly used types are plate and frame presses and belt presses.

Plate and Frame Press
The *plate and frame press* consists of vertical plates that are held in a frame and that are pressed together between a fixed and moving end. A cloth filter medium is mounted on the face of each individual plate. The press is closed, and biosolids is pumped into the press at pressures up to 225 psi and passes through feed holes in the trays along the length of the press. Filter presses usually required a precoat material, such as incinerator ash or diatomaceous earth to aid in solids retention on the cloth and to allow easier release of the cake.

Performance factors for plate and frame presses include feed biosolids characteristics, type and amount of chemical conditioning, operating pressures, and the type and amount of precoat.

Filter press calculations (and other dewatering calculations) typically used in wastewater solids handling operations include solids loading rate, net filter yield, hydraulic loading rate, biosolids feed rate, solids loading rate, flocculant feed rate, flocculant dosage, total suspended solids, and percent solids recovery.

Solids Loading Rate
The solids loading rate is a measure of the lbs/hr solids applied per square foot of plate area.

$$\text{Sol. Loading Rate, lbs/hr/sq ft} = \frac{\text{(Biosolids, gph) (8.34, lbs/gal) (\% Sol./100)}}{\text{Plate Area, sq ft}}$$

✔ **Key Point:** The solids loading rate measures the lbs/hr of solids applied to each sq ft of plate surface area. However, this does not reflect the time when biosolids feed to the press is stopped.

Belt Filter Press
The *belt filter press* consists of two porous belts. The biosolids is sandwiched between the two porous belts. The belts are pulled tight together as they are passed around a series of rollers to squeeze water out of the biosolids. Polymer is added to the biosolids just before it gets to the unit. The biosolids is then distributed across one of the belts to allow for some of the water to drain by gravity. The belts are then put together with the biosolids in between.

Filter Strip: Strip or area of vegetation used for removing sediment, organic mater, and other pollutants from runoff and wastewater.

Filter Yield: Operated in the batch mode, biosolids is fed to the plate and frame filter press until the space between the plates is completely filled with solids. The biosolids flow to the press is then stopped and the plates are separated, allowing the biosolids cake to fall into a hopper or conveyor below. The *filter yield or net filter yield,* measured in lbs/hr/sq ft, reflects the run time as well as the down time of the plat and frame filter press. To calculate the net filter yield, simply multiply the solids loading rate (in lbs/hr/sq ft) by the ratio of filter run time to total cycle time as follows:

$$\text{N. F. Y.} = \frac{\text{(Biosolids, gph) (8.34 lbs/gal) (\% Sol/100)}}{\text{Plate Area, sq ft}} \quad \frac{\text{Filter Run Time}}{\text{Total Cycle Time}}$$

Example
Problem:
A plate and frame filter press receives a flow of 660 gallons of biosolids during a 2-hour period. The solids concentration of the biosolids is 3.3 percent. The surface area of the plate is 110 sq ft. If the down time for biosolids cake discharge is 20 minutes, what is the net filter yield in lbs/hr/sq ft?

Solution:
First, calculate solids loading rate then multiply that number by the corrected time factor:

$$\text{Solids Loading Rate} = \frac{(\text{Biosolids, gph})\,(8.34\ \text{lbs/gal})\,(\%\ \text{Sol.}/100)}{\text{Plate Area, sq ft}}$$

$$= \frac{(330\ \text{gph})\,(8.34\ \text{lbs/gal})\,(3.3/100)}{100\ \text{sq ft}}$$

$$= 0.83\ \text{lbs/hr/sq ft}$$

Next, calculate net filter yield, using the corrected time factor:

$$\text{Net Filter Yield, lbs/hr/sq ft} = (0.83\ \text{lbs/hr/sq ft})\ \frac{(2\ \text{hrs})}{2.33\ \text{hrs}}$$

$$= 0.71\ \text{lbs/hr/sq ft}$$

Filtering Router: An inter-network router that selectively prevents the passage of data packets according to a security policy, often used as a firewall or part of a firewall. A router usually receives a packet from a network and decides where to forward it on a second network. A filtering router does the same, but first decides whether the packet should be forwarded at all, according to some security policy. The policy is implemented by rules (packet filters) loaded into the router.

Filtration: 1. Process of passing a liquid though a filter to remove suspended matter. 2. Technique by which suspended solid particles in a fluid are removed by passing the mixture through a filter. The particles are retained by the filter to form a residue and the fluid passes through to make up the filtrate.

Financial Assurance for Closure: Documentation or proof that an owner or operator of a facility such as a landfill or other waste repository is capable of paying the projected costs of closing the facility and monitoring it afterwards as provided in RCRA regulations.

Finding of No Significant Impact: A document prepared by a federal agency showing why a proposed action would not have significant impact on the environment and thus would not require preparation of an Environmental Impact Statement. An FNSI is based on the results of an environmental assessment.

Fine Materials: Wood residues not suitable for chipping, such as planer shavings and sawdust.

Fine Textured Soil: Sandy clay, silty clay, and clay.

Finger Geometry Recognition: Use of 3D geometry of the finer to determine identification.

Fingerprinting: Sending strange packets to a system to gauge how it responds to determine the operating system.

Finished Water: Water is "finished" when it has passed through all the processes in a water treatment plant and is ready to be delivered to consumers.

Fire: A chemical reaction between oxygen and a combustible fuel.

Fire Area: An area of a building separated from the remained of the building by special construction. This area has a fire resistance of at least one hour and has all communicating openings properly protected by an assembly that also has a fire resistance rating of at least one hour.

Fire Barrier: A continuous membrane, either vertical or horizontal, such as wall or floor assembly that is designed and constructed with a specified fire resistance rating to limit the spread of fire and that also will restrict the movement of smoke.

Fire Extinguishers: Classes of Fires and Proper Extinguishers

1. Class A Fires: This is the most common type of fire; wood, cloth, paper, or other common combustibles are involved. This type of fire is best extinguished with a pressurized tank usually containing either plain water or water in combination with special wetting agents and aqueous film-forming foam (AFFF). This type of extinguisher is often found in corridors and in offices. A special fire blanket may also be used.
2. Class B Fires: Flammable liquids are involved. These fires are extinguished by using pressurized carbon dioxide, halogenated compounds such as Halon, dry chemicals (ammonium phosphate, sodium/potassium bicarbonates, potassium chloride), or possibly by means of AFFF.
3. Class C Fires: Live electrical circuits are involved either as the cause of the fire or as simply being near the fire. Use carbon dioxide, Halon, or dry chemical extinguishers. Aqueous-based or electrically conductive reagents must not be used to fight such fires.
4. Class D Fires: Combustible metals, such as magnesium, sodium or potassium are involved. Class D Fire Extinguishers contain dry chemicals such as sodium chloride containing a thermoplastic binder that forms a solid suffocating crust over the fire. None of the common extinguishers should be used since they can

increase the intensity of the fire by adding an additional chemical reaction.

Although fire is generally a panic situation, try not to panic—when panic sets in, mistakes are made and a bad situation turns worse, usually in an exponential fashion. To fight the fire, direct the spray at the base of the fire, not at the flames. The object is to suffocate and cool the chain reaction that is occurring at the level of the fuel. Slowly sweep the extinguishing agent over the base of the fire until all flames are extinguished. Even after the flames have subsided, continue to apply the agent to prevent a flare-up or flashback of the fire.

Fire Fighting Gear: Turnout gear including footwear, trousers, a coat, gloves, a helmet, and respiratory protection (NFPA 472).

Fire Hazards Analysis: An assessment of the risks from fire within an individual fire area in a DOE nuclear facility analyzing the relationship to existing or proposed fire protection.

Fire Loss: The dollar cost of restoring damaged property to its pre-fire condition. When determining loss, the estimated damage to the facility and contents should include replacement cost, less salvage value. Fire loss should exclude the costs for:

A. Property scheduled for demolition
B. Decommissioned property not carried on books as a value

Fire loss should include the cost of:

A. Decontamination and cleanup
B. The loss of production or program continuity
C. The indirect costs of fire extinguishment
D. The effects on related areas (DOE-SDT-1066-99).

Fire Point: The lowest temperature at which a liquid will ignite and achieve sustained burning when exposed to a test flame.

Fire Protection: A broad term which encompasses all aspects of fire safety, including: building construction and fixed building fire features, fire suppression and detection systems, fire water systems, emergency process safety control systems, emergency fire fighting organizations (fire departments, fire brigades, etc.), fire protection engineering, and fire prevention. Fire protection is concerned with preventing or minimizing the direct and indirect consequences of fire. It also includes aspects of the following perils as they relate to fire protection: explosion, natural phenomenon, smoke, and water damage from fire (DOE O 5480.7A).

Fire Resistance Rating: The time that a particular construction will withstand a standard fire exposure in hours as determined by American Society of Testing and Materials Standard ASTM E-119 (DOE-STD-1066-99).

Fire Safety: Preventing Fires**:** A fire may be prevented or stopped by removing any of the three necessary elements: fuel, oxygen, and ignition source.

1. Restrict the fuel by using only minimal amounts of flammable materials in the work area. Large containers of flammable solvents of other chemicals should be kept in an approved safety cabinet with doors closed.
2. Limit access to oxygen by keeping all containers capped when not in use. Especially with volatile solvents it is important to ensure that the containers are closed immediately after dispensing the necessary amounts. Remove the working container from the work area after it is no longer needed.
3. Keep ignition sources away from available fuels**.** Although it should be obvious that an ignition source never should be near combustible materials, it is often overlooked. It may not be uncommon to use solvents in close proximity to electrically powered equipment such as stirrers, ultrasonic baths, or even ovens. Since solvent vapors may travel some distance, a spark or heating coil may ignite the vapor phase, which may then serve as a conduit back to the fluid phase. One should never store solvents in a standard refrigerator since a spark from the thermostat, compressor, or other electrical relays may cause an explosion. Instead, a specially designed explosion-proof or flammables refrigerator may be used to store volatile chemicals. Self-defrosting refrigerators cannot be safely modified to store volatile materials.

NOTE: Care must be taken to ensure that no open solvents are left near the high-temperature ovens.

Stopping Fires
1. Evacuate all persons to a safe location. Evacuation is always to an upwind direction of fire or chemical spill. Note the wind direction and assemble in the designated mustering location on the side of the environmental laboratory building that is upwind. If the upwind side is the street, gather directly across the street. Everyone must gather at the pre-arranged assembly point. It is important in order to determine if anyone is still in the building. The chemist for each section will perform a head-count to assure that all technicians working that day are safe. If the chemist

is not present, the senior technician in the section will count those present. If anyone is injured, do not attempt to move them unless the fire appears to be out of control.

2. If it is possible to extinguish the fire safely, do so immediately. After determining the type of fire, select the proper fire extinguisher and position yourself between the fire and the room exit. Do not permit the fire to block your exit. After the fire is safely out, notify the fire department so that it may evaluate the need for further measures.
3. If it is not possible to quickly extinguish the fire, close off the room and activate the fire alarm to alert others in the building. Telephone the fire department, giving the exact location of the fire. Indicate the nature of the fire (electrical, chemical, flammable liquids, etc.) and if hazardous materials are involved. Proceed to the assembly point and be prepared to meet the fire department with further directions as needed.

Fire Watch: The act of watching for the occurrence of fires in industrial surroundings; required during many hot work (welding, brazing, grinding) operations.

Firedamp: In *mining*, is a flammable gas, primarily methane, found in coal mines.

First Aid: The chance that at some point you or anyone else may witness someone in a medical emergency is high. This certainly includes workplaces. As safety and health professional, you're responsible for ensuring that the victim of any sort of medical emergency has help at hand.

OSHA demands certain first aid capabilities. Subpart K of OSHA's 1910 standard directly addresses eye-flushing capabilities in the workplace and indirectly addresses that medical personnel be readily available. "Readily available" can mean that a clinic or hospital is nearby. If such a facility is not located nearby, employers must have a person on site with first-aid training. Because of these OSHA requirements, the organization's safety and health personnel must, as with all other regulatory requirements, ensure that the organization is in full compliance.

First aid awareness and training in the workplace usually involves providing lectures, interactive video presentations, discussions, and hands-on training to teach participants how to:

- recognize emergency situations;
- check the scene and call for help;
- avoid bloodborne pathogen exposure;
- care for wounds, bone and soft-tissue injuries, head and spinal injuries, burns, and heat and cold emergencies;
- manage sudden illnesses, stroke, seizure, bites, and poisoning;
- minimize stroke damage.

One of the most common medical emergencies not related to accident or injury is cardiac arrest. In fact, CardioPulmonary Resuscitation (CPR) was developed to improve the chances of survival of those who suffer cardiac arrest, because it is so frequent an emergency, and because CPR can strongly improve the victim's chances of survival. Anyone who has stood by, useless, while someone else performed CPR, utterly absorbed in an active process of life saving, or worse, with no one near who knew CPR, knows what that could mean.

First aid services in the workplace typically include training and certification of selected individuals to perform CPR on workers when necessary. This training usually combines lectures, video demonstrations, and hands-on manikin training. This training teaches participants how to:

- call and work with EMS;
- recognize breathing and cardiac emergencies that call for CPR;
- perform CPR and care for breathing and cardiac emergencies;
- avoid bloodborne pathogen exposure;
- know the role of AEDs in the cardiac chain of survival.

Automated External Defibrillators (AEDs) are electronic devices with internal microprocessors and computers. When the device's adhesive electrodes are properly attached and the victim is completely still, the AED analyses cardiac rhythm and interprets the data, determining whether or not the victim's heart is in either ventricular fibrillation or fast ventricular tachycardia. If so, the operator is prompted to activate the AED to perform a series of electric shocks, delivered to the heart through the chest wall.

AED units are designed to be used by trained non-medical personnel, just as people train to perform CPR. Firefighters, police, flight attendants, security guards and other lay rescuers may be required to undergo AED training. AED devices represent a financial investment for an organization or community, and the more widely they are available, and the more people who learn to use them, the better for potential victims.

The American Red Cross points out that typical first aid/CPR training for the workplace has been enhanced to include training on the Automated External Defibrillator (AED). *"Although the idea of using a handheld device to deliver a shock directly into a coworker's heart may seem daunting, the American Red Cross hopes this life-saving practice becomes more common over the next year"* (Orfinger, 2002).

AED training focuses on typical AED equipment with hands-on simulation, lectures, and live and video demonstrations. Participants learn to:

- call and work with EMS;
- care for conscious and unconscious choking victims;
- perform rescue breathing and CPR;
- use an AED safely on a victim of sudden cardiac arrest.

First Draw: The water that comes out when a tap is first opened, likely to have the highest level of lead contamination from plumbing materials.

First Law of Thermodynamics: Natural law that dictates that during physical or chemical change energy is neither created not destroyed, but it may be changed in form and moved from place to place. Given this principle, we should be able to account for all the energy in a system in an energy budget, a diagrammatic representation of the energy flows through an ecosystem.

First Responder: The individual who arrives at the scene of a Hazmat incident with the responsibility to act.

Fischer-Tropsch Fuels: Liquid hydrocarbon fuels produced by a process that combines carbon monoxide and hydrogen. The process is used to convert coal, natural gas, and low-value refiner products into a high-value diesel substitute.

Fission Product: The atomic fragments left after large nucleus fissions.

Fissionable Materials: A nuclide capable of sustaining a neutron-induced chain reaction (e.g., uranium-233, uranium 235, plutonium-238, plutonium-239, pojtonim-241, neptunium-237, americium-241, and curium-244) (10CFR 830.3).

Fit Testing: OSHA's 29 CFR 1910.134 specifies under its Respiratory Protection Program that fit-testing of respirators must be conductor before the respirator wearer dons the respirator. The goal of respirator fit-testing is to (1) provide the employee with a face seal on a respirator that exhibits the most protective and comfortable fit and (2) to instruct the employee on the proper use of respirators and their limitations.

There are three levels of fit testing: Initial, Annual, and Pre-Use Self-Testing.

A. The Initial and Annual fit tests are rigorous procedures used to determine whether the employee can safely wear a respirator.
   The Initial and Annual tests are conducted by designated safety personnel. Both tests use the Cartridge and SCBA-type respirators to check each employee's suitability for wearing either type. Fit testing requires special equipment and test chemicals such as banana oil, irritant smoke, or saccharin. In general, any change to the face or mouth may alter respirator fit, and may require the use of a specially fitted respirator; safety personnel will make this determination.
B. Pre-Use Self-Testing—A routine requirement for all employees who wear respirators.
   Each time the respirator is used, it must be checked for positive and negative seal.
   1. Positive Pressure Check Procedure (cartridge style respirator): After the respirator has been put in place and straps adjusted for firm but comfortable tension, the exhalation valve is blocked by the wearer's palm. He or she takes a deep breath and gently exhales a little air. Hold the breath for ten (10) seconds. If the mask fits properly, it will feel as if it wants to pop away from the face, but no leakage will occur.
   2. Negative Pressure Check Procedure (cartridge style respirator): While still wearing the respirator, cover both filter cartridges with the palms, and inhale slightly to partially collapse the mask. Hold this negative pressure for ten seconds. If no air leaks into the mask, it can be assumed the mask is fitting properly.

NOTE: Self-test fit testing can be conducted for both positive and negative pressure checks on the SCBA type respirator by crimping the hoses with fingers, and vise blocking airways with palm of hands.

If either test shows leakage, the following procedure should be followed:

1. Ensure mask is clean. A dirty or deteriorated mask will not seal properly, nor will one that has been stored in a distorted position. Proper cleaning and storage procedures must be used.
2. Adjust the head straps to have snug, uniform tension on the mask. If only extreme tension on the straps will seal the respirator, report this to the Supervisor. Note that a mask with uncomfortably tight straps rapidly becomes obnoxious to the wearer.

1910.134 (g)(1)(A) states: Personnel with facial hair that comes between the sealing surface of the facepiece and the face, or that interferes with valve function shall not be permitted to wear tight-fitting respirators. Thus, respirator wearers with beards or side burns that interfere with the face-seal are prohibited from wearing tight-fitting respirators on the job. Dental changes—loss of teeth, new dentures, braces, and so forth—may affect respirator fit and may require a new fitting with a different type mask.

Fix a Sample: A sample is "fixed" in the field by adding chemicals that prevent water quality indicators of interest in the sample from changing before laboratory measurements are made.

Fixed-Film Wastewater Treatment System: A biological wastewater treatment process that employs a medium such as rock, plastic, wood, or other natural or synthetic solid material that will support biomass on its surface. Fixed-film systems include those in which the medium is held in pace and is stationary relative to fluid flow (trickling filter), those in which the medium is in motion relative to the wastewater (e.g., rotating biological disk), and dual process systems that include both fixed and suspended biomass together or in a series.

Fixed-Location Monitoring: Sampling of an environmental or ambient medium for pollutant concentration at one location continuously or repeatedly.

Fixed Solids: Water/wastewater solids that remain after firing a sample in a muffle oven.

Flagella: A threadlike appendage (that gives some bacteria motility) extending outward from the plasma membrane and cell wall.

Flagellates: Organisms with one or more whip-like organelles called flagella.

Flame Resistant: The property of a material whereby combustion is prevented, terminated, or inhibited following the application of a flaming or non-flaming source of ignition, with or without subsequent removal of the ignition source (NFPA 70E).

Flame Spread Rating: Flame spread rating is a numerical classification determined by the test method in American Society of Testing and Materials standard ASTM-84, which indexes the relative burning behavior of a material by quantifying the spread of flame of a test specimen. The surface burning characteristic of a material is not a measure of resistance to fire exposure (DOE-STD-1066-99).

Flammable: Any material that ignites easily and will burn rapidly.

Flammable Liquid: Any liquid having a flash point below 37.8°C (100°F).

Flammable Solid: A non-explosive solid liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or heat retained from a manufacturing process, or that can be ignited readily and when ignited, burns so vigorously and persistently as to create a serious hazard.

Flammable Storage Cabinet: A listed storage cabinet designed in accordance with NFPA 30. Such a cabinet is designed and constructed to limit the internal temperature to no more than 325° F from the center of the cabinet to within 1 inch of the top of the cabinet when subjected to a 10-minute fire test.

Flare: A control device that burns hazardous material to prevent their release into the environment; may operate continuously or intermittently, usually on top of a stack.

Flash Hazard: A dangerous condition associated with the release of energy caused by an electric arc (NFPA 70E).

Flash Hazard Analysis: A study investigating a worker's potential exposure to arc-flash energy, conducted for the purpose of injury prevention and the determination of safe work practices and the appropriate levels of personal protective equipment (NFPA 70E).

Flash Point: Lowest temperature at which a liquid or solid gives off vapor in such a concentration that, when the vapor combines with air near the surface of the liquid or solid, a flammable mixture is formed. Hence, the lower the flash point, the more flammable the material.

Flash Protection Boundary: An approach limit at a distance from exposed live parts within which a person could receive a second degree burn if an electrical arc flash were to occur (NFPA 70E).

Flash Steam: Steam produced when the pressure on a geothermal liquid is reduced. Also called flashing.

Flash Suit: A complete flame resistant clothing and equipment system that covers the entire body, except for the hands and feet. This includes pants, jacket, and beekeeper-type hood fitted with a face shield (NFPA 70E).

Flat Plate Pumped: A medium-temperature solar thermal collector that typically consists of a metal frame, glazing, absorbers (usually metal), and insulation and that uses a pump liquid as the heat-transfer medium: predominant use is in water heating applications.

Flexible-Membrane Liner (FML): A rubber or plastic liner used in sanitary landfills.

Floc: A clump of solids formed in sewage by biological or chemical action.

Flocculation: Process of using chemical compounds that will react with nutrients to produce a precipitant or complex that can easily be separated from the waste stream.

Flood: An overflow of water onto lands that are used or usable by man and not normally covered by water. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean.

Flood, 100-Year: A 100-year flood does not refer to a flood that occurs once every 100 years, but to a flood level with a 1 percent chance of being equaled or exceeded in any given year.

Flooding: An attack that attempts to cause a failure in (especially, in the security of) a computer system or other data processing entity by providing more input than the entity can process properly.

Floodplain: A strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood.

Flood Stage: The elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

Floor Sweep: Capture of heavier-than-air gases that collect at floor level.

Flotation Thickeners: *Flotation thickening* is used most efficiently for waste sludges from suspended-growth biological treatment process, such as the activated sludge process. In operation, recycled water from the flotation thickener is aerated under pressure. During this time the water absorbs more air than it would under normal pressure. The recycled flow together with chemical additives (if used) is mixed with the flow. When the mixture enters the flotation thickener, the excess air is released in the form of fine bubbles. These bubbles become attached to the solids and lift them toward the surface. The accumulation of solids on the surface is called the **float cake**. As more solids are added to the bottom of the float cake it becomes thicker and water drains from the upper levels of the cake. The solids are then moved up an inclined plane by a scraper and discharged. The supernatant leaves the tank below the surface of the float solids and is recycled or returned to the wastestream for treatment. Typically, flotation thickener performance is 3–5 percent solids for waste activated sludge with polymer addition and 2–4 percent solids without polymer addition.

The flotation thickening process requires pressurized air, a vessel for mixing the air with all or part of the process residual flow, a tank for the flotation process to occur, solids collector mechanisms to remove the float cake (solids) from the top of the tank and accumulated heavy solids from the bottom of the tank. Since the process normally requires chemicals be added to improve separation, chemical mixing equipment, storage tanks, and metering equipment to dispense the chemicals at the desired dose are required.

The performance of dissolved air-thickening process depends on various

- bubble size
- solids loading
- sludge characteristics
- chemical selection
- chemical dose

Expected performance ranges for gravity and dissolved air flotation thickeners follows:

- primary sludge—8–19 percent Solids
- waste-activated sludge—2–4 percent Solids
- trickling filter sludge—7–9 percent Solids
- combined sludges—4–9 percent Solids

Typical operational problems with sludge thickeners include odors, rising sludge, thickened sludge below desired solids concentration, dissolved air concentration too low, effluent flow contains excessive solids, and torque alarm conditions.

Flow: Volume of water, expressed as cubic feet of cubic meters per second, passing a point in a given amount of time.

Flow Battery: An electrochemical energy storage device, which utilizes tanks of rechargeable electrolyte to refresh the energy producing reaction. Since its capacity is limited only by the size of its electrolyte tanks, it is useful for large scale backup system sot supplement other forms of generation which may be intermittent in nature.

Flow Chart: A graphic presentation of the components of a system and how the process flows.

Flow Line: The idealized path followed by particles of water.

Flow Lines: Lines indicating the direction followed by groundwater toward points of discharge. Flow lines are perpendicular to equipotential lines.

Flow Meters: In water and wastewater treatment, while it is clear that maintaining water and wastewater flow is at the heart of any treatment process, clearly, it is the measurement of flow that is essential to ensuring the proper operation of a water and wastewater treatment system. Few knowledgeable operators would argue with this statement. Hauser (1996) asks: "Why measure flow?" Then she explains: "The most vital activities in the operation of water and wastewater treatment plants are dependent on a knowledge of how much water is being processed."

In this statement, Hauser makes clear that flow measurement is not only important, but also routine, in water/wastewater operations. Routine, yes, but also the most important variable measured in a treatment plant. Hauser also pointed out that there are several reasons to measure flow in a treatment plant. The American Water Works Association (1995) lists several additional reasons to measure flow. These additional reasons are:

- The flow rate through the treatment processes needs to be controlled so that it matches distribution system use.
- It is important to determine the proper feed rate of chemicals added in the processes.
- The detention times through the treatment processes must be calculated. This is particularly applicable to surface water plants that must meet *CxT* values required by the Surface Water Treatment Rule.
- Flow measurement allows operators to maintain a record of water furnished to the distribution system for periodic comparison with the total water metered to customers. This provides a measure of "water accounted for," or conversely (as pointed out earlier by Hauser), the amount of water wasted, leaked, or otherwise not paid for; that is, lost water.
- Flow measurement allows operators to determine the efficiency of pumps. Pumps that are not delivering their designed flow rate are probably not operating at maximum efficiency, and so power is being wasted.
- For well systems, it is very important to maintain records of the volume of water pumped and the hours of operation for each well. The periodic computation of well pumping rates can identify problems such as worn pump impellers and blocked well screens.
- Reports that must be furnished to the state by most water systems must include records of raw- and finished-water pumpage.
- Wastewater generated by a treatment system must also be measured and recorded.
- Individual meters are often required for the proper operation of individual pieces of equipment. For example, the makeup water to a fluoride saturator is always metered to assist in tracking the fluoride feed rate.

Note: Simply put, measurement of flow is essential for operation, process control, and recordkeeping of water and wastewater treatment plants.

All of the uses just discussed create the need, obviously, for a number of flow-measuring devices, often with different capabilities. In this section, we discuss many of the major flow measuring devices currently used in water/wastewater operations.

Flow Measurement: The Old-Fashioned Way

An approximate but very simple method to determine open-channel flow has been used for many years. The procedure involves measuring the velocity of a floating object moving in a straight uniform reach of the channel or stream. If the cross-sectional dimensions of the channel are known and the depth of flow is measured, then flow area can be computed. From the relationship $Q = A \times V$, the discharge Q can be estimated.

In preliminary fieldwork, this simple procedure is useful in obtaining a ballpark estimate for the flow rate, but is not suitable for routine measurements.

EXAMPLE

Problem:

A floating object is placed on the surface of water flowing in a drainage ditch and is observed to travel a distance of 20 meters downstream in 30 seconds. The ditch is 2 meters wide and the average depth of flow is estimated to be 0.5 meters. Estimate the discharge under these conditions.

Solution:

The flow velocity is computed as distance over time, or

$$V = D/T = 20\text{ m}/30\text{ s} = 0.67\text{ m/s}$$

The channel area is $A = 2\text{ m} \times 0.5\text{ m} = 1.0\text{ m}^2$

The discharge $Q = A \times V = 1.0\text{ m}^2 \times 0.66\text{ m}^2 = 0.66\text{ m}^3/\text{s}$

Basis of Traditional Flow Measurement

Flow measurement can be based on flow rate, or flow amount. *Flow rate* is measured in gallons per minute (gpm), million gallons per day (MGD), or cubic feet per second (cfs). Water/wastewater operations need flow rate meters to determine process variables within the treatment plant, in wastewater collection, and in potable water distribution. Typically, flow rate meters used are pressure differential meters, magnetic meters, and ultrasonic meters. Flow rate meters are designed for metering flow in closed pipe or open channel flow.

Flow amount is measured in either gallons (gal) or in cubic feet (cu ft). Typically, a totalizer, which sums up the gallons or cubic feet that pass through the meter, is used. Most service meters are of this type. They are used in private, commercial and industrial activities where the total amount of flow measured is used in determining customer billing. In wastewater treatment, where sampling operations are important, automatic composite sampling unit—flow proportioned to grab a sample every so many gallons—are used. Totalizer meters can be the velocity (propeller or turbine), positive displacement, or compound types. In addition, weirs and flumes are used extensively for measuring flow in wastewater treatment plants because they are not affected (to a degree) by dirty water or floating solids.

Flow Measuring Devices

In recent decades, flow measurement technology has evolved rapidly from the "old fashioned way" of measuring flow, discussed earlier, to the use of simple practical measuring devices too much more sophisticated devices. Physical phenomena discovered centuries ago have been the starting point for many of the viable flowmeter designs used today. Moreover, the recent technology explosion has enabled flowmeters to handle many more applications than could have been imagined centuries ago.

Before selecting a particular type of flow measurement device, Kawamura (2000) recommends consideration of several questions.

1. Is liquid or gas flow being measured?
2. Is the flow occurring in a pipe or in an open channel?
3. What is the magnitude of the flow rate?
4. What is the range of flow variation?
5. Is the liquid being measured clean, or does it contain suspended solids or air bubbles?
6. What is the accuracy requirement?
7. What is the allowable headloss by the flow meter?
8. Is the flow corrosive?
9. What types of flow meters are available to the region?
10. What types of post-installation service is available to the area?

Differential Pressure Flowmeters (Kawamura 2000)

For many years *differential pressure* flowmeters have been the most widely applied flow-measuring device for water flow in pipes that require accurate measurement at reasonable cost. The differential pressure type of flowmeter makes up the largest segment of the total flow measurement devices currently being used. Differential pressure-producing meters currently on the market are the venturi, Dall tvpe, Hershel venturi, universal venturi, and venture inserts.

The differential pressure-producing device has a flow restriction in the line that causes a differential pressure or "head" to be developed between the two measurement locations. Differential pressure flowmeters are also known as head meters, and, of all the head meters, the orifice flowmeter is the most widely applied device.

The advantages of differential pressure flowmeters include

- simple construction
- relatively inexpensive
- no moving parts
- transmitting instruments are external
- low maintenance
- wide application of flowing fluid; suitable for measuring both gas and liquid flow
- ease of instrument and range selection
- extensive product experience and performance database

Disadvantages include

- flow rate is a nonlinear function of the differential pressure
- low flow rate rangeability with normal instrumentation

Operating Principle

Differential pressure flowmeters operate on the principle of measuring pressure at two points in the flow, which provides an indication of the rate of flow that is passing by. The difference in pressures between the two measurement locations of the flowmeter is the result of the change in flow velocities. Simply, there is a set relationship between the flow rate and volume, so the meter instrumentation automatically translates the differential pressure into a volume of flow. The volume of flow rate through the cross-sectional area is given by,

$$Q = A \text{ x } v(average)$$

where:
Q = the volumetric flow rate
A = flow in the cross-sectional area
v = the average fluid velocity

Differential pressure flowmeters operate on the principle of developing a differential pressure across a restriction that can be related to the fluid flow rate.

Note: Optimum measurement accuracy is maintained when the flowmeter is calibrated, the flowmeter is installed in accordance with standards and codes of practice, and the transmitting instruments are periodically calibrated.

The most common differential pressure flowmeter types used in water/wastewater treatment are

1. orifice
2. Venturi
3. nozzle
4. Pitot-static tube

Orifice

The most commonly applied *orifice* is a thin, **concentric**, and flat metal plate with an opening in the plate, installed perpendicular to the flowing stream in a circular conduit or pipe. Typically, a sharp-edged hole is bored in the center of the orifice plate. As the flowing water passes through the orifice, the restriction causes an increase in velocity. A concurrent decrease in pressure occurs as potential energy (static pressure) is converted into kinetic energy (velocity). As the water leaves the orifice, its velocity decreases and its pressure increases as kinetic energy is converted back into potential energy according to the laws of conservation of energy. However, there is always some permanent pressure loss due to friction, and the loss is a function of the ratio of the diameter of the orifice bore (d) to the pipe diameter (D).

For dirty water applications (i.e., wastewater), a concentric orifice plate will eventually have impaired performance due to dirt buildup at the plate. Instead, **eccentric** or **segmental** orifice plates are often used. Measurements are typically less accurate than those obtained from the concentric orifice plate. Eccentric or segmental orifices are rarely applied in current practice.

The orifice differential pressure flowmeter is the lowest cost differential flowmeter, is easy to install, and has no moving parts. However, it also has high permanent head loss (ranging from 40 to 90 percent) higher pumping costs, an accuracy of ± 2 percent for a flow range of 4:1, and is affected with wear or damage.

Note: Orifice meters are not recommended for permanent installation to measure wastewater flow; solids in the water easily catch on the orifice, throwing off accuracy. For installation, it is necessary to have ten diameters of straight pipe ahead of the orifice meter to create a smooth flow pattern, and five diameters of straight pipe on the discharge side.

Venturi

A *Venturi* is a restriction with a relatively long passage with smooth entry and exit. It has long life expectancy, simplicity of construction, relatively high-pressure recovery, (i.e., produces less permanent pressure loss than a similar sized orifice), but is more expensive, is not linear with flow rate, and is the largest and heaviest differential pressure flowmeter. It is often used in wastewater flows since the smooth entry allows foreign material to be swept through instead of building up as it would in front of an orifice. The accuracy of this type flowmeter is ± 1 percent for a flow range of 10:1. The headloss across a venturi flow meter is relatively small, ranging from 3 to 10 percent of the differential, depending on the ratio of the throat diameter to the inlet diameter (a.k.a., beta ratio).

Nozzle

Flow nozzles (flow tubes) have a smooth entry and sharp exit. For the same differential pressure, the permanent pressure loss of a nozzle is of the same order as that of an orifice, but it can handle wastewater and abrasive fluids better than an orifice can. Note that for the same line size and flow rate, the differential pressure at the nozzle is lower (headloss ranges from 10 to 20 percent of the differential) than the differential pressure for an orifice; hence, the total pressure loss is lower than that of an orifice. Nozzles are primarily used in steam service because of their rigidity, which makes them dimensionally more stable at high temperatures and velocities than orifices.

Note: A useful characteristic of nozzles it that they reach a critical flow condition, that is, a point at which further reduction in downstream pressure does not produce a greater velocity through the nozzle. When operated in this mode, nozzles are very predictable and repeatable.

Pitot Tube

A *Pitot tube* is a point velocity-measuring device. It has an impact port; as fluid hits the port, its velocity is reduced to zero and kinetic energy (velocity) is converted to potential energy (pressure head). The pressure at the impact port is the sum of the static pressure and the velocity head. The pressure at the impact port is also known as stagnation pressure or total pressure. The pressure difference between the impact pressure and the static pressure measured at the same point is the velocity head. The flow rate is the product of the measured velocity and the cross-sectional area at the point of measurement. Note that the Pitot tube has negligible permanent pressure drop in the line, but the impact port must be located in the pipe where the measured velocity is equal to the average velocity of the flowing water through the cross section.

Magnetic Flowmeters (USEPA 1991)

Magnetic flowmeters are relatively new to the water/wastewater industry. They are volumetric flow devices designed to measure the flow of electrically conductive liquids in a closed pipe. They measure the flow rate based on the voltage created between two electrodes (in accordance with Faraday's Law of Electromagnetic Induction) as the water passes through an electromagnetic field. Induced voltage is proportional to flow rate. Voltage depends on magnetic field strength (constant), distance between electrodes (constant), and velocity of flowing water (variable).

Properties of the magnetic flowmeter include: (1) minimal head loss (no obstruction with line size meter); (2) no effect on flow profile; (3) suitable for size range between 0.1 inch to 120 inch; (4) have an accuracy rating of form 0.5–2 percent of flow rate; and (5) it measures forward or reverse flow.

The advantages of magnetic flowmeters include:

- obstruction less flow
- minimal head loss
- wide range of sizes
- bi-directional flow measurement
- variations in density, viscosity, pressure, and temperature yield negligible effect.
- can be used for wastewater
- no moving parts

Disadvantages include:

- metered liquid must be conductive (but you wouldn't use this type meter on clean fluids anyway)
- bulky, expensive in smaller sizes, and may require periodic calibration to correct drifting of the signal

The combination of the magnetic flowmeter and the transmitter is considered as a system. A typical system has a transmitter mounted remote from the magnetic flowmeter. Some systems are available with transmitters mounted integral to the magnetic flowmeter. Each device is individually calibrated during the manufacturing process, and the accuracy statement of the magnetic flowmeter includes both pieces of equipment. One is not sold or used without the other.

It is also interesting to note that since 1983 almost every manufacturer now offers the microprocessor-based transmitter.

Regarding minimum piping straight run requirements, magnetic flowmeters are quite forgiving of piping configuration. The downstream side of the magnetic flowmeter is much less critical than the upstream side. Essentially, all that is required of the downstream side is that sufficient backpressure is provided to keep the magnetic flowmeter full of liquid during flow measurement. Two diameters downstream should be acceptable (Mills 1991).

Note: Magnetic flowmeters are designed to measure conductive liquids only. If air or gas is mixed with the liquid, the output becomes unpredictable.

Ultrasonic Flowmeters

Ultrasonic flowmeters use an electronic transducer to send a beam of ultrasonic sound waves through the water to another transducer on the opposite side of the unit. The velocity of the sound beam varies with the liquid flow rate, so the beam can be electronically translated to indicate flow volume. The accuracy is ± 1 percent for a flow velocity ranging from 1 to 25 ft/s, but the meter reading is greatly affected by a change in the fluid composition

Two types of ultrasonic flowmeters are in general use for closed pipe flow measurements. The first (time of flight or transit time) usually uses pulse transmission and is for clean liquids, while the second (Doppler) usually uses continuous wave transmission and is for dirty liquids.

Time of Flight Ultrasonic Flowmeters (Brown 1991)

Time of flight flowmeters make use of the difference in the time for a sonic pulse to travel a fixed distance, first in the direction of flow and then against the flow. This is accomplished by opposing transceivers positioned on diagonal path across meter spool. Each transmits and receives ultrasonic pulses with flow and against flow. The fluid velocity is directly proportional to time difference of pulse travel.

The time of flight ultrasonic flowmeter operates with minimal head loss; has an accuracy range of 1 percent to 2.5 percent full scale; they can be mounted as integral spool piece transducers or as externally mountable clamp-ons. They can measure flow accurately when properly installed and applied.

The advantages of time of flight ultrasonic flowmeters include:

- no obstruction to flow
- minimal head loss
- clamp-ons
  - can be portable
  - no interruption of flow
- no moving parts
- linear over wide range
- wide range of pipe sizes
- bi-directional flow measurement

Disadvantages include:

- sensitive to solids or bubble content
  - interfere with sound pulses
- sensitive to flow disturbances
- alignment of transducers is critical
- clamp-on—pipe walls must freely pass ultrasonic pulses

Doppler Type Ultrasonic Flowmeters

Doppler ultrasonic flowmeters make use of the Doppler frequency shift caused by sound scattered or reflected from moving particles in the flow path. Doppler meters are not considered to be as accurate as time of flight flowmeters. However, they are very convenient to use and generally more popular and less expensive than time of flight flowmeters.

In operation, a propagated ultrasonic beam is interrupted by particles in moving fluid and reflected toward a receiver. The difference of propagated and reflected frequencies is directly proportional to fluid flow rate.

Ultrasonic Doppler flowmeters feature minimal head loss with an accuracy of 2 percent to 5 percent full scale. They are either of the integral spool piece transducer type or externally mountable clamp-ons.

The advantages of the Doppler ultrasonic flowmeter includes:

- no obstruction to flow
- minimal head loss
- Clamp-on
    - can be portable
    - no interruption of flow
- no moving parts
- linear over wide range
- wide range of pipe sizes
- low installation and operating costs
- bi-directional flow measurement

The disadvantages include:

- requires minimum concentration and size of solids or bubbles for reliable operation
- requires a minimum speed to maintain suspension
- clamp-on type limited to sonically conductive pipe

Velocity Flowmeters

Velocity or *turbine* flowmeters use a propeller or turbine to measure the velocity of the flow passing the device. The velocity is then translated into a volumetric amount by the meter register. Sizes exist from a variety of manufacturers to cover the flow range from 0.001 gpm to over 25,000 gpm for liquid service. End connections are available to meet the various piping systems. The flowmeters are typically manufactured of stainless steel but are also available in a wide variety of materials, including plastic. Velocity meters are applicable to all clean fluids. Velocity meters are particularly well suited for measuring intermediate flow rates on clean water (Oliver 1991).

The advantages of the velocity meter includes

- highly accurate
- corrosion-resistant materials
- long-term stability
- liquid or gas operation
- wide operating range
- low pressure drop
- wide temperature and pressure limits
- high shock capability
- wide variety of electronics available

A turbine flowmeter consists of a rotor mounted on a bearing and shaft in a housing. The fluid to be measured is passed through the housing, causing the rotor to spin with a rotational speed proportional to the velocity of the flowing fluid within the meter. A device to measure the speed of the rotor is employed to make the actual flow measurement. The sensor can be a mechanically gear-driven shaft to a meter or an electronic sensor that detects the passage of each rotor blade generating a pulse. The rotational speed of the sensor shaft and the frequency of the pulse are proportional to the volumetric flow rate through the meter.

Positive-Displacement Flowmeters

Positive-displacement flowmeters are most commonly used for customer metering; they have long been used to measure liquid products. These meters are very reliable and accurate for low flow rates because they measure the exact quantity of water passing through them. Positive-displacement flowmeters are frequently used for measuring small flows in a treatment plant because of their accuracy. Repair or replacement is easy since they are so common in the distribution system (Barnes 1991).

In essence, a positive-displacement flowmeter is a hydraulic motor with high volumetric efficiency that absorbs a small amount of energy from the flowing stream. This energy is used to overcome internal friction in driving the flowmeter and its accessories and is reflected as a pressure drop across the flowmeter. Pressure drop is regarded as unavoidable that must be minimized. It is the pressure drop across the internals of a positive displacement flowmeter that actually creates a hydraulically unbalanced rotor, which causes rotation.

Simply, a positive-displacement flowmeter is one that continuously divides the flowing stream into known volumetric segments, isolates the segments momentarily, and returns them to the flowing stream while counting the number of displacements.

A positive-displacement flowmeter can be broken down into three basic components: the external housing, the measuring unit, and the counter drive train.

The external housing is the pressure vessel that contains the product being measured.

The measuring unit is a precision metering element and is made up of the measuring chamber and the displacement mechanism. The most common displacement mechanisms include the oscillating piston, sliding vane, oval gear, trirotor, birotor, and nutating disc types.

The counter drive train is used to transmit the internal motion of the measuring unit into a usable output signal. Many positive-displacement flowmeters use a mechanical gear train that requires a rotary shaft seal or packing gland where the shaft penetrates the external housing.

The positive-displacement flowmeter can offer excellent accuracy, repeatability, and reliability in many applications.

The positive-displacement flowmeter has satisfied many needs in the past and should play a vital role in serving the future needs as required.

Flow of Energy: The Basics: In *environmental science and ecology*, simply defined, energy is the ability or capacity to do work. For an ecosystem to exist, it must have energy. All activities of living organisms involve work, which is the expenditure of energy. This means the degradation of a higher state of energy to a lower state. The flow of energy through an ecosystem is governed by two laws: the First and Second Laws of Thermodynamics.

The first law, sometimes called the conservation law, states that energy may not be created or destroyed. The second law states that no energy transformation is 100 percent efficient. That is, in every energy transformation, some energy is dissipated as heat. The term entropy is used as a measure of the non-availability of energy to a system. Entropy increases with an increase in dissipation. Because of entropy, input of energy in any system is higher than the output or work done; thus, the resultant, efficiency, is less than 100 percent.

Odum (1975) explains that "the interaction of energy and materials in the ecosystem is of primary concern of ecologists." It is important to remember that in the biogeochemical nutrient cycles it is the flow of energy that drives these cycles. Again, it should be noted that energy does not cycle as nutrients do in biogeochemical cycles. For example, when food passes from one organism to another, energy contained in the food is reduced step by step until all the energy in the system is dissipated as heat. Price (1984) refers to this process as "a unidirectional flow of energy through the system, with no possibility for recycling of energy." When water or nutrients are recycled, energy is required. The energy expended in this recycling is not recyclable. And, as Odum (1975) points out, this is a "fact not understood by those who think that artificial recycling of man's resources is somehow an instant and free solution to shortages."

While there is a slight input of geothermal energy, as pointed out earlier, the principal source of energy for any ecosystem is sunlight. Green plants, through the process of photosynthesis, transform the sun's light energy into chemical energy: carbohydrates which are consumed by animals. This transfer of energy, as stated previously, is unidirectional—from producers to consumers—it is accomplished by cellular respiration is the process by which organisms (like mammals) break the glucose back down into its constituents, water and carbon dioxide, thus regaining the stored energy the sun originally gave to the plants. Often this transfer of energy to different organisms is called a **food chain**. It is safe to say that food energy passes through a community in various ways—each separate way is called a food chain.

All organisms, alive or dead, are potential sources of food for other organisms. All organisms that share the same general type of food in a food chain are said to be at the same trophic level (nourishment or feeding level—each level of consumption in a food chain is called a trophic level). Since green plants use sunlight to produce food for animals, they are called the producers, or the first trophic level. The herbivores, which eat plants directly, are called the second trophic level or the primary consumers. The carnivores are flesh eating consumers; they include several trophic levels from the third on up. At each transfer, a large amount of energy (about 80 to 90 percent) is lost as heat and wastes. Thus, nature normally limits food chains to four or five links; however, in aquatic ecosystems, "food chains are commonly longer than those on land" (Dasmann 1984). The aquatic food chain is longer because several predatory fish may be feeding on the plant consumers. Even so, the built-in inefficiency of the energy transfer process prevents development of extremely long food chains.

Tomera (1989) describes a simple food chain that can be seen in a prairie dog community.

> The grass in the community manufactures food. The grass is called a food producer. The grass is eaten by a prairie dog. Because the prairie dog lives directly off the grass, it is termed a first-order consumer. A weasel [or other predator] may kill and eat the prairie dog. The weasel is, therefore a predator and would be termed a second-order consumer. The second-order consumer is twice removed from the green grass. The weasel, in turn, may be eaten by a large hawk or eagle. The bird that kills and eats the weasel would therefore be a third-order consumer, three times removed from the grass. Of course, the hawk would give off waste materials and eventually die itself. Wastes and dead organisms are then acted on by decomposers (50).

Only a few simple food chains are found in nature. Thus, when attempting to identify the complex food relationships among many animals and plants within a community, it is useful to create a feed web. The fact is that most simple food chains are interlocked; this interlocking of food chains form a food web. A **food web** can be characterized as a map that shows what eats what (Miller 1988). Most ecosystems support a complex food web. A food web involves animals that do not feed on one trophic level. For example, humans feed on both plants and animals. The point is, an organism in a food web may occupy one or more trophic levels. Trophic level is determined by an organism's role in its particular community, not by its species. Food chains and webs help to explain how energy moves through an ecosystem.

An important trophic level of the food web that has not been discussed thus far is comprised of the decomposers (bacteria, mushrooms, etc.). The decomposers feed on dead plants or animals and play an important role in recycling nutrients in the ecosystem. As Miller (1988) points out, "there is no waste in ecosystems. All organisms, dead or alive, are potential sources of food for other organisms." The important point to be gained is that there is a distinct difference between the food web and food chain. A food chain, for example, is a simple straight-line process going from producer to first-, second-, and possibly third-order consumers, and ending with the decomposers. On the other hand, in a food web, there are a number of second- and third-order consumers.

Flow Net: The grid pattern formed by a network of flow lines and equipotential lines.

Flow Rate: Volume flow rates are described by the conservation of mass formula. Q = VA [Q (volume) = V (velocity) A (cross-sectional area of air flow].

Flow, Steady: Steady flow occurs when at any point the magnitude and direction of the specific discharger are constant in time.

Flow, Uniform: A property is uniform if, at a given instant, it is the same at every point. Thus, uniform flow occurs if at every point the specific discharge ahs the same magnitude and direction.

Flow, Unsteady, or Nonsteady: Occurs when at any point the magnitude or direction of the specific discharge changes with time. In practice, the term transient is used in reference to the temporary features of unsteady flow. Thus, in unsteady flow, the specific discharge, the head, and perhaps other factors consist of a steady component plus a transient component.

Flowable: Pesticide and other formulations in which the active ingredients are finely ground insoluble solids suspended in a liquid. They are mixed with water for application.

Flowback: The process of causing fluid to flow back to the well of a fracture after a hydraulic fracturing event is complete.

Flowing Well/Spring: A well or spring that taps ground water under pressure so that water rises without pumping. If the water rises above the surface, it is known as a flowing well.

Flue Gas: The air coming out of a chimney after combustion in the burner if is venting. It can include nitrogen oxides, carbon oxides, water vapor, sulfur oxides, particles, and many chemical pollutants.

Flue Gas Desulfurization: A technology that employs a sorbent, usually lime or limestone, to remove sulfur dioxide from the gases produced by burning fossil fuels. Flue gas desulfurization is current state-of-the-art technology for major $S0_2$ emitters, like power plants.

Fluid Mechanics: Hydraulics (liquids only) and pneumatics (gases only) make up the study of fluid mechanics, which in turn is the study of forces acting on fluids (liquids and gases are considered fluids). Safety professionals/engineers encounter many fluid mechanics problems and applications of fluid mechanics. In particular, safety engineers working in chemical industries, or in or around processes using or producing chemicals need an understanding of flowing liquids or gases to be able to predict and control their behavior.

Fluid Potential, Φ [L^2T^{-2}]: The fluid potential is the mechanical energy per unit mass of a fluid at any given point in space and time with respect to an arbitrary state and datum. Loss of fluid potential incurred as the fluid moves from a region of high potential to one of low potential represents loss of mechanical energy which is converted to heat by friction. In groundwater movement the kinetic energy term $v^2/2$ ordinarily is negligible. If the expansion and contraction of the fluid due to changes in pressure are unimportant to the problem being considered, the fluid can be assumed to be incompressible. At a given point in a body of liquid, the fluid potential is proportional to the head; that is,

$$\Phi = gh$$

Fluidized: A mass of solid particles that is made to flow like a liquid by injection of water or gas is said to have been fluidized. In water treatment, a bed of filter media is fluidized by backwashing water thrugh the filter.

Fluidized Bed Incinerator: An incinerator that uses a bd of hot sand or other granular material to transfer heat directly to waste. Used mainly for destroying municipal sludge.

Flume: A natural or man-made channel that diverts water.

Fluoridation: The addition of a chemical to increase the concentration of fluoride ions in drinking water to reduce the incidence of tooth decay.

Fluoride: Fluoride salt is added to public drinking water supplies for improving resistance to dental carries. According to Phyllis J. Mullenix, Ph.D., water fluoridation is not the safe public health measure we have been led to believe. Concerns about uncontrolled dosage, accumulation in the body over time and effects beyond the teeth (brain as well as bones) have not been resolved for fluoride. The health of citizens necessitates that all the facts be considered, not just those that are politically expedient.

Most medical authorities would take issue with Ms. Mullenix's view on the efficacy of fluoride in reducing tooth decay. Most authorities seem to hold that a moderate amount of *fluoride* ions (F^-) in drinking water contributes to good dental health. Fluoride is seldom found in appreciable quantities of surface waters and appears in groundwater in only a few geographical regions, though it is sometimes found in a few types of igneous or sedimentary rocks. Fluoride is toxic to humans in large quantities (the key words are "large quantities" or in Ms. Mullenix's view "uncontrolled dosages") and also toxic to some animals.

Fluoride used in small concentrations (about 1.0 mg/L in drinking water) can be beneficial. Experience has shown that drinking water containing a proper amount of fluoride can reduce tooth decay by 65 percent in children between the ages 12 and 15. However, when the concentration of fluorides in untreated natural water supplies is excessive, either alternative water supply must be used, or treatment to reduce the fluoride concentration must be applied, because excessive amounts of fluoride cause mottled or discolored teeth, a condition called *dental fluorosis*.

Fluorocarbons (FCs): Any of a number of organic compounds analogous to hydrocarbons in which one or more hydrogen atoms are replaced by fluorine. Once used in the United States as a propellant fore domestic aerosols, they are now found mainly in coolants and some industrial processes. FCs containing chlorine are called chlorofluorocarbons (CFCs). They are believed to be modifying the ozone layer in the stratosphere, thereby allowing more harmful solar radiation to reach the earth's surface.

Fluorosis: A health condition caused by a child receiving too much fluoride during tooth development.

Flush: 1. To open a cold-water tap to clear out all the water which may have been sitting for a long time in the pipes. In new homes, to flush a system means to sent large columns of water gushing through the unused pipes to remove lose particles of solder and flux. 2. To force large amounts of water through a system to clean out piping out or tubing, and storage or process tanks.

Flushing System: System that collects and transports or moves waste material with the use of water, such as in washing of pens and flushing confinement livestock facilities.

Flux: 1. A flowing of flow. 2. A substance used to help metals fuse together.

Fly Ash: Non-combustible residual particles expelled by flue gas.

Foam: A substance that is formed by trapping many gaseous bubble sin a liquid or solid.

Fog: Liquid particles dispersed in air.

Fogging: Applying a pesticide by rapidly heating the liquid chemical so that it forms very fine droplets that resemble smoke or fog. Used to destroy mosquitoes, black flies, and similar pests.

Food Chain: A sequence of transfers of energy in the form of food from organisms in one trophic level to organisms in another trophic level when one organisms eats or decomposes another.

Food Chain Efficiency: Energy from the sun is captured (via photosynthesis) by green plants and used to make food. Most of this energy is used to carry on the plant's life activities. The rest of the energy is passed on as food to the next level of the food chain.

✔ **Important Point**: A food chain is the path of food from a given final consumer back to a producer.

It is important to note that nature limits the amount of energy that is accessible to organisms within each food chain. Not all food energy is transferred from one trophic level to the next. For ease of calculation, "ecologists often assume an ecological efficiency of 10 percent (10-percent rule) to estimate the amount of energy transferred through a food chain" (Moran et al. 1986). For example, if we apply the 10 percent rule to the diatoms-copepods-minnows-medium fish-large fish food chain, we can predict that 1000 grams of diatoms produce 100 grams of copepods, which will produce 10 grams of minnows, which will produce 1 gram of medium fish, which, in turn, will produce 0.1 gram of large fish. Thus, only about 10 percent of the chemical energy available at each trophic level is transferred and stored in usable form at the next level. What happens to the other 90 percent? The other 90 percent is lost to the environment as low-quality heat in accordance with the second law of thermodynamics.

✔ **Important Point:** The ratio of net production at one level to net production at the next higher level is called the *conversion efficiency*.

✔ **Important Point**: When an organism loses heat, it represents one-way flow of energy out of the ecosystem. Plants only absorb a small part of energy from the sun. Plants store half of the energy and lose the other half. The energy plants lose is metabolic heat. Energy from a primary source will flow in one direction through two different types of food chains. In a grazing food chain, the energy will flow from plants (producers) to herbivores, and then through some carnivores. In a detritus-based food chains, energy will flow from plants through detrivores and decomposers. In terms of the weight (or biomass) of animals in many ecosystems, more of their body mass can be traced back to detritus than to living producers. Most of the time the two food webs will intersect one another. For example, in the Chesapeake Bay bass fish of the grazing food web will eat a crab of the detrital food web (Spellman, 1996).

Food Processing Waste: Food residues produced during agricultural and industrial operations.

Food Terminology: Food labeled "USDA Organic" has a number of selling points.

- *Nutrition*—No conclusive evidence shows that organic food is more nutritious than conventionally grown food. And the USDA, although it certifies organic food, doesn't claim that these products are safer or more nutritious.
- *Quality and appearance*—Organic foods meet the same quality and safety standards as conventional foods. The difference lies in how the food is produced, processed and handled. Organic fruits and vegetables may spoil faster because they aren't treated with waxes or preservatives. Also, less-than-perfect appearances in some organic produce is to be expected—odd shapes, varying colors and smaller sizes. In most cases, however, organic foods look identical to their conventional counterparts.
- *Pesticides*—Conventional growers use pesticides to protect their crops from molds, insects and diseases. When farmers spray pesticides, this can leave residue on residue on produce. Some people buy organic food to limit their exposure to these residues. Most experts say, however, that the amount of pesticides found on fruits and vegetables poses a very small health risk.
- *Environment*—Some people buy organic food for environmental reasons. Organic farming practices are designed to benefit the environment by reducing pollution and conserving water and soil.
- *Cost*—Most organic food costs more than conventional food products.
- *Taste*—Some people say they can taste the difference between organic and non-organic food. Others say they find no difference. But whether you buy organic or not, fining the freshest foods available may have the biggest effect on taste.

A few terms are commonly used to describe the degree of organic-ness of food:

- *Organic seal*—The USDA has established an organic certification program that requires all organic foods to meet government standards. These standards regulate how such foods are grown, handled and processed. Any farmer or food manufacturer who labels and sells a product as organic must be USDA certified as meeting these standards. Only producers who sell less than $5,000 a year in organic foods are exempt from this certification; however, they must follow the same government standards to label their foods as organic. If a food bears a USDA Organic label, it means it's produced and processed according to the USDA standards and that at least 95 percent of the food's ingredients are organically produced. The seal is voluntary, but many organic producers use it.
- *100 percent organic*—Products that are completely organic or made of all organic ingredients can carry a USDA seal.
- *Organic*—Products that are at least 95 percent organic.
- *Made with organic ingredients*—These are products that contain at least 70 percent organic ingredients. The organic seal can't be used on these packages. Foods with less that 70 percent organic ingredients can't use the organic seal or the word "organic" on their product label. But they can include the organic items in their ingredient list.

Other common food labels:

- *Low fat*—Contains less than 3 gram of fat per serving.
- *Lower or reduced fat*—Contains at least 25 percent less per serving than the reference food. (An example might be reduced fat cream cheese, which would have at least 25 percent less fat than original cream cheese).
- *Light/Lite*—The products must contain either half the fat or one-third the calories of the regular version. The product may not necessary be low in calories or fat; it depends on the original.
- *No fat or fat free*—Contains less than 0.5 grams of fat per serving.
- *Cholesterol free*—This means products must contain less than 2 milligrams of cholesterol and 2 grams or less of saturated fat. Just because a food is cholesterol free doesn't mean it can't raise your cholesterol—especially if it is high in trans fats.
- *Free-range*—Livestock labeled free-range must have access to the outdoors for more than half of their lives. The USDA does not perform inspections unless it has reason to believe the farmer is not complying with labeling requirements.
- *Good/excellent source of* —To be "a good source" of a nutrient, the food needs to provide 10 to 19 percent of the daily value (DV) or the reference daily intake (RDI). "An excellent source" needs to provide 20 percent or more. However, the daily value is based on a 2,000 calorie per day diet. If you consume more than 2,00 calories per day, this claim can be misleading.
- *Low sodium*—Contains less than 140 mgs of sodium per serving.

- *No salt or salt-free*—Contains less than 5 mgs of sodium per serving.
- *Natural*—Labels that claim the food is natural or all natural simply means that the meat or poultry product was minimally processed without adding synthetic ingredients such as artificial flavors, colors and preservatives. The label must explain the use of the term natural. According to the director of the U.S. Department of Agriculture's food safety and Inspection Service Labeling, "natural" was not intended to describe how the animal was raised. Other federal regulations apply to whether antibiotics and growth hormones can be used.
- *No calories or calorie-free*—Contains less than 5 calories per serving.
- *Low calorie*—Contains a third of the calories of the original version or a similar product.
- *No trans fats*—The new Food and Drug Administration labeling rules allow food manufacturers to list "zero" grams of trans fat (hydrogenated fat) on a food label when the amount of trans fat is less than 0.5 grams. But remember, if you eat several of these items, you may be consuming more trans fat than you think.
- *Sugar-free/sugarless*—This claim requires the products to have less than 0.5 grams of sugar. However, the FDA does not define honey, molasses or other natural sweeteners as sugar, so the products claiming to be sugar-free could contain these in higher amounts. Natural sweeteners produce similar effects on the body as sugar and often had the same amount of calories per serving. If you have diabetes, this is especially important; always read the ingredient list when this claim is made.
- *Reduced sugar*—The food has at least 25 percent less sugar per serving than the referenced food.
- *Whole grain*—Whole grains have the bran, germ, and endosperm intact; these contain fiber, calcium, magnesium, and potassium. Examples include whole-wheat flour, bulgur (cracked wheat), oatmeal, whole cornmeal, and brown rice. Foods can be labeled "wheat" and hot have whole grains, so you should look for "whole" before you buy. Foods labeled with the words "multigrain," "stone-ground," "100 percent wheat," "cracked wheat," "seven-grain" or "bran" are usually not whole-grain products. A "multigrain" bread, for example, could be made out of several types of refined grains. Or, more likely, it's made with lots of refined white flour and small amounts of other whole grains. So multigrain doughnuts are probably not the nutritional powerhouses some might think. Refined grains have been milled, a process that removes the bran and germ. This gives grains a finer texture and improves their shelf life, but it also removes dietary fiber, iron, and many B vitamins. Some examples of refined grain products are white flour, degermed cornmeal, white bread, and white rice. Most refined grains are enriched. This means certain B vitamins (thiamin, riboflavin, niacin, folic acid) and iron are added back after processing. Fiber is not added back to enriched grains. Check the ingredient list on refined grain products to make sure that the word "enriched" is included in the grain name. Some foods are made from mixtures of whole grains and refined grains.
- *Certified humane*—The label means the product has met the standards of the Human Farm Animal Care Program, where farmers are inspected annually to ensure the livestock are given adequate shelter, space and gentle handling to limit stress. Animals also must get plenty of fresh water and a healthy diet (free from antibiotics and hormones) and are allowed to engage in their natural behaviors. A higher standard of slaughtering must also be used.
- *Heart healthy*—The heart checkmark means the product meets the American Heart Association's criteria for saturated fat and cholesterol for healthy people older than age two. The America Heart Association's heart-checkmark program has faced nagging questions since it was developed in 1995. A case in point: A cereal that is heart healthy and contains antioxidants can also have a whopping 14 grams of sugar per serving. The AHA defends the check mark. It says scientists disagree on how much to limit added sugars in a healthy diet, though most say less is better.
- *No preservatives*—Contains no preservatives (chemical or natural).
- *No preservatives added*—Contains no added chemicals to preserve the product. Some of these products may contain natural preservatives.
- *High fiber*—Five grams or more per serving. Foods making high-fiber claims must meet the definition for low fat, or the level of total fat must appear next to the high-fiber claim.
- *Good source of fiber*—2.5 g to 4.9 g per serving.

Food-to-Microorganism Ratio (F/M): In *wastewater treatment*, the food-to-microorganism ratio (F/M ratio) is a process control method/calculation based upon maintaining a specified balance between available food materials (BOD or COD) in the aeration tank influent, and the aeration tank mixed liquor volatile suspended solids (MLVSS) concentration. The chemical oxygen demand (CDO) test is sometimes used, because the results are available in a relatively short period of time.

To calculate the F/M ratio, the following information is required:

- aeration tank influent flow rate, MGD
- aeration tank influent BOD or COD, mg/L

- aeration tank MLVSS, mg/L
- aeration tank volume, MG

$$\text{F/M Ratio} = \frac{\text{Primary Eff. COD/BOD mg/L} \times \text{Flow MGD} \times 8.34\ \text{lb/mg/L/MG}}{\text{MLVSS mg/L} \times \text{Aerator Vol., MG} \times 8.34\ \text{lb/mg/L/MG}}$$

Typical F/M ratio for activated biosolids process is shown in the following:

Food Waste: Uneaten food and food preparation wastes for residences and commercial establishments such as grocery stores, restaurants, and produce stands, institutional cafeterias and kitchens, and industrial sources like employee lunchrooms.

Food Web: A complex network of many interconnected food chains and feeding interactions.

Foot-Candle: A unit of illumination. The illumination at a point on a surface one foot from, and perpendicular to, a uniform point source of one candle.

Force: In physics, we define *force* as a push or pull from the object's interaction with another object that can cause an object with mass to accelerate. Force has both magnitude (size) and direction, making it a vector quantity. When the interaction between two objects ceases, the objects no longer experience the force. All interactions (forces) between objects can be placed into two categories: contact forces (e.g., friction, normal, applied forces, etc.), and forces resulting from action-at-distance (e.g., magnetic, gravitational, or electrical force). Force is represented in units of newtons (abbreviated N). A *newton* is the force required to accelerate a 1-kg mass at a rate of 1 m/s^2.

Force, Mass, and Acceleration: According to Newton's second law of motion:

> The acceleration produced by an unbalanced force acting on a mass is directly proportional to the unbalanced force, in the direction of the unbalanced force, and inversely proportional to the total mass being accelerated by the unbalanced force.

If we express Newton's second law mathematically, it is greatly simplified and becomes

$$F = ma$$

This equation is extremely important in physics and engineering. It simply relates acceleration to force and mass. Acceleration is defined as the change in velocity divided by the time taken. This definition tells us how to measure acceleration. F = ma tells us what causes the acceleration—an unbalanced force. Mass may be defined as the quotient obtained by dividing the weight of a body by the acceleration caused by gravity. Since gravity is always present, we can, for practical purposes, think of mass in terms of weight, making the necessary allowance for gravitational acceleration.

Forced Expiratory Volume (FEV): That volume of air that can be forcibly expelled during the first second of expiration.

Forced Vital Capacity (FVC): The maximal volume of air that can be exhaled forcefully after a maximal inhalation.

Forel-Ule Color Scale: A method to approximately determine the color of bodies of water, used in limnology and oceanography.

Forklift Operation: OSHA, under its 29 CFR 1910.138 *Powered Industrial Trucks Standard* requires forklift operators to be trained. Specifically, the standard states, "Only trained and authorized operators shall be permitted to operate a powered industrial truck (forklift and other type powered trucks). Methods shall be devised to train operators in the safe operation of powered industrial trucks." Obviously, if the safety engineer determines that his or her organization has forktrucks, rents forktrucks, borrows forktrucks, and for any reason requires workers to operate such machines, then training is required. However, if the organization does not require its workers to operate forktrucks or other powered trucks, training is not required.

Formaldehyde Exposure: Formaldehyde (HCHO) is a colorless, flammable gas with a pungent suffocating odor. The most important aldehyde produced commercially, it is used in the preparation of urea-formaldehyde and phenol-formaldehyde resins. It is also produced during the combustion of organic materials, and is a component of smoke.

The major sources in workplace settings are in manufacturing processes (used in the paper, photographic and clothing industries) and building materials. Building materials may contain phenol, urea, thiourea, or melamine resins that contain HCHO. Degradation of HCHO resins can occur when these materials become damp from exposure to high relative humidity, or if the HCHO materials are saturated with water during flooding, or when leaks occur. The release of HCHO occurs when the acid catalysts involved in the resin formulation are reactivated. When temperatures and relative humidity increase, out-gassing increases (DOH, Wash., 2003).

For exposure control, the best prevention is provided by source control (if possible). The selection of HCHO-free or low-emitting products such as exterior grade plywood that use phenol HCHO resins for indoor use is the best starting point.

Secondary controls include filtration, sealants, and fumigation treatments. Filtration can be achieved using selected adsorbents. Sealants involve coating the materials in question with two or three coats of nitro-cellulose varnish, or water-based polyurethane. Three coats of these materials can reduce out-gassing by as much as 90 percent.

Formula Weight: The sum of the atomic weight of all atoms that comprise one formula unit.

Formulation: The substances comprising all active and inert ingredients in a pesticide.

Fossil Fuels: Fuels derived from ancient organic remains; e.g., peat, coal, crude oil, and natural gas.

Fracture Conductivity: The capability of the fracture to conduct fluids under a given hydraulic head difference.

Fracturing Treatments: Fracturing treatments are performed by pumping fluid into the subsurface at pressures above the fracture pressure of the reservoir formation to create a highly conductive flow path between the reservoir and the wellbore.

Frangible Discs: An operating part in the form of a disc, usually of metal and which is so held as to close the safety relief device channel under normal conditions. The disc is intended to burst at a predetermined pressure to permit the escape of gas.

Free Electrons: In *electricity*, the components that make up electrical current flow.

Free Residual Chlorine: The total concentration of HOCl and OCl ions.

Free Water Surface Wetlands: Wetlands system where the water surface is exposed tot the atmosphere**.**

Freeboard: 1. Vertical distance from the normal water surface to the top of a confined wall. 2. Vertical distance from the sand surface to the underside of a trough in a sand filter.

Freeze: To change from a liquid state to a solid state.

Freezing Point: 1. The temperature at which a liquid of specified composition solidifies under a specified pressure. 2. The temperature at which the liquid and solid phases of a substance of specified composition are in equilibrium at atmospheric pressure.

Frequency (AC): The number of occurrences of a repeating event per unit time.

Freshwater: Water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids; generally, more than 500 mg/L of dissolved is undesirable for drinking and many industrial uses.

Friable: Readily crumbled in hand.

Friable Asbestos: Any material containing more than one-percent asbestos, and that can be crumble or reduce to powder by hand pressure.

Front: In meteorology, the boundary between two air masses of different temperature or humidity.

Frostbite: Injury caused to skin or other tissue by very cold material. The medical consequences are to those caused by burns.

Frustules: The distinctive two-piece wall of silica in diatoms.

Fuel Cell: 1. One or more cells capable of generating an electrical current by converting the chemical energy of a fuel directly into electrical energy. Fuel cells differ from conventional electrical cells in that the active materials such as fuel and oxygen are not contained within the cell but are supplied from outside. 2. **Hydrogen**[1] Containing only one electron and one proton, Hydrogen, chemical symbol H, is the simplest element on earth. Hydrogen as is a diatomic molecule—each molecule has two atoms of hydrogen (which is why pure hydrogen is commonly expressed as H_2). Although abundant on earth as an element, hydrogen combines readily with other elements and is almost always found as part of another substance, such as water hydrocarbons, or alcohols. Hydrogen is also found in biomass, which includes all plants and animals.

- Hydrogen is an energy carrier, not an energy source. Hydrogen can store and deliver usable energy, but it doesn't typically exist by itself in nature; it must be produced from compounds that contain it.
- Hydrogen can be produced using diverse, domestic resources including nuclear; natural gas and coal; and biomass and other renewables including solar, wind, hydro-electric, or geothermal energy. This diversity of domestic energy sources makes hydrogen a promising energy carrier and important to our nation's energy

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[1] Information in this section from USDOE 2008, Hydrogen, Fuel Cells & Infrastructure Technologies Program. Accessed @ http://www1.eere.energy.gov/hydrogenandfuelcells/production/basics.html.

security. It is expected and desirable for hydrogen to be produced using a variety or resources and process technologies (or pathways).

- DOE focuses on hydrogen-production technologies that result in near-zero, net greenhouse gas emissions and use renewable energy sources, nuclear energy, and coal (when combined with carbon sequestration). To ensure sufficient clean energy for our overall energy needs, energy efficiency is also important.
- Hydrogen can be produced via various process technologies, including thermal (natural gas reforming, renewable liquid and bio-oil processing, and biomass and coal gasification), electrolytic (water splitting using a variety of energy resources), and photolytic (splitting water using sunlight via biological and electrochemical materials).
- Hydrogen can be produced in large, central facilities (50-300 miles from point of use), smaller semi-central (located within 25-100 miles of use) and distributed (near or at point of use). Learn more about distributed vs. centralized production.
- In order for hydrogen to be successful in the market place, it must be cost-competitive with the available alternatives. In the light-duty vehicle transportation market, this competitive requirement means that hydrogen needs to be available untaxed at $2-$3/gge (gasoline gallon equivalent). This price would result in hydrogen fuel cell vehicles having the same cost to the consumer on a cost-per-mile-driven basis as a comparable conventional internal-combustion engine or hybrid vehicle.
- DOE is engaged in research and development of a variety of hydrogen production technologies. Some are further along in development than others—some can be cost-competitive for the transition period (beginning in 2015), and others are considered long-term technologies (cost-competitive after 2030).

Infrastructure is required to move hydrogen from the location where it's produced to the dispenser at a refueling station or stationary power site. Infrastructure includes the pipelines, trucks, railcars, ships, and barges that deliver fuel, as well as the facilities and equipment needed to load and unload them.

Delivery technology for hydrogen infrastructure is currently available commercially, and several U.S. companies deliver bulk hydrogen today. Some of the infrastructure is already in place because hydrogen has long been used in industrial applications, but it's not sufficient to support widespread consumer use of hydrogen as an energy carrier. Because hydrogen has a relatively low volumetric energy density, its transportation, storage, and final delivery to the point of use comprise a significant cost and result in some of the energy inefficiencies associated with using it as an energy carrier.

Options and trade-offs for hydrogen delivery from central, semi-central, and distributed production facilities to the point of use are complex. The choice of a hydrogen production strategy greatly affects the cost and method of delivery.

For example, larger, centralized facilities can produce hydrogen at relatively low costs due to economies of scale, but the delivery costs for centrally produced hydrogen are higher than the delivery costs for semi-central or distributed production options (because the point of use is farther away). In comparison, distributed production facilities have relatively low delivery costs, but the hydrogen production costs are likely to be higher—lower volume production means higher equipment costs on a per-unit-of-hydrogen basis.

Key challenges to hydrogen delivery include reducing delivery cost, increasing energy efficiency, maintaining hydrogen purity, and minimizing hydrogen leakage. Further research is needed to analyze the trade-offs between the hydrogen production options and the hydrogen delivery options taken together as a system. Building a national hydrogen delivery infrastructure is a big challenge. It will take time to develop and will likely include combinations of various technologies. Delivery infrastructure needs and resources will vary by region and type of market (e.g., urban, interstate, or rural). Infrastructure options will also evolve as the demand for hydrogen grows and as delivery technologies develop and improve.

Hydrogen Storage

Storing enough hydrogen on-board a vehicle to achieve a driving range of greater than 300 miles is a significant challenge. On a weight basis, hydrogen has nearly three times the energy content of gasoline (120 MJ/kg for hydrogen versus 44 MJ/kg for gasoline). However, on a volume basis the situation is reversed (8 MJ/liter for liquid hydrogen versus 32 MJ/liter for gasoline). ON-board hydrogen storage in the range of 5–13 kg H_2 is required to encompass the full platform of light-duty vehicles.

Hydrogen can be stored in a variety of ways, but for hydrogen to be a competitive fuel for vehicles, the hydrogen vehicle must be able to travel a comparable distance to conventional hydrocarbon-fueled vehicles.

Hydrogen can be physically stored as either a gas or a liquid. Storage as a gas typically requires high-pressure tanks (5000 -10,000 psi tank pressure). Storage of hydrogen as a liquid requires cryogenic temperatures because the boiling point of hydrogen at one atmosphere pressure –252.8ºC.

Hydrogen can also be stored on the surfaces of solids (by adsorption) or within solids (by absorption). In adsorption, hydrogen is attached to the surface of material either as hydrogen molecules or as hydrogen atoms. In absorption, hydrogen is dissociated into H-atoms, and then the hydrogen atoms are incorporated into the solid lattice framework.

Hydrogen storage in solids may make it possible to store large quantities of hydrogen in smaller volumes at low pressures and at temperatures close to room temperature. It is also possible to achieve volumetric storage densities greater than liquid hydrogen because the hydrogen molecule is dissociated into atomic hydrogen within the metal hydride lattice structure.

Finally, hydrogen can be stored through the reaction of hydrogen-containing materials with water (or other compound such as alcohols). In this case, the hydrogen is effectively store din both the material and in the water. The term "chemical hydrogen storage" or chemical hydrides is used to describe this form of hydrogen storage. It is also possible to store hydrogen in the chemical structures of liquids and solids.

Hydrogen Fuel Cell

The fuel cell uses the chemical energy of hydrogen to cleanly and efficiently produce electricity with water and heat as byproducts. Fuel cells are unique in terms of variety of their potential applications; they can provide energy for systems as large as a utility power station and as small as a laptop computer.

Fuel cells have several benefits over conventional combustion-based technologies currently used in many power plants and passenger vehicles. They produce much smaller quantities of greenhouse gases and none of the air pollutants that create smog and cause health problems. If pure hydrogen is used as a fuel, fuel cells emit only heat and water as byproducts.

A *fuel cell* is a device that uses hydrogen (or hydrogen-rich fuel) and oxygen to create electricity by an electrochemical process. A single fuel cell consists of an electrolyte and two catalyst-coated electrodes (a porous anode and cathode). While there are different fuel cell types, all fuel cells work similarly:

- Hydrogen, or a hydrogen-rich fuel, is fed to the anode where a catalyst separates hydrogen's negatively charged electrons from positively charge ions (protons).
- At the cathode, oxygen combines with electrons and, in some cases, with species such as protons or water, resulting in water or hydroxide ions, respectively.
- For polymer electrolyte membrane and phosphoric acid fuel cells, protons move through the electrolyte to the cathode to combine with oxygen and electrons, producing water and heat.
- For alkaline, molten carbonate, and solid oxide fuel cells, negative ions travel through the electrolyte to the anode where they combine with hydrogen to generate water and electrons.
- The electrons from the anode cannot pass through the electrolyte to the positively charged cathode; they must travel around it via an electrical circuit to reach the other side of the cell. This movement of electrons is an electrical current.

Fuelwood: Wood and wood products, possibly including coppices, scrubs, branches, etc., bought or gathered, and used by direct combustion.

Fugitive Dust: In *mining*, consists of silt, dust, and sand that becomes airborne and is thereby carried away from a mine property by air currents.

Fugitive Emissions: Emissions identified with a discrete process but not traceable to a single emission point such as the end of a stack (e.g., grain unloading). Fugitive emissions from a cattle feedlot or an open lot dairy include dust resulting from cattle activity on the feedlot surface or from vehicle traffic on unpaved roads. Analogous to nonpoint source water pollution.

Full Sun: In *solar*, the amount of power density in sunlight received at the earth's surface at noon on a clear day (about 1,000 watts/square meter).

Fume: 1. Airborne particulate matter formed by the evaporation of solid materials, e.g., metal fume emitted during welding. Usually less that one micron in diameter. 2. Solid particles generated by condensation from the gaseous state.

Fumigant: A pesticide vaporized to kill pests. Used in buildings and greenhouses.

Fumigation: Results when emissions from a smokestack that is under an inversion layer head downward, leading to greatly elevated downwind ground-level concentrations of contamination.

Functional Equivalent: Term used to describe EPA's decision-making process and its relationship to the environmental review conducted under the National Environmental Policy act (NEPA). A review is considered functionally equivalent when it addressed the substantive components of a NEPA review.

Fungi: 1. Simple plants lacking in ability to produce energy through photosynthesis. 2. A saprophytic or parasitic organisms that may be unicellular or made up of tubular filaments and that lacks chlorophyll. 3. In water/wastewater treatment, *Fungi* are of relatively minor importance (except for biosolids composting, where they are critical). Fungi, like bacteria, are also extremely diverse. They are multicellular, autotrophic, photosynthetic protists. They grow as filamentous, mold-like forms or as yeast-like (single-celled) organisms. They feed on organic material.

Note: Aquatic fungi grow as parasites on living plants or animals and as saprophytes on those that are dead.

Fungicide: Pesticides which are used to control, deter, or destroy fungi.

Fungistat: A chemical that keeps fungi from growing.

Furuncle: A boil.

Fuses: Protects circuits by means of a link that melts from the heat caused by excessive current flow, thereby opening the circuit.

Future Liability: Refers to potentially responsible parties' obligations to pay for additional response activities beyond those specified in the record of Decisions or Consent Decree.

G

Gaging Station: A site on a stream, lake, reservoir or other body of water where observations and hydrologic data are obtained. The U.S. Geological Survey measures stream discharge at gaging stations.

Gaining Stream: Typical of humid regions, where groundwater recharges the stream.

Gallon: A volumetric measure equal to 4 quarts (231 cubic inches) used to measure fuel oil. One gallon equals 3.785 liters; I barrel equals 42 gallons.

Galvanic Action: The creation of an electrical current by electrochemical action.

Galvanic Corrosion: An electrochemical process in which one metal corrodes preferentially when in electrical contact with a different type of metal and both metals are immersed in an electrolyte.

Gamma Radiation: Very penetrating electromagnetic radiations emitted from a nucleus and an atom during radioactive decay.

Gamma Radiation and X-rays: Gamma radiation and X-rays are used for sterilization of food and medical products; radiography of welds, castings, and assemblies; gauging of liquid levels and material density; and oil well logging, and material analysis.

The characteristics of gamma radiation and X-rays are listed below.

- Gamma (γ) is not a particle (electromagnetic wave) composed of high energy electron with source: Tc-99.
- X-Ray is composed of photons (generated by electrons leaving an orbit) with source: Most radioactive materials, X-ray machines, secondary to β.
- Gamma radiation and X-rays are electromagnetic radiation like visible light, radio waves, and ultraviolet light. These electromagnetic radiations differ only in the amount of energy they have. Gamma rays and X-rays are the most energetic of these.
- Gamma radiation is able to travel many meters in air and many centimeters in human tissue. It readily penetrates most materials and is sometimes called "penetrating radiation."
- X-rays are like gamma rays. They, too, are penetrating radiation.
- Radioactive materials that emit gamma radiation and X-rays constitute both an external and internal hazard to humans.
- Dense materials are needed for shielding from gamma radiation. Clothing and turnout gear provide little shielding from penetrating radiation but will prevent contamination of the skin by radioactive materials.
- Gamma radiation is detected with survey instruments, including civil defense instruments. Low levels can be measured with a standard Geiger counter, such as the CD V-700. High levels can be measure with an ionization chamber, such as a CD V-715.
- Gamma radiation or X-rays frequently accompany the emission of alpha and beta radiation.
- Instruments designed solely for alpha detection (such as an alpha scintillation counter) will not detect gamma radiation.
- Pocket chamber (pencil) dosimeters, film badges, thermoluminescent, and other types of dosimeters can be used to measure accumulated exposure to gamma radiation.
- The principal health concern associated with gamma radiation is external exposure by penetrating radiation and physically strong source housing. Sensitive organs include the lens of the eye, the gonads, and the bone marrow.

Gamma Radiation Detection Instrumentation: The types of equipment used to evaluate gamma radiation in the workplace include:

- Ion chamber
- Gas proportional
- Geiger Mueller

Garbage: The generic name for waste emanating from households containing mostly vegetable matter and paper.

Gas: 1. A state of matter in which the material has very low density and viscosity, can expand and contract greatly in response to changes in temperature and pressure, easily diffuses into other gases, and readily and uniformly distributes itself throughout any container. 2. A substance in the gaseous state at ordinary temperature and pressure. 3. In the widest sense, applied to all aeriform bodies, the minutest particles of which exhibit the tendency to fly apart from each other in all directions. Normally these gases are found in that state at ordinary temperature and pressure. They can only be liquefied or solidified by artificial means, either through high pressure or extremely low temperatures.

Gas Chromatograph/Mass Spectrometer: Research laboratory device that both identifies and measures gas concentrations by having very small samples of air injected into a carrier (nitrogen or helium) gas stream. This gas stream is passed through a column that adsorbs and desorbs the chemicals in the air at different rates plus a detector, which identifies individual chemicals and the amount in the sample.

Gas Laws: The physical laws concerning the behavior of gases. They include Boyle's law and Charles's law, which are concerned with the relationships between the pressure, temperature, and volume of an ideal (hypothetical) gas.

Gas Mask: A face covering device used to protect the wearer from injurious gases and other noxious materials by filtering and purifying inhaled air. It usually consists of a face cover with two eyepieces and a mouthpiece that contacts a canister containing a filter; the filter absorbs noxious gases as they ass through the canister to the mouth. The face cover also has a one-way outlet valve for exhaled air.

Gas Physics: A knowledge of air physics (or more correctly stated: physics of gases and particles), is foundational to gaining an understanding of the characteristics of a system in which control equipment is used. For example, if you are required to select most air handling equipment (including fans, simple duct work, and collection equipment), you must be able to determine the volume of air to be handled.

Units of Pressure

Pressure is force per unit area and can be expressed in a number of different units, including the *atmosphere* (atm), which is the average pressure exerted by air at sea level, or the *pascal* (Pa), usually expressed in kilopascal (1 kPa = 1000 Pa, and 101.3 kPa = 1 atm). Pressure can also be given as *millimeters of mercury* (mm Hg), which is based on pressure required to hold up a column of mercury in a mercury barometer. One mm of mercury is a unit called the *torr* and 760 torr equal 1 atm.

Units Often Used in Air Studies

In air studies, it is often the concentration of some substance (foreign or otherwise) in air that is of interest. In either the gaseous or liquid medium, concentrations may be based on volume or weight, or a combination of the two, which may lead to some confusion. To understand how weight and volume are used to determine concentrations when studying liquids or gases/vapors, the following explanations are provided.

1. *Liquids*

Concentrations of substances dissolved in water are usually expressed in terms of weight of substance per unit volume of mixture. In environmental science, a good practical example of this weight per unit volume is best observed whenever a contaminant is dispersed in the atmosphere in solid or liquid form as a mist, dust, or fume. When this occurs, its concentration is usually expressed on a weight-per-volume basis. Outdoor air contaminants and stack effluents are frequently expressed as grams, milligrams, or micrograms per cubic meter; ounces per thousand cubic feet; pounds per thousand pounds of air; and grains per cubic foot. Most measurements are expressed in metric units. However, the use of standard U.S. units is justified for purposes of comparison with existing data, especially those relative to the specifications for air-moving equipment.

Alternatively, concentrations in liquids are expressed as weight of substance per weight of mixture, with the most common units being parts per million (ppm), or parts per billion (ppb). Since most of the concentrations of pollutants are very small, 1 L of mixture weighs essentially 1000 g, so that for all practical purposes we can write

$$1 \text{ mg/L} = 1 \text{ g/m}^3 = 1 \text{ ppm (by weight)}$$
$$1 \text{ µg/L} = 1 \text{ mg/m}^3 = 1 \text{ ppb (by weight)}$$

The air science practitioner may also be involved with concentrations of liquid wastes (which may contaminate the atmosphere) that are so high that the *specific gravity* (the ratio of an object's or substance's weight to that of an equal volume of water) of the mixture is affected, in which case a correction to the above may be required:

$$\text{mg/L} = \text{ppm (by weight)} \times \text{specific gravity}$$

2. *Gases/Vapors*
For most air pollution work, it is customary to express pollutant concentrations in volumetric terms. For example, the concentration of a gaseous pollutant in parts per million (ppm) is the volume of pollutant per million volumes of the air mixture. That is,

$$\text{ppm} = \frac{\text{parts of contaminant}}{\text{million parts of air}}$$

Note that calculations for gas and vapor concentrations are based on the gas laws:

- The volume of gas under constant temperature is inversely proportional to the pressure.
- The volume of a gas under constant pressure is directly proportional to the Kelvin temperature. The Kelvin temperature scale is based on absolute zero (OºC = 273 K).
- The pressure of a gas of a constant volume is directly proportional to the Kelvin temperature.

Thus, when measuring contaminant concentrations, you must know the atmospheric temperature and pressure under which the samples were taken. At *standard temperatures and pressure* (STP), 1 g-mol of an ideal gas occupies 22.4 L. The STP is 0ºC and 760 mmhg. If the temperature is increased to 25ºC (room temperature) and the pressure remains the same, 1 g-mol of gas occupies 24.45 L.

\Sometimes it is necessary to convert milligrams per cubic meter (mg/m^3)—weight-per-volume ratio—into a volume-per-unit volume ratio. If it is understood that 1 g-mole of an ideal gas at 25ºC occupies 24.45 L, the following relationships can be calculated.

$$\text{ppm} = \frac{24.45}{\text{molecular wt}}\ \text{mg/m}^3$$

$$\text{mg/m}^3 = \frac{\text{molecular wt}}{24.45}\ \text{ppm}$$

Material Balance
Material balances are one of the most basic and useful tools in the air pollution engineering field. Stated simply, a materials balance means "what goes in, must come out." Matter is neither created nor destroyed in industrial processes (nonradioactive only).

$$\text{Mass}_{(\text{Out})} = \text{Mass}_{(\text{In})}$$

Material balances are used in a wide variety of air pollution control calculations. For example, they are used to evaluate the following:

- Formation of combustion products in boilers
- Rates of air infiltration into air pollution control systems
- Material requirements for process operations
- Rate of ash collection in air pollution control systems
- Humidities of exhaust gas streams
- Exhaust gas flow rates from multiple sources controlled by a single air pollution control system
- Gas flow rates from combustion processes

This principle, called the conservation of matter, can be applied in solving problems involving the quantities of matter moving in various parts of a process.

Force, Weight, and Mass
In air science work, the properties of gases must be known for proper selection and operation of air pollution control devices and ancillary equipment (ductwork). Along with knowing the properties of gases, the air science practitioner must also be familiar with and understand their meaning as well as the difference between the terms force, weight, and mass.

Force is any influence that tends to change the state of rest or the uniform motion in a straight line of a body. Stated in simpler terms, force is a push or a pull exerted on an object to change its position or movement, including starting, stopping, and changing its speed or direction of movement. In a compressed air (pneumatic) system, force must be present at all times for the system to function.

A substance or object has *weight* depending on its *mass* (represents the amount of matter in an object, and its **inertia**, or resistance to movement) and the strength of the Earth's gravitational pull, which decrease with height. Consequently, an object weighs less at the top of a mountain than at sea level. An object's inertia determines how much force is needed to lift or move the object or to change its speed or direction of movement.

Another important physical property is *density*, which is a scaler quantity. The density of an object is its weight for a specific volume or unit of measure; a measure of the compactness of a substance. Density is equal to its mass per unit volume and is measured in kilogram per cubic meter or pounds per cubic foot. The density of a mass m occupying a volume V is given by the formula:

$$D = m/V$$

The density of a cubic foot of dry air at atmospheric pressure and a temperature of 60°F is 0.076 lb and is more commonly expressed as 0.076 lb/ft^3. The density of *wet* air at atmospheric pressure with 100 percent relative humidity and a temperature of 60°F is 0.075 lb/ft^3. Humid air is less dense than dry air because the water vapor will not allow the air to compress as much. As a result, humid air weighs less. Air's relatively low density makes its suitable for long-distance and high-speed control applications in pneumatic systems.

The densities of some common gases are given in the Table.

Densities of Gases at STP

(Standard temperature and pressure: 0°C and 1 atm)

air	1.3
hydrogen	0.09
helium	0.18
methane	0.72
nitrogen	1.25
oxygen	1.43
carbon dioxide	1.98
propane	2.02
butane	2.65

Pressure

Pressure is the amount of force (in pounds) exerted on an object or a substance, divided by the area (in square inches) over which this force is exerted. Pressure can be measured and specified in different ways but is commonly measured in pounds per square inch (psi). The SI unit of pressure is the pascal (newton per square meter), equal to 0.01 millibars. At the edge of Earth's atmosphere, pressure is zero, whereas at sea level atmospheric pressure due to weight of the air above is about 100 kilopascals (1,013 millibars or 1 atmosphere).

Gas Pressure

The pressures of the gas streams throughout the particulate control system are very important because gas pressure data is often used to evaluate operating conditions. The total pressure of a gas stream is the sum of the static pressure and velocity pressure of the gas stream.

$$TP = SP + VP$$

Where:

TP = Total pressure
SP = Static pressure
VP = Velocity pressure

Velocity pressure is exerted only in gas streams that are in motion. This part of the total pressure is of concern only during emision tests and gas flow rate measurements and is not routinely monitored by plant personnel.

Static pressure is the pressure exerted by all gases. This pressure is basically related to the number of gas molecules in a given volume and at a given temperature. If the number of molecules in the space increases, the pressure increases. An increase in the gas temperature increases the kinetic energy of the molecules, and the static pressure increases (EPA 2007).

Pressure Scales

Like temperature, gas pressure can be expressed in both relative and absolute terms. The absolute pressure scale starts at zero gas pressure (no molecules—a vacuum) and has no practical maximum limit. The absolute temperature and pressure scales are most useful for the scientific an d engineering calculations necessary to evaluate the following:

- Hoods and ventilation systems
- Source emission rates
- Air pollution control equipment performance

Absolute pressure is used whenever it is necessary to use the ideal Gas Laws to calculate gas flow rates. However, in the air pollution control and emission measurement fields, gas pressures are often monitored in terms of relative pressures and it is necessary to convert the data to absolute pressure prior to performing the calculations.

Atmospheric Pressure

In this section we are primarily concerned with *atmospheric pressure* (i.e., the static pressure exerted by ambient air) but it should be noted that two other kinds of pressure—below atmospheric and pneumatic system pressure—are also common. Atmospheric pressure is an absolute pressure because it is directly related to the number of molecules and their kinetic energy. Atmospheric pressure at sea level equals 14.7 psi; pressure is lower above sea level, and higher below sea level.

The complete or partial absence of air (indicating below atmospheric pressure) is often referred to as a *vacuum* or partial vacuum. In some applications it may also be called a negative or suction pressure. Vacuum is normally measured using special gages or with a column of mercury. When all the air above the column is evacuated, atmospheric pressure is exerted on the pool of mercury below the tube. This pressure raises the column to a height of approximately 30 in. In most applications a vacuum is measured in inches of mercury instead of psi.

Note that most pressure gages in a pressurized air system measure only pressure that is higher than the atmospheric pressure surrounding them. You may have noticed that, when a pressure gage is disconnected, it reads zero pounds per square inch, which is known as *gage pressure* (0 psig). For example, a reading of 300 on an air system pressure gage tells you that the air pressure is 300 psi above atmospheric. If we add atmospheric pressure to this gage pressure, the total pressure is 314.7 pounds per square inch (300 + 14.7), which is known as *absolute pressure* (psia). Remember that although absolute pressure readings are important in some pressurized air system calculations, the distinction between psig and psia is usually unimportant in the average air system. As a result, gage pressure readings are usually expressed in psi.

Work and Energy

Work is the transference of energy that occurs when a force is applied to a body that is moving in such a way that the force has a component in the direction of the body's motion. Stated in simpler fashion: Work takes place when a force (in pounds or newtons) moves through a distance (in inches, feet, or meters). The amount of work done is expressed in the English system of measurement in foot-pounds or inch-pounds, as shown in the following equation:

$$\begin{aligned}\text{Work} &= \text{Force (pounds)} \times \text{Distance (feet or inches)}\\ &= \text{foot pounds or inch-pounds}\end{aligned}$$

Pascal's law states that when there is an increase in pressure at any point in a confined fluid (air), there is an equal increase at every other point in the container.

Pascal's law allows forces to be multiplied. The cylinder on the left shows a cross-section area of 1 square inch, while the cylinder on the right shows a cross-section area of 10 square inches. The cylinder on the left has a weight (force) on 1 pound acting downward on the piston, which lowers the fluid 10 inches. As a result of this force, the piston on the right lifts a 10 pound weight a distance of 1 inch.

The 1 pound load on the 1 square inch area causes an increase in pressure on the fluid in the system. This pressure is distributed equally throughout and acts on every square inch of the 10 square inch area of the large piston. As a result, the larger piston lifts up a 10 pound weight. The larger the cross-section area of the second piston, the larger the mechanical advantage, and the more weight it lifts (NASA 2007).

Power is defined as the time rate of doing work—or as the amount of work (foot-pounds) done in a given length of time (seconds or minutes), or foot-pounds per minute. The following equation is used to determine the amount of power:

$$\text{Power (P)} = \frac{\text{Work}}{\text{Time}}$$

$$= \frac{\text{Foot-pounds}}{\text{Seconds (or Minutes)}}$$

To convert foot-pounds to inch-pounds you should *multiply* by 12.

Note that, for the amount of power calculated to be meaningful, it must be compared with a unit of measurement. The common unit of power measurement is *horsepower*, calculated as follows:

$$1 \text{ hp} = \frac{33{,}000 \text{ ft-lb}}{\text{Seconds (or Minutes)}}$$

When power is used to perform work, *energy* is expended. The *Law of Conservation of Energy* states that "Energy cannot be created or destroyed. It can only be transformed." Thus, we use one kind of energy to get other kinds of energy. Some of this energy does useful work while some of it is wasted (as heat energy—remember, energy cannot be destroyed or lost) in overcoming friction.

Diffusion and Dispersion

Diffusion can be described as the spontaneous and random movement of molecules or particles in a gas (or liquid) from a region in which they are at a high concentration, until a uniform concentration is achieved throughout. No mechanical mixing or stirring is involved. This should not be confused with evaporation, which is the changing of a liquid to a gas.

Dispersion can be described as the temporary mixing of liquid particles with a gas.

Diffusion and dispersion are important in air pollution. For example, in dispersion, air pollutants are diluted and reduced in concentration. Air pollution dispersion mechanisms are a function of the prevailing meteorological conditions. Diffusion and dispersion (in air pollution) will be discussed much more fully later.

Compressibility

Air, unlike liquids, is readily compressible, and large quantities can be stored in relatively small containers. The more the air is compressed, the higher its pressure becomes. The higher the pressure in a container, the stronger the container must be. Gases are important compressible fluids, not only from the standpoint that a gas can be a pollutant, but also because gases convey the particles (particulate matter) and gaseous pollutants (Hesketh, 1991).

Gas Laws

Gases can be pollutants as well as the conveyors of pollutants. Air (which is mainly nitrogen) is usually the main gas stream. Gas conditions are usually described in two ways: *standard temperature and pressure (STP)*, and *Standard Conditions (SC)*. STP represents 0°C (32°F) and 1 atm. SC is more commonly used and represents typical room conditions of 20°C (70°F) and 1 atm; SC is usually measured in cubic meters, Nm^3, or standard cubic feet (scf).

To understand the physics of air it is imperative to have an understanding of various physical laws that govern the behavior of pressurized gases. One of the more well-known physical laws, mentioned earlier, is *Pascal's Law*. In addition to one of its previously mentioned parameters, Pascal's Law also states that a confined gas (fluid) transmits externally applied pressure uniformly in all directions, without change in magnitude. This parameter can be seen in a container that is flexible; it will assume a spherical (balloon) shape. However, you probably have noticed that most compressed-gas tanks are cylindrical in shape (which allows use of thinner sheets of steel without sacrificing safety) with spherical ends to contain the pressure more effectively.

Boyle's Law

Though gases are compressible, note that, for a given mass flow rate, the actual volume of gas passing through the system is not constant within the system due to changes in pressure. This physical property (the basic relationship between the pressure of a gas and its volume) is described by *Boyle's Law* (Named for its discoverer: Irish physicist and chemist Robert Boyle in 1662), which states: "The absolute pressure of a confined quantity of gas varies inversely with its volume, if its temperature does not change." For example, if the pressure of a gas doubles, its volume will be reduced by a half, and vice versa. That is, *as pressure goes up, volume goes down*, and vice versa. This means, for example, that if 12 ft^3 of air at 14.7 psia is compressed to 1 ft^3, air pressure will rise to 176.4 psia, as long as air temperature remains the same. This relationship can be calculated as follows:

$$P_1 \times V_1 = P_2 \times V_2$$

where

P_1 = original pressure (units for pressure must be absolute)
P_2 = new pressure (units for pressure must be absolute)
V_1 = original gas volume at pressure P_1
V_2 = new gas volume at pressure P_2

This equation can also be written as:

$$\frac{P_2}{P_1} = \frac{V_1}{V_2} \text{ or } \frac{P_1}{P_2} = \frac{V_2}{V_1}$$

To allow for the effects of atmospheric pressure, always remember to convert from gage pressure *before* solving the problem, then convert back to gage pressure *after* solving it:

$$\text{Psia} = \text{psig} + 14.7 \text{ psi}$$

and

$$\text{Psig} = \text{psia} - 14.7 \text{ psi}$$

Note that in a pressurized gas system where gas is caused to move through the system by the fact that gases will flow from an area of high pressure to that of low pressure, we will always have a greater actual volume of gas at the end of the system than at the beginning (assuming the temperature remains constant).

Let's take a look at a typical gas problem using Boyle's Law:

Example
What is the gage pressure of 12 ft^3 of air at 25 psig when compressed to 8 ft^3?

Solution:

$$25 \text{ psig} + 14.7 \text{ psi} = 39.7 \text{ psia}$$

$$P_2 = P_1 \times \frac{V_1}{V_2} = 39.7 \times \frac{12}{8} = 59.6 \text{ psia}$$

$$\text{Psig} = \text{psia} - 14.7 \text{ psi}$$

$$= (59.6 \text{ psia}) - (14.7 \text{ psi}) = 44.9 \text{ psig}$$

The gage pressure is 44.9 psig (remember that the pressures should always be calculated on the basis of absolute pressures instead of gage pressures).

Charles's Law

Another physical law dealing with temperature is *Charles's Law* (discovered by French physicist Jacques Charles in 1787). It states, "the volume of a given mass of gas at constant pressure is directly proportional to its absolute temperature." [The temperature in Kelvin (273 + °C) or Rankine (absolute zero = -460°F, or 0°R).]

This is calculated by using the following equation:

$$P_2 = P_1 \times \frac{T_2}{T_1}$$

Charles's Law also states: "If the pressure of a confined quantity of gas remains the same, the change in the volume (V) of the gas varies directly with a change in the temperature of the gas," as given in the equation:

$$V_2 = V_1 \times \frac{T_2}{T_1}$$

Ideal Gas Law

The *Ideal Gas Law* combines Boyle's and Charles's Laws because air cannot be compressed without its temperature changing. The Ideal Gas Law is expressed by the equation:

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Note that the Ideal Gas Law is still used as a design equation even though the equation shows that the pressure, volume, and temperature of the second state of a gas are equal to the pressure, volume, and temperature of the first state. In actual practice, however, other factors such as humidity, heat of friction, and efficiency losses all affect the gas. Also, this equation uses absolute pressure (psia) and absolute temperatures (°R) in its calculations.

In air science practice, the importance of the Ideal Gas Law cannot be overstated. It is one of the fundamental principles used in calculations involving gas flow in air pollution-related work. This law is used to calculate actual gas flow rates based on the quantity of gas present at standard pressures and temperatures. It is also used to determine the total quantity of that contaminant in a gas that can participate in a chemical reaction.

- Number of moles of gas
- Absolute temperature
- Absolute pressure

In practical applications, practitioners generally use the following standard ideal gas law equation:

$$V = \frac{nRT}{P} \text{ or } PV = nRT$$

Where:
V = Volume
n = Number of moles
R = Universal gas constant
T = Absolute temperature
P = Absolute pressure

Example
What is the volume of 1 pound mole (denoted "lb mole") of combustion gas at an absolute pressure of 14.7 psia and a temperature of 68ºF? (These are EPA-defined standard conditions.)

Solution

$$V = \frac{nRT}{P}$$

1. Convert the temperature from relative to absolute scale (from ºF to ºR).

$$T_{\text{Absolute}} = 68^{\circ}\text{F} + 460 = 528^{\circ}\text{R}$$

2. Calculate the gas volume.

$$1 \text{ lb mole} \times \frac{10.73 \text{ (psia) (ft}^3)}{(\text{lb mole})(^{\circ}\text{R})} \times 528^{\circ}\text{R}$$

$$V = 14.7 \text{ psia}$$
$$= 385.4 \text{ ft}^3$$

Flow Rate
Gas flow rate is a measure of the volume of gas that passes a point in an industrial system during a given period of time. The ideal gas law tells us that this gas flow rate varies depending on the temperature and pressure of the gas stream and the number of moles of gas moving per unit of time.

When gas flow rtes are expressed at actual conditions of temperature and pressure, the actual gas flow rate is being used. As you will learn later, gas flow rates can also be expressed at standard conditions of temperature and pressure, this is referred to as the standard gas flow rate.

Gas Conversions
Gases of interest in air pollution control are usually mixtures of several different compounds. For example, air is composed of three major constituents: nitrogen (N_2) at approximately 78.1 percent, oxygen (O_2) at approximately 20.9 percent, and argon at 0.9 percent. Many flue gas streams generated by industrial processes consist of the following major constituents: (1) nitrogen, (2) oxygen, (3) argon, (4) carbon dioxide (CO_2), and (5) water vapor (H_2O). Both air and industrial gas streams also contain minor constituents, including air pollutants, present at concentrations that are relatively low compared to these major constituents.

There is a need for ways to express both the concentrations of the major constituents of the gas stream and the concentrations of the pollutants present as minor constituents at relatively low concentrations. There are a variety of ways to express gas phase concentrations, which can easily be converted from on type of units to another. They include the following:

Major Constituents

- *Volume percent*—is one of the most common formats used to express the concentrations of major gas stream constituents such as oxygen, nitrogen, carbon dioxide, and water vapor. The format is very common partially because the gas stream analysis techniques used in EPA emission testing methods provide data directly in a volume percent format.
- *Partial pressure*—concentrations can also be expressed in terms of partial pressures. This expression refers to the part of the total pressure exerted by one of the constituent gases.

Gases composed of different chemical compounds such as molecular nitrogen and oxygen behave physically the same as gases composed of a single compound. At any give temperature, one mole of a gas exerts the same pressure as one mole of any other type of gas. All of the molecules move at a rate that is dependent on the absolute temperature, and they exert pressure. The total pressure is the sum of the pressures of each of the components. The equations below are of often Called Dalton's law of partial pressures.

$$P_{Total} = p_i + p_{ii} + p_{iii \ldots}\, p_n$$

$$P_{Total} = \sum_{i=1}^{n} p_i$$

$$\text{Partial pressure (Gas)} = \left[\frac{\text{Volume \% (Gas)}}{100\ \%}\right] \times P_{Total}$$

Because the partial pressure value is related to the total pressure, concentration data expressed as partial pressure are not the same at actual and standard conditions. The partial pressure values are also different in American Engineering units and Cgs units.

Both Major and Minor Constituents

- *Mole fraction*—is simply an expression of the number of moles of a compound divided by the total number of moles of all the compounds present in the gas.

Minor Constituents

- Parts per million (ppm)
- Milligrams per cubic meter (mg/m^3)
- Micrograms per cubic meter (µg/m^3)
- Nanograms per cubic meter (ng/m^3)

All of the concentration units above can be expressed in a dry format as well as corrected to a standard oxygen concentration. These corrections are necessary because moisture and oxygen concentrations can vary greatly in gas streams, causing variations in pollutant concentrations.

Gas Velocity

Gas velocity is one of the fundamental design variables for ventilation systems and air pollution control equipment. Gas streams containing particulate are usually maintained at velocities of 3,000 to 4,500 ft/min n ductwork leading to particulate collectors to minimize particle deposition. The velocity of gas streams without particulate matter is often in the range of 1,500 to 3,000 ft/min. The gas velocities in air pollution control equipment are usually low to allow for sufficient time to remove the contaminants. For example, gas velocities through electrostatic precipitators are usually in the range of 2.5 to 6 ft/sec. The filtration velocities through pulse jet fabric filters are usually in the range of 2 to 10 ft/min. Variations in the gas velocity can have direct impact ton the contaminant removal efficiency.

The average velocity of a gas stream in an emission testing probe, an industrial duct, or an air pollution control device is a function of the actual gas flow rate and the cross-sectional flow area.

$$v = \text{Gas velocity} = \frac{\text{Gas flow rate, actual}}{\text{Area}}$$

Gas Stream Treatment (Residence) Time

The flow rate of the gas stream through an air pollution control system determines the length of time that the pollutants can be removed from the gas stream. This is termed the *treatment time* or *residence time*. These common equipment sizing parameters are defined mathematically in the Equation below.

$$\text{Treatment Time} = \text{Residence Time}$$

$$= \frac{\text{Volume of control device}}{\text{Gas flow rate, actual}}$$

Gas Density

Gas density is important primarily because it affects the flow characteristics of the moving gas streams. Gas density affects the velocities of gas through ductwork and air pollution control equipment. It determines the ability to move the gas steam using a fan. Gas density affects the velocities of gases emitted from the stack and thereby influences the dispersion of the pollutants remaining in the stack gases. It affects the ability of particles to move through gases. It also affects emission testing. Gas density data is needed in many of the calculations involved in air pollution control equipment evaluation, emission testing, and other air pollution control-related studies.

As discussed earlier, the volume of a gas increases as the temperature increases due to the motion of the gas molecules. As the volume occupied by the gas increases, its density decreases. Density is the mass per unit volume as indicated in the Equation below.

$$P_{(T=i,\ P=j)} = \frac{m}{V_{(T=I\ ,\ P=j)}}$$

Where:

$P_{(T=I,\ P=j)}$ = Density at T = I, P = j
m = Mass of a substance
$V_{(T=I,\ P=j)}$= Volume at T = I, P = j
T= Absolute temperature
P= Absolute pressure

Heat Capacity and Enthalpy

The heat capacity of a gas is the amount of heat required to change the temperature of a unit-mass of gas one temperature degree.

Enthalpy represents the total quantity of internal energy, such as heat, measured for a specific quantity of material at a given temperature. Enthalpy data are often represented in units of energy (e.g. Btu, kcal, joule, et.). The enthalpy content change is often expressed in Btu/unit mass (Btu/lb_m) or Btu/unit time (Btu/SCF). The change in enthalpy of the total quantity of material present in a system is expressed in units of Btu/unit time (BTU/min). The symbols, H and ΔH, denote enthalpy and the change in enthalpy, respectively.

Heat and Energy in the Atmosphere

In addition to the importance of heat on a particular air stream, it is important to point out that heat also has an impact on Earth's atmosphere and thus on atmospheric science. The sun's energy is the prime source of Earth's climatic system. From the sun, energy is reflected, scattered, absorbed and reradiated within the system but without uniform distribution. Some areas receive more energy than they lose; in some areas the reverse occurs. If this situation were able to continue for long the areas with an energy surplus would get hotter—too hot, and those with a deficit would get colder—too cold. This does not happen because the temperature differences produced help to drive the wind and ocean currents of the world. They carry heat with them, either in the sensible or latent forms, and help to counteract the radiation imbalance. Winds from the tropics are therefore normally warm, carrying excess heat with them. Polar winds are blowing from areas with a deficit of heat and so are cold. Acting together, these energy transfer mechanisms help to produce the present climates on Earth.

Adiabatic Lapse Rate

The atmosphere is restless, always in motion either horizontally or vertically or both. As air rises, pressure on it decreases and in response it expands. The act of expansion to encompass its new and larger dimensions requires an expenditure of energy; since temperature is a measure of internal energy, this use of energy makes its temperature drop—this is an important point—an important process in physics (especially in air physics).

This phenomenon is known as the *adiabatic lapse rate*. Simply, **adiabatic** refers to a process that occurs with or without loss of heat, especially the expansion or contraction of a gas in which a change takes place in the pressure or volume, although no heat is allowed to enter or leave.

Lapse rate refers to the rate at which air temperature decreases with height. The normal lapse rate in stationary air is on the order of 3.5°F/1000 ft (6.5°C/km). This value may vary with latitude and changing atmospheric conditions (e.g., seasonal changes). A parcel of air that is not immediately next to the earth's surface is sufficiently well insulated by its surroundings that either expansion or compression of the parcel may be assumed to be adiabatic.

The air temperature may be calculated for any height by the general formula

$$T = T_0 - Rh$$

where

T = temperature of the air

h = height of air

T_0 = temperature of the air at the level from which the height is measured

R = lapse rate

Example

If the air temperature of stationary air (R= 3.5°F/1000 ft) at the earth's surface is 70°F, then at 5000 ft, the stationary air temperature would be

$$\begin{aligned} T &= T_0 - Rh \\ &= 70°\text{F} - (3.5°\text{F}/1000\ \text{ft})(5000\ \text{ft}) \\ &= 70°\text{F} - 17.5°\text{F} = 52.5°\text{F} \end{aligned}$$

The formula simply says that for every 1000 ft of altitude (height), 3.5° is subtracted from the initial air temperature, in this case.

Adiabatic lapse rates have an important relationship with atmospheric stability and will be discussed in greater detail later in the text.

Viscosity

All fluids (gases included) resist flow. *Absolute viscosity* is a measure of this resistance to flow. The absolute viscosity of a gas for given conditions may be calculated from the following formula:

$$\mu = 51.12 + 0.372(T) + 1.05 \times 10^{-4}(T)^2 + 53.147\ (\%\ O_2/100\%) - 74.143\ (\%\ H_2O/100\%)$$

Where:

μ = Absolute viscosity of gas at the prevailing conditions, micropoise

T= Gas absolute temperature, ºK

% O_2 = Oxygen concentration, % by volume

% H_2O = Water vapor concentration, % by Volume

As this equation indicates, the viscosity of a gas increases as the temperature increases. It's harder to push something (e.g. particles) through a hot gas stream than a cooler one due to increased molecular activity as temperature rises, which results in increased momentum transfer between the molecules. For liquids, the opposite relationship between viscosity and temperature holds. The viscosity of a liquid decreases as temperature increases. It's harder to push something through a cold liquid than a hot one because in liquids, hydrogen bonding increases with colder temperatures. Gas viscosity actually increases very slightly with pressure, but this variation is very small in most air pollution-related engineering calculations.

The absolute viscosity and density of a gas are occasionally combined into a single parameter since both of these parameters are found in many common equations describing gas flow characteristics. The combined parameter is termed the kinematic viscosity. It is defined in the following Equation.

$$u = \mu/p$$

Where:
u = Kinematic viscosity, m^2/sec
μ = Absolute viscosity, Pa•sec
p = Gas density, gm/cm^3

The kinematic viscosity can be used in equations describing particle motion through gas streams. The expression for kinematic viscosity is used to simplify these calculations.

Flow Characteristics

When fluids such as gases are moving slowly, the bulk material moves as distinct layers in parallel paths. The only movement across these layers is the molecular motion, which creates viscosity. This is termed *laminar flow*.

As the velocity of the gas stream increases, the bulk movement of the gas changes. Eddy currents develop which cause mixing across the flow stream. This is called *turbulent flow*, and is essentially the only flow characteristic that occurs in air pollution control equipment and emission testing-related situations.

A dimensionless parameter called the *Reynolds number* is used to characterize fluid flow. It is the ratio of the inertial force which is causing gas movement to the viscous force which is restricting movement. Consistent units must be used to ensure that the Reynolds number is dimensionless. The Reynolds number is calculated using

$$N_{Re(g)} = L\ v\ p/\mu$$

Where:
L = Linear dimensions (usually duct diameter)
v = Fluid velocity
p = Fluid density
μ = Fluid viscosity

Reynolds numbers less than 2,000 are associated with laminar flow conditions. Due to the relatively low velocities associated with this type of flow, they are rarely encountered in air pollution field situations.

Reynolds numbers above 10,000 are associated with turbulent flow. In many field situations, the Reynolds numbers exceed 100,000.

Essentially, all gas flow situations are turbulent in air pollution control systems, emission test and monitoring equipment, and dispersion modeling studies. However, this does not mean that the gas stream is entirely well mixed. In reality, the side-to-side mixing (and even mixing in the direction of flow) can be limited. For this reason, it is possible to have different concentrations of pollutants at different positions in the duct. This is called *pollutant stratification*. It can be caused by a variety of factors: combining of two separate gas streams into a single duct, temperature differences in the gas stream, and in-leakage of cold ambition air into the duct.

Stratification does not exist in most industrial gas handling systems. However, it is important to check for this condition prior to installation of continuous emission monitors or other instruments, which are located at a single sampling or measurement point in the gas stream. These measurements can be in error if stratification is severe.

Gasification: A chemical or heat process to convert a solid fuel to a gaseous form.

Gasoline Volatility: The property of gasoline whereby it evaporates into a vapor. Gasoline vapor is a mixture of volatile organic compounds.

Gastric Acid: Digestive acid in the stomach secreted by glands in the stomach wall.

Gauge Height: The height of the water surface above the gage datum (zero point). Gage height is often used interchangeably with the more general term, stage, although gage height is more appropriate when used with a gage reading.

Gauge Pressure: Pressure relative to the local atmospheric or ambient pressure.

Gauge Pressure (psig): The difference between two absolute pressures, one of which is usually atmospheric pressure.

Gasoline Gallon Equivalents (GGE)(USEPA 2007)

Fuel	*GGE*	*Btu/unit*
Gasoline (Base)	1 US Gallon	114,000 Btu/gal
Gasoline (conventional, summer)	0.996 US gallon	114,500 Btu/gal
Gasoline (convention, winter)	1.013 US gallon	112,500 Btu/gal
Gasoline (reformulated gasoline, ethanol	1.019 US gallon	111,836 Btu/gal
Gasoline (reformulated gasoline, ETBE)	1.019 US gallon	111,811 Btu/gal
Gasoline (reformulated gasoline, MTBE)	1.020 US gallon	111,745 Btu/gal
Gasoline (10% MBTE)	1.02 US gallon	112,000 Btu/gal
Gasoline (regular unleaded)	1 US gallon	114,100 Btu/gal
Diesel #2	0.88 US gallons	129,500 Btu/gal
Biodiesel (B100)	0.96 US gallons	118,300 Btu/gal
Bio Diesel (B20)	0.90 US gallons	127,250 Btu/gal
Liquid natural gas (LNG)	1.52 US gallons	75,000 Btu/gal
Compressed natural gas	1.26 cu ft (3.587 m^3)	900 Btu/cu ft
Hydrogen at 101.325 kPa	357.37 cu ft	319 Btu/cu ft
Hydrogen by weight	0.997 kg (2.198 lb)	119.9 MJ/kg (51,500Btu/lb)
Liquefied petroleum gas (LPG)	1.35 US gallons	84,300 Btu/gal
Methanol fuel (M100)	2.01 US gallons	56,800 Btu/gal
Ethanol fuel (E100)	1.500 US gallons	76,100 Btu/gal
Ethanol (E85)	1.39 US gallons	81,800 Btu/gal
Jet fuel (naphtha)	0.97 US gallons	118,700 Btu/gal

Gauss: In *measurement*, a unit of magnetic induction in the centimeter-gram-second system, equivalent to 1 maxwell per cm^2.

GC: Gas chromatography.

General Biological Succession: The process whereby communities of plant and animal species in a particular area are replaced over time by a series of different and usually more complex communities (aka *ecological succession*).

General Circulation Model (GCM)[1]: In *earth science*, is a mathematical model of the general circulation of a planetary atmosphere or ocean and is based on the a rotating sphere with thermodynamic terms for various energy sources (latent heat, radiation); the Navier-Stokes equations.

General Permit: A permit applicable to a class or category of dischargers.

General Population Limit (GPL): An airborne exposure limit designed to protect the general public.

General Reporting Facility: A facility having one or more hazardous chemical above the 10,000 pound threshold or planning quantities. Such facilities must file SDS and emergency inventory information with the SERC, LEPC, and local fire departments.

Generally Recognized as Safe (GRAS): Designation by the FDA that a chemical or substance (including certain pesticides) added to food is considered safe by experts, and so is exempted from the usual FFDCA food additive tolerance requirements.

General Ventilation Systems: Sometimes referred to as heat control ventilation systems, these are used to control indoor atmospheric conditions associated with hot industrial environments (such as those found in foundries, laundries, bakeries, and other workplaces that generate excess heat) for the purpose of preventing acute discomfort or injury. General ventilation also functions to control the comfort level of the worker in just about any indoor working environment. Along with the removal of air that has become process-heated beyond a desired temperature level, a general ventilation system supplies air to the work area to condition (by heating or cooling) the air, or to make up for the air that has been exhausted by dilution ventilation in a local exhaust ventilation system.

Generation Time (bacteria): Time required for a given population to double in size.

Generator: 1. A facility or mobile soruce that emits pollutants into the air or release hazardous waste into water or soil. 2. Any person, by site, whose act or process produces regulated medical waste or whose act first causes such waste to become subject to regulation. Where more than one person (e.g., doctors with separate medical practices) are locate in the same building, each business entity is a separate generator. 3. Any person whose act first creates or produces hazardous waste.

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[1] Sun, S and Hansen, J.E., 2003. *Climate Simulations for 1951-2050 with a Coupled Atmosphere-Ocean Model*. New York, NASA Goddard Institute for Space Studies.

Genetic Engineering: A process of inserting new genetic information into existing cells in order to modify a specific organism for the purpose of changing one of its characteristics.

Genome: A complete haploid set of chromosomes.

Genotoxic: Damaging to DNA; pertaining to agents known to damage DNA.

Geographic Information System (GIS): A computer system designed for storing, manipulating, analyzing, and displaying data in a geographic context.

Geological Log: A detailed description of all underground features (depth, thickness, types of formation) discovered during the drilling of a well.

Geology: The science of Earth, its origin, composition, structure, and history.

Geophone: A seismic detector, placed on or in the ground that responds to ground motion at its point of location.

Geosphere: Consists of the inorganic, or nonliving, portions of earth, which are home to the entire globe's organic, or living, matter.

Geothermal: Of or relating to the earth's interior heat. The name of temperature increase with depth in the earth.

Germicide: Any compound that kills disease-causing microorganisms.

Germinal: Of, relating to, or having the nature of a germ cell (sperm, egg, or their precursors).

Geyser: A geothermal spring of the earth where there is an opening in the surface that contains superheated water that periodically erupts in a shower of water and steam.

Giardia lamblia: Also known as hiker's/traveler's scourge or disease is a microscopic parasite that can infect warm-blooded animals and humans. Although *Giardia* was discovered in the nineteenth century, not until 1981 did the World Health Organization (WHO) classify *Giardia* as a pathogen. *An outer shell called a cyst that allows it to survive outside the body for long periods protects giardia*. If viable cysts are ingested, *Giardia* can cause the illness known as *Giardiasis*, an intestinal illness that can cause nausea, anorexia, fever, and severe diarrhea. The symptoms last only for several days, and the body can naturally rid itself of the parasite in one to two months. However, for individuals with weakened immune systems, the body often cannot rid itself of the parasite without medical treatment.

In the United States, *Giardia* is the most commonly identified pathogen in waterborne disease outbreaks. Contamination of a water supply by *Giardia* can occur in two ways: (1) by the activity of animals in the watershed area of the water supply; or (2) by the introduction of sewage into the water supply. Wild and domestic animals are major contributors in contaminating water supplies. Studies have also shown that, unlike many other pathogens, *Giardia* is not host-specific. In short, *Giardia* cysts excreted by animals can infect and cause illness in humans. Additionally, in several major outbreaks of waterborne diseases, the *Giardia* cyst source was sewage contaminated water supplies.

Treating the water supply, however, can effectively control waterborne *Giardia*. Chlorine and ozone are examples of two disinfectants known to effectively kill *Giardia* cysts. Filtration of the water can also effectively trap and remove the parasite from the water supply. The combination of disinfection and filtration is the most effective water treatment process available today for prevention of *Giardia* contamination.

In drinking water, *Giardia* is regulated under the Surface Water Treatment Rule (SWTR). Although the SWTR does not establish a Maximum Contaminant Level (MCL) for *Giardia,* it does specify treatment requirements to achieve at least 99.9 percent (3-log) removal and/or inactivation of *Giardia.* This regulation requires that all drinking water systems using surface water or groundwater under the influence of surface water must disinfect and filter the water. The Enhanced Surface Water Treatment Rule (ESWTR), which includes *Cryptosporidium* and further regulates *Giardia,* was established in December 1996.

Giardiasis (CDC 1995): During the past fifteen years, Giardiasis has been recognized as one of the most frequently occurring waterborne diseases in the United States. *Giardia lamblia* cysts have been discovered in the U.S. in places as far apart as Estes Park, Colorado (near the Continental Divide); Missoula, Montana; Wilkes-Barre, Scranton, and Hazleton, Pennsylvania; and Pittsfield and Lawrence, Massachusetts, just to name a few.

Giardiasis is characterized by intestinal symptoms that usually last one week or more and may be accompanied by one or more of the following: diarrhea, abdominal cramps, bloating, flatulence, fatigue, and weight loss. Although vomiting and fever are commonly listed as relatively frequent symptoms, people involved in waterborne outbreaks in the U.S have not commonly reported them.

While most *Giardia* infections persist only for one or two months, some people undergo a more chronic phase, which can follow the acute phase or may become manifest without an antecedent acute illness. Loose stools and increased abdominal gassiness with cramping, flatulence, and burping characterize the chronic phase. Fever is not common, but malaise, fatigue, and depression may ensue

(Weller 1985). For a small number of people, the persistence of infection is associated with the development of marked malabsorption and weight loss (Weller 1985). Similarly, lactose (milk) intolerance can be a problem for some people. This can develop coincidentally with the infection or be aggravated by it, causing an increase in intestinal symptoms after ingestion of milk products.

Some people may have several of these symptoms without evidence of diarrhea or have only sporadic episodes of diarrhea every three or four days. Still others may not have any symptoms at all. Therefore, the problem may not be whether you are infected with the parasite or not, but how harmoniously you both can live together or how to get rid of the parasite (either spontaneously or by treatment) when the harmony does not exist or is lost.

Note: Three prescription drugs are available in the United States to treat giardiasis: quinacrine, metronidazole, and furazolidone. In a recent review of drug trials in which the efficacies of these drugs were compared, quinacrine produced a cure in 93 percent of patients, metronidazole cured 92 percent, and furazolidone cured about 84 percent of patients (Davidson 1984).

Giardiasis occurs worldwide. In the United States, *Giardia* is the parasite most commonly identified in stool specimens submitted to state laboratories for parasitologic examination. During a three-year period, approximately 4 percent of one million stool specimens submitted to state laboratories tested positive for *Giardia* (CDC 1979). Other surveys have demonstrated *Giardia* prevalence rates ranging from 1 to 20 percent, depending on the location and ages of persons studied. Giardiasis ranks among the top twenty infectious diseases that cause the greatest morbidity in Africa, Asia, and Latin America; it has been estimated that about two million infections occur per year in these regions (Walsh 1981). People who are at highest risk for acquiring *Giardia* infection in the United States may be placed into five major categories:

1. People in cities whose drinking water originates from streams or rivers, and whose water treatment process does not include filtration, or where filtration is ineffective because of malfunctioning equipment
2. Hikers/campers/outdoor people
3. International travelers
4. Children who attend day-care centers, day-care center staff, and parents and siblings of children infected in day-care centers.
5. Homosexual men

People in categories 1, 2, and 3 have in common the same general source of infection, i.e., they acquire *Giardia* from fecally contaminated drinking water. The city resident usually becomes infected because the municipal water treatment process does not include the filter necessary to physically remove the parasite from the water. The number of people in the United States at risk (i.e., the number who receive municipal drinking water from unfiltered surface water) is estimated to be twenty million. International travelers may also acquire the parasite from improperly treated municipal waters in cities or villages in other parts of the world, particularly in developing countries. In Eurasia, only travelers to Leningrad appear to be at increased risk. In prospective studies, 88 percent of U.S. and 35 percent of Finnish travelers to Leningrad who had negative stool tests for *Giardia* on departure to the Soviet Union developed symptoms of giardiasis and had positive test for *Giardia* after they returned home (Brodsky et al. 1974). With the exception of visitors to Leningrad, however, *Giardia* has not been implicated as a major cause of traveler's diarrhea—it has been detected in fewer than 2 percent of travelers who develop diarrhea. However, hikers and campers risk infection every time they drink untreated raw water from a stream or river.

Persons in categories 4 and 5 become exposed through more direct contact with feces or an infected person; exposure to soiled of an infected child (day-care center-associated cases), or through direct or indirect anal-oral sexual practices in the case of homosexual men.

Although community waterborne outbreaks of giardiasis have received the greatest publicity in the United States during the past decade, about half of the *Giardia* cases discussed with the staff of the Centers for Disease Control over a three-year period had a day-care exposure as the most likely source of infection. Numerous outbreaks of *Giardia* in day-care centers have been reported in recent years. Infection rates for children in day-care center outbreaks range from 21 to 44 percent in the United States and from 8 to 27 percent in Canada (Black et al. 1981). The highest infection rates are usually observed in children who wear diapers (one to three years of age). In a study of eighteen randomly selected day-care centers in Atlanta, 10 percent of diapered children were found infected (CDC Unpublished). Transmission from this age group to older children, day-care staff, and household contacts is also common. About 20 percent of parents, caring for an infected child becomes infected.

Local health officials and managers or water utility companies need to realize that sources of *Giardia* infection other than municipal drinking water exist. Armed with this knowledge, they are less likely to make a quick (and sometimes wrong) assumption that a cluster of recently diagnosed cases in a city is related to municipal drinking water. Of course, drinking water must not be ruled out as a source of infection when a larger than expected number of cases is recognized in a community, but the possibility that the cases are associated with a day-care center outbreak, drinking untreated stream water, or international travel should also be entertained.

To understand the finer aspects of *Giardia* transmission and strategies for control, the drinking water practitioner must become familiar with several aspects of the parasite's biology. Two forms of the parasite exist: a *trophozoite* and a *cyst*, both of which are much larger than bacteria. Trophozoites live in the upper small intestine where they attach to the intestinal wall by means of a disc-shaped suction pad on their ventral surface. Trophozoites actively feed and reproduce at this location. At some time during the trophozoites life, it releases its hold on the bowel wall and floats in the fecal stream through the intestine. As it makes this journey, it undergoes a morphologic transformation into an egg like structure called a cyst. The cyst (about 6 to 9 nanometers in diameter X 8 to 12 micrometers –1/100 millimeter—in length) has a thick exterior wall that protects the parasite against the harsh elements that it will encounter outside the body. This cyst form of parasite is infectious to other people or animals. Most people become infected either directly (by hand-to-mouth transfer of cysts from the feces of an infected individual) or indirectly (by drinking feces-contaminated water). Less common modes of transmission included ingestion of fecally contaminated food and hand-to-mouth transfer of cysts after touching a fecally contaminated surface. After the cyst is swallowed, the trophozoite is liberated through the action of stomach acid and digestive enzymes and becomes established in the small intestine.

Although infection after ingestion of only one *Giardia* cyst is theoretically possible, the minimum number of cysts shown to infect a human under experimental conditions is ten (Rendtorff 1954). Trophozoites divide by binary fission about every twelve hours. What this means in practical terms is that if a person swallowed only a single cyst, reproduction at this rate would result in more than one million parasites ten days later, and one billion parasites by day fifteen.

The exact mechanism by which *Giardia* causes illness is not yet well understood, but is not necessarily related to the number of organisms present. Nearly all of the symptoms, however, are related to dysfunction of the gastrointestinal tract. The parasite rarely invades other parts of the body, such as the gall bladder or pancreatic ducts. Intestinal infection does not result in permanent damage.

Note: *Giardia* has an incubation period of one to eight weeks.

Data reported by the CDC indicate that *Giardia* is the most frequently identified cause of diarrheal outbreaks associated with drinking water in the United States. The remainder of this section is devoted specifically to waterborne transmissions of *Giardia. Giardia* cysts have been detected in 16 percent of potable water supplies (lakes, reservoirs, rivers, springs, and groundwater) in the United States at an average concentration of three cysts per 100L (Rose 1983). Waterborne epidemics of giardiasis are a relatively frequent occurrence. In 1983, for example, *Giardia* was identified as the cause of diarrhea in 68 percent of waterborne outbreaks in which the causal agent was identified. From 1965 to 1982, more than fifty waterborne outbreaks were reported (CDC 1984). In 1984, about 250,000 people in Pennsylvania were advised to boil drinking water for six months because of *Giardia*-contaminated water.

Many of the municipal waterborne outbreaks of *Giardia* have been subjected to intense study to determine their cause. Several general conclusions can be made from data obtained in those studies. Waterborne transmission of *Giardia* in the U.S. usually occurs in mountainous regions where community drinking water obtained from clear running streams is chlorinated but not filtered before distribution. Although mountain streams appear to be clean, fecal contamination upstream by human residents or visitors, as well as by *Giardia*-infected animals such as beavers, has been well documented. Water obtained from deep wells is an unlikely source of *Giardia* because of the natural filtration of water as it percolates through the soil to reach underground cisterns. Well-waste sources that pose the greatest risk of fecal contamination are poorly constructed or improperly located ones. A few outbreaks have occurred in towns that included filtration in the water treatment process, where the filtration was not effective in removing *Giardia* cysts because of defects in filter construction, poor maintenance of the filter media, or inadequate pretreatment of the water before filtration. Occasional outbreaks have also occurred because of accidental cross-connections between water and sewage systems.

From these data, we conclude that two major ingredients are necessary for waterborne outbreak. *Giardia* cysts must be present in untreated source water, and the water purification process must either fail to kill or to remove *Giardia* cysts from the water.

Though beavers are often blamed for contaminating water with *Giardia* cysts, that they are responsible for introducing the parasite into new areas seem unlikely. Far more likely is that they are also victims: *Giardia* cysts may be carried in untreated human sewage discharged into the water by small-town sewage disposal plants or originate from cabin toilets that drain directly into streams and rivers. Backpackers, campers, and sports enthusiasts may also deposit *Giardia*-contaminated feces in the environment, which are subsequently washed into streams by rain. In support of this concept is a growing amount of data that indicate a higher *Giardia* infection rate in beavers living downstream from U.S. National Forest campgrounds, compared with a near zero rate of infection in beavers living in more remote areas.

Although beavers may be unwitting victims of the *Giardia* story, they still play an important part in the contamination scheme, because they can (and probably do) serve as amplifying hosts. An *amplifying host* is one that is easy to infect, serves as a good habitat for the parasite to reproduce, and in the case of *Giardia*, returns millions of cysts to the water for every one ingested. Beavers are especially important in this regard, because they tend to defecate in or very near the water, which ensures that most of the *Giardia* cysts excreted are returned to the water.

The microbial quality of water resources and the management of the microbially laden wastes generated by the burgeoning animal agriculture industry are critical local, regional and national problems. Animals wastes from cattle, hogs, sheep, horses, poultry and other livestock and commercial animals can contain high concentrations of microorganism, such as *Giardia,* that are pathogenic to humans.

The contribution of other animals to waterborne outbreaks of *Giardia* is less clear. Muskrats (another semiaquatic animal) have been found in several parts of the United States to have high infection rates (30 to 40 percent) (Frost et al. 1984). Recent studies have shown that muskrats can be infected with *Giardia* cysts from humans and beavers. Occasional *Giardia* infections have been reported in coyotes, deer, elk, cattle, dogs, and cats (but not in horses and sheep) encountered in mountainous regions of the United States. Naturally occurring *Giardia* infections have not been found in most other wild animals (bear, nutria, rabbit, squirrel, badger, marmot, skunk, ferret, porcupine, mink, raccoon, river otter, bobcat, lynx, moose, bighorn sheep) (Frost et al. 1984).

Scientific knowledge about what is required to kill or remove *Giardia* cysts from a contaminated water supply has increased considerably. For example, we know that cysts can survive in cold water (4ºC) for at least two months, and they are killed instantaneously by boiling water (100ºC) (Frost et al. 1984). We do not know how long the cysts will remain viable at other water temperatures (e.g., at 0ºC or in a canteen at 15-20ºC), nor do we know how long the parasite will survive on various environment surfaces, e.g., under a pine tree, in the sun, on a diaper-changing table, or in carpets in a day-care center.

The effect of chemical disinfection (chlorination, for example) on the viability of *Giardia* cysts is an even more complex issue. The number of waterborne outbreaks of *Giardia* that have occurred in communities where chlorination was employed as a disinfectant-process demonstrates that the amount of chlorine used routinely for municipal water treatment is not effective against *Giardia* cysts. These observations have been confirmed in the laboratory under experimental conditions (Jarroll et al. 1980). This does not mean that chlorine does not work at all. It does work under certain favorable conditions. Without getting too technical, gaining some appreciation of the problem can be achieved by understanding a few of the variables that influence the efficacy of chlorine as a disinfectant.

1. Water pH: at pH values above 7.5, the disinfectant capability of chlorine is greatly reduced.
2. Water temperature: the warmer the water, the higher the efficacy. Chlorine does not work in ice-cold water from mountain streams.
3. Organic content of the water: mud, decayed vegetation, or other suspended organic debris in water chemically combines with chlorine, making it unavailable as a disinfectant.
4. Chlorine contact time: the longer *Giardia* cysts are exposed to chlorine, the more likely the chemical will kill them.
5. Chlorine concentration: the higher the chlorine concentration, the more likely chlorine will kill *Giardia* cysts. Most water treatment facilities try to add enough chlorine to give a free (unbound) chlorine residual at the customer tap of 0.5 mg per liter of water.

The five variables above are so closely interrelated that improving another can often compensate for an unfavorable occurrence in one. For example, if chlorine efficacy is expected to be low because water is obtained from an icy stream, the chlorine contact time, chlorine concentration, or both could be increased. In the case of *Giardia*-contaminated water, producing safe drinking water with a chlorine concentration of 1 mg per liter and contact time as short as 10 minutes might be possible—if all the other variables were optimal (i.e., pH of 7.0, water temperature of 25ºC, and a total organic content of the water close to zero). On the other hand, if all of these variables were unfavorable (i.e., pH of 7.9, water temperature of 5ºC, and high organic content), chlorine concentrations in excess of 8 mg per liter with several hours of contact time may not be consistently effective. Because water conditions and water treatment plant operations (especially those related to water retention time, and therefore, to chlorine contact time) vary considerably in different parts of the United States, neither the USEPA nor the CDC has been able to identify a chlorine concentration that would be safe yet effective against *Giardia* cysts under all water conditions. Therefore, the use of chlorine as a preventive measure against waterborne giardiasis generally has been used under outbreak conditions when the amount of chlorine and contact time have been tailored to fit specific water conditions and the existing operational design of the water utility.

In an outbreak, for example, the local health department and water utility may issue an advisory to boil water, may increase the chlorine residual at the consumer's tap from 0.5 mg/L to 1 or 2 mg/L, and if the physical layout and operation of the water treatment facility permit, increase the chlorine contact time. These are emergency procedures intended to reduce the risk of transmission until a filtration device can be installed or repaired or until an alternative source of safe water (a well, for example) can be made operational.

The long-term solution to the problem of municipal waterborne outbreaks of giardiasis involves improvements in and more widespread use of filters in the municipal water treatment process. The sand filters most commonly used in municipal water treatment today cost millions of dollars to install, which makes them unattractive for many small communities. The pore sizes in these filters are not sufficiently small to remove a *Giardia* (6 to 9 micrometers X 8 to 12 micrometers). For the sand filter to remove *Giardia* cysts from the water effectively, the water must receive some additional treatment before it reaches the filter. The flow of water through the filter bed must also be carefully regulated.

An ideal prefilter treatment for muddy water would include sedimentation (a holding pond where large suspended particles are allowed to settle out by the action of gravity) followed by flocculation or coagulation (the addition of chemicals such as alum or ammonium to cause microscopic particles to clump together). The sand filter easily removes the large particles resulting from the flocculation/coagulation process, including Giardia cysts bound to other microparticulates. Chlorine is then added to kill the bacteria and viruses that may escape the filtration process. If the water comes from a relatively clear source, chlorine may be added to the water before it reaches the filter.

The successful operation of a complete waterworks operation is a complex process that requires considerable training. Troubleshooting breakdowns or recognizing the potential problems in the system before they occur often requires the skills of an engineer. Unfortunately, most small water utilities with water treatment facilities that include filtration cannot afford the services of a full-time engineer. Filter operation or maintenance problems in such systems may not be detected until a *Giardia* outbreak is recognized in the community. The bottom line is that although filtration is the best that water treatment technology has to offer for municipal water systems against waterborne giardiasis, it is not infallible. For municipal water filtration facilities to work properly, they must be properly constructed, operated, and maintained.

Whenever possible, persons in the out-of-doors should carry drinking water of known purity with them. When this is not practical, when water from streams, lakes, ponds, and other outdoor sources must be used, time should be taken to properly disinfect the water before drinking it.

Glaciation: In *earth science*, the covering and alteration of the earth's surface by glaciers including such effects as erosion, deposition, leveling, change of drainage systems, and creation of numerous lakes.

Glacier: In a *environmental science*, a huge mass of ice, formed on land by the compaction and recrystallization of snow that moves very slowly downslope or outward due to its own weight.

Glass Containers: For recycling purposes, containers like bottle sand jars for drinks, food, cosmetics, and other products. When being recycled, container glass is generally separated into color categories for conversion into new containers, construction materials or fiberglass insulation.

Glazing: Transparent or translucent material (glass or plastic) used to admit light and/or to reduce heat loss; used for building window, skylights, or greenhouse, or for covering the aperture of a solar collector.

Global Dimming: The gradual reduction in the amount of global direct irradiance at the earth's surface. A recent *USAToday* (2009) article read: Your eyes aren't deceiving you: skies are dimmer. Air pollution has caused skies above most the world's land areas to dim slightly over the past thirty years. Scientists found that most of the blame can be traced to aerosols—suspended airborne pollution—that are released from the burning of fossil fuels.

Before discussing global dimming it is important to have a fundamental understanding of albedo. *Albedo* (the ratio between the light reflected from a surface and the total light falling on it; that is, incident to it) always has a value less than or equal to 1. An object with a high albedo, near 1, is very bright, while a body with a low albedo, near 0, is dark. For example, freshly fallen snow typically has an albedo that is between 75 percent and 90 percent; that is, 75 percent to 95 percent of the solar radiation that is incident on snow is reflected. Thus, a surface cover such as clean snow has the ability to reflect solar radiation because of its high albedo. At the other extreme, the albedo of a rough, dark surface, such as a green forest, may be as low as 5 percent. The albedos of some common surfaces are listed in the Table. The portion of insolation not reflected

The ALBEDO of some surface types in % reflected

Surface	*Albedo*
Water (low sun)	10–100
Water (high sun)	3–10
Grass	16–26
Glacier ice	20–40
Deciduous forest	15–20
Coniferous forest	5–15
Old snow	40–70
Fresh snow	75–95
Sea ice	30–40
Blacktopped tarmac	5–10
Desert	25–30
Crops	15–25

is absorbed by the earth's surface, warming it. This means Earth's albedo plays an important part in the earth's radiation balance and influences the mean annual temperature and the climate on both local and global scales.

Global dimming (a term coined by Gerry Stanhill 2004) is the gradual reduction in the amount of global direct irradiance at the earth's surface that was observed for several decades (1950–1990). The effect varies by location; however, worldwide it has been estimated to be on the order of a 4 percent reduction over the 1960-1990 timeframe (Hegerl et al., 2007).

Global dimming is a result, along with the production of greenhouse gases, of fossil fuel production. More precisely, it is the by-products (i.e., sulfur dioxide, soot, and ash) produced during fossil fuel use that change the properties of clouds. Clouds are formed when water droplets are seeded by airborne particles, such as ash and pollen. Polluted clouds have a larger number of droplets than unpolluted clouds. This then makes those clouds more reflective of the sun's heat and energy which is therefore reflected back into space.

In addition to fossil fuel generated pollutants, it is thought that global dimming is also the result of increased presence of aerosol particles in the atmosphere caused by human action. However, since 1990 this trend has decreased because of the world-wide band on certain aerosol use in spray cans and other applications.

Global Distillation (or Grasshopper Effect): The slow geochemical process by which certain chemicals, most notably persistent organic pollutants (POPs), are transported from warmer to colder regions of the Earth.

Global Pollution, Causal Factors[2]: Before beginning a brief overview of global pollution problems, let us point out that many nations (in regards to environmental degradation attributed to pollution) lack the ability to measure environmental change, to monitor change brought about by pollution, and to anticipate the impact of interaction among factors such as population size, availability of natural resources (energy), supplies of food and water, and environmental quality. Let us also point out that the United States and most other nations fail to link the results of any existing projections to current decision-making.

It is also important to point out that when discussing or explaining causal factors, there are two levels of causation: proximate and ultimate causation. *Proximate causation* (closest cause) answers the question "How?" (How did the local stream become polluted with raw sewage?). This factor is causal at the immediate, direct level. But underlying that, there is a second, deeper cause. This level is referred to as the *ultimate causation* (distal cause) which answers the question "Why?" (Why was the stream vulnerable to sewage pollution?).

Frontier Mentality

It was one of the most famous trails ever. It was the longest overland trail in North America. In 1843, Americans were encouraged by the U.S. Government to travel the 2000 miles from Independence, Missouri to their final destination in the Oregon territory to homestead the land. By settling the land with more Americans than British, Oregon would belong to the United States.

The 2000-mile trek to Oregon Territory was no walk in the woods; it was a Great Migration of hordes of people traveling in covered wagons over mostly uncharted lands and trails (or so this was the case early on). The seemingly endless lines of prairie schooners snaked their way along the trail for more than six months before they arrived at their destinations.

The pioneers took what they could carry in their wagons. For example, it was not unusual for each wagon to be loaded with food that included: yeast for baking, crackers, cornmeal, bacon, eggs, dried meat, potatoes, rice, beans, and a big barrel of water. They would also take a cow if they had one. Pioneers made their own clothing so they brought cloth to sew, needles, thread, pins, scissors, and leather to fix worn-out shoes. They had to make their own repairs so they brought saws, hammers, axes, nails, string and knives.

Occasionally, and against the advice of the wagon master, pioneers would also pack away personal treasures; heirlooms such as pianos, family trunks and furniture, mirrors, assorted chinaware, silver, paintings, and other decorative household goods of the day. These items not only took up a lot of space within the wagon but also were clumsy to handle and added extra weight to the wagon.

It usually did not take too many miles before many of those who had packed too much started to drop off or discard various personal treasures along the trail. So many personal property items were discarded along the trail that by the late 1840s it was no longer necessary to follow the tracks of the wagons that had preceded them to follow and stay on the trail. All one needed do was to follow the strewn and rotting personal treasures (and assorted gravesites) that marked the trail. The parting with their personal treasures must have been heartbreaking to many of the pioneers as they made the difficult trek along the Oregon Trail to their new homesteads in the West.

For decades many have asked what was it that drove or enticed these people to undertake such a perilous adventure into lands unknown. The main draw, of course, was the promise of free land. For others it was freedom from the squalor of eastern city life or the drudgery of farm life in trying to eke out a living on worn-out soils

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[2] This section is from F.R. Spellman's (2009) *The Science of Environmental Pollution*, 2nd ed. Boca Raton, FL: CRC Press.

as tenet farmers that drove them to undertake the arduous western adventure. For others it was draw of wide open untamed spaces and the quest for adventure that was the drawing card.

This burning desire to conquer new lands, exploit it and become rich was like a powerful magnet attracting and aligning the metal filings of their mentalities. This outlook, mode or way of thought that drove the pioneers to trek across barren, rugged unforgiving wilderness is commonly called frontier mentality. That is, we live as though we can't effectively harm the natural world in a significant way because it is so big and we are so little, and if we damage one place, there will always be a new frontier to move to. The reality is that this mode of thought, this frontier mentality can be summed up today by simply stating that in the United States there has always been a Western frontier, a place to go and start over where there are riches just for the taking for hardy spirit and determined worker.

Let's get back to the pioneers' trek along the Oregon Trail, where they have marked the trail with ruts carved by their wagon wheels and various other signposts provided by their discarded personal goods. Again, after years of traversing the Oregon Trail, wagon train after wagon train discarded goods that dotted the prairie areas for miles. Humans have this tendency; that is, when some object they own is no longer needed or no longer pleases them or has outlived its usefulness they simply discard it—out of sight, out of mind. The pioneers' frontier mentality about the west being an expanse of wide open untamed space gave them no qualms about leaving their personal goods to rot along the trail—no qualms about polluting the landscape.

This same frontier mentality—"I no longer want or need it so I'll throw it away"—did not stop when the pioneers reached their destinations. The mindset alters a bit, but stops? No. It began with settlements which were almost exclusively built along rivers. The rivers provided a convenient means of disposing of the unwanted. Beginning with simple discards such as coffee grounds to more complex items such as white goods (washers, dryers, refrigerators, etc.), to even more complex and persistent chemical compounds and mixtures, the river was the repository of choice for all. The thinking was, of course, that no matter what you threw into the river the running water would purify itself every ten miles or so. But when there are several settlements with hundreds or thousands of people up and down the length of the river, the purification capacity of the running is exhausted. However, even though we are running out of pristine areas to pollute our throw-away society continues to be strongly influenced by our consumerism and excessive disposal of short-lived items.

Population Growth

A contributing factor to degradation of the world's environment is a result of over-population. How serious is over-population's impact on Earth's environment? With our population increasing rapidly, pollution is a problem of increasing proportions. To gain perspective on the over-population problem, let's take a look at the record. From about 2 billion in 1960 and around 3 billion in 1995, the world's population has rapidly grown to its current level of approximately 6.7 billion—and counting. The world's population increases by more than 80–90 million each year, and is projected to reach 10 billion by the year 2050, unless significant increases in the use of birth control occurs worldwide.

The opinion that population is the fundamental cause of environmental pollution is arguable. There are those, however, who hold that this opinion has merit. Garrett Harden, for example, writing in *Tragedy of the Commons* argues that there wouldn't be large problems with air pollution and land degradation if there weren't so many people. In illustrating his point, he uses the example of the "commons;" a resource (like air) owned by no one but utilized by many (a pasture, in the case of his example). He argues that, in a commons, there is no incentive to be conserving of resources, for he who is conserving "loses," and he extends the analogy to people's right to have as many children as they wish (Hardin 1986).

In contrast to Hardin's view, Barry Commoner holds that rather than too many people being blamed for environmental pollution, the real root cause of our environmental pollution problems is the inappropriate use of technology (Goldfarb 1989). He suggests that if we used resources more efficiently and cleanly, there wouldn't be problems even though there are some 5 billion (currently 6+ billion) of us.

Whenever we discuss differing opinions on any topic it is not too long before we run across an even more extreme position than those previously discussed. In this discussion about population being a possible contributor to environmental pollution, one such extreme opinion is expressed by noted economist, Julian Simon. Simon says that there are not too many people, and that the quality of life will only improve as the human population increases. This is because he believed that our supply of resources is virtually infinite, by virtue of an infinite capacity to substitute one resource for another. Simon said that it was only human ingenuity that limited our use of available resources as substitutes for exhausted resources. Hence, he argued that our condition will improve as population increases because there will be more clever people who will be able to arrive at innovative solutions (Simon 1980).

Along with the rapidly increasing population growth is a trend associated with population pressure: *population concentrations*. These population concentrations tend to exacerbate the pollution problem by increasing the level of pollution and the accompanying environmental degradation—increased deforestation, desertification, and soil erosion. Not only do population concentrations increase pollution, they also change the nature of the pollutants, by producing pollutants that become hazardous because of the sheer quantities involved, as is the case with all types of municipal wastes.

In recent decades, population concentrations within different regions of the world have demonstrated a certain dynamism—a trend toward increasingly rapid change. This problem is most apparent in developing countries, those which not only have rapid increases in overall population (compared to developed countries), but also have large populations that have been lured by economic opportunities to more congested areas. These congested areas typically are responsible for consuming more natural resources than rural areas, and produce mountains of waste products. Not only is more waste produced per capita than in rural areas, but in urban areas, this waste is also more hazardous. It places strains on the city's infrastructures, increasing demand on the city's ability to absorb and handle wastes. Pressure is also increased on the non-urban residents (the agrarian sector) to produce more food on less land, straining soil productivity and aggravating the agricultural pollution problem. The level of urbanization in developing countries increased at a rate of 4 to 1 as compared to the level of urbanization in developed countries from 1970 to 1995.

Another pollution-related problem associated with over-population and the unprecedented rush toward urbanization by developed and undeveloped countries can be seen in the difference in views on the pollution problem itself. Many industrialized countries have experienced industrialization for more than a century, and more importantly, have also felt the effects of pollution for a longer period of time. These developed countries have been modifying their polluting activities for several years, working to clean up existing pollution. Developing countries, where population is on the increase and economic resources limited, are inadvertently escalating activities that lead to pollution. Pollution and its effects take a back seat to more pressing concerns; namely, the daily struggle to survive. However, the problem is more than attitudinal—it is not just a free-will expression of the view that survival is number one, so pollution is not a concern. Historically, pollution problems are generally exacerbated by lack of financial resources and other economic problems.

One measure of the impact of global population is the fraction of the basic energy supply of all terrestrial animals directly consumed, co-opted, or eliminated by human activity. According to Vitousek et al. (1996), this figure has reached 40 percent. This level of exploitation could double as population growth meets expectations.

So, what is the bottom line on the impact of a growing population on environmental pollution (and the environment in general)? Well, using science and mathematics we can resort to a well-known equation, I = PAT, to help us answer this question. The impact (I) of any population can be expressed as a product of three characteristics: the population's size (P), its affluence or per-capita consumption (A), and the environmental damager (T) inflicted by the technologies used to extract resources and supply each unit of consumption (Daily and Ehrlich 1992).

$$I = PAT$$

Thus, human impact on the environment is a function of the population size, the level of resource use, and the environmental impacts associated with obtaining and using those resources. This formulation suggests that no one factor alone is responsible for our environmental problems. The relative important of the various factors will differ depending on the particular problem (Daily and Ehrlich 1992).

Development

Increasing worldwide population without a corresponding growth in development is virtually impossible—though the development is not always as we would envision it. As a case in point, consider the following comment by Reid et al. (1988). "The Third World is littered with the rusting good intentions of projects that did not achieve social and economic success; environmental problems are now building even more impressive monuments to failure in the form of sediment-choked reservoirs and desertified landscapes (p.1)."

One thing is certain; economic development cannot proceed without natural resources. The environmental degradation problem develops when natural resources are mismanaged, misused, wasted, and then exhausted. When this occurs, development leads to degradation—not only of the economic well-being of the inhabitants but of the environment as well. Soil, fresh water, and air are all, in one way or another, degraded.

Development and Soil Degradation

Soil degradation takes on many forms. Serious soil erosion, which commonly occurs in most the world's important agricultural regions (i.e., from overgrazing of animals; planting of a monoculture; row cropping; tilling or plowing; crop removal; land-use conversion), is one form of degradation. Another form, just as serious as erosion, develops from our waste disposal practices. In the past, throw-away societies were able to dispose of unwanted materials and wastes with little impact on the environment. Most of the waste products of the past were biodegradable, and Earth's natural systems were able to self-purify environmental mediums, including soil to an extent. The problem today is that we are introducing thousands of substances into our environment that are not biodegradable; instead, they are quite persistent and hang around for a very long time.

Development and Fresh Water Degradation

Poor management, lack of adequate conservation, pollution, and rapid local increases in demand create localized shortages of potable water worldwide. In developing nations, the problem is even worse; only about half of the people have access to safe drinking water. In the western world we have come to believe that the waterborne intestinal diseases that killed so many in the past are a problem of the past. This is not the case, however. In developing nations, an estimated ten million deaths each year result from waterborne intestinal diseases. Even in the United States, recent localized outbreaks of illness and death from *Cryptosporidium*- and *E. Coli*-contaminated water supplies have forced communities to recognize that we all are at risk at times.

These problems are not limited to developing nations. Surface and underground water supplies in industrial nations are being polluted by industrial and municipal wastes and by surface runoff from urban and agricultural areas. Heavy demands for water by industry, agriculture, and municipalities are rapidly depleting groundwater supplies.

Development and Atmospheric Air Degradation

We have all read news accounts on El Niño, El Niña, global climate change due to global warming, the greenhouse effect, acid rain, and damage to the ozone layer. The terms have become part of our common vocabulary. However, no consensus on what these issues will really mean to us has yet been reached. Note the two typical responses that we usually hear to arguments related to atmospheric degradation. One side argues that “the sky is falling” or “the world as we know it is doomed by pollution” or some other scare tactic to grab our attention and to provide lead-in to some political statement. The other side disputes the doom-and-gloom reports and states that all such statements are simply hyperbole and worse—that the real truth of the matter is that (in our opinion) our environment is doing just fine, thank you very much.

Global Positioning System (GPS): A navigation system using satellite signals to fix the location of a radio receiver on or above the earth’s surface.

Global Warming and Greenhouse Effect: Global warming is the long-term increase in the average temperature of the earth. To understand global warming it is important to understand “greenhouse effect.” Water vapor, carbon dioxide and other atmospheric gases (greenhouse gases) help warm the Earth. Earth’s average temperature would be closer to zero than its actual 60ºF, without the greenhouse effect. But the average temperature could increase, changing orbital climate, as gases are added to the atmosphere.

How does greenhouse effect actually work? Earth’s greenhouse effect, of course, took its name because of similarity of effect. Because greenhouse glass walls and ceilings are largely transparent to short-wave radiation from the sun, surfaces and objects inside the greenhouse absorb the radiation. The radiation, once absorbed, transforms into long-wave (infrared) radiation (heat), and radiates back from the greenhouse interior. But the glass prevents the long-wave radiation from escaping again, absorbing the warm rays. The interior of the greenhouse becomes much warmer than the air outside, because of the heat trapped inside.

Earth and its atmosphere undergoes a process very similar to this. Short-wave and visible radiation reaching Earth is absorbed by the surface as heat. The long heat waves radiate back out toward space, but the atmosphere absorbs many of them, trapping them. This natural and balanced process is essential to supporting our life systems on earth. Changes in the atmosphere can radically change the amount of absorption (therefore the amount of heat) the earth’s atmosphere retains. In recent decades, scientists speculate that various air pollutants have caused the atmosphere to absorb more heat. At the local level with air pollution, the greenhouse effect causes heat islands in and around urban centers, a widely recognized phenomenon.

The main contributors to this effect are the greenhouse gases: water vapor, carbon dioxide, carbon monoxide, methane, volatile organic compounds (VOCs), nitrogen oxides, chlorofluorocarbons (CFCs), and surface ozone. These gases cause a general climatic warming by delaying the escape of infrared radiation from the earth into space. Scientist’s stress this is a natural process. Indeed, if the “normal” greenhouse effect did not exist, the earth would be 33ºC cooler than it presently is (Hansen et al. 1986).

Human activities are now rapidly intensifying the natural phenomenon of Earth’s greenhouse effect, which may lead to problems of warming on a global scale. Much debate, confusion, and speculation about this potential consequence is underway, because scientists cannot yet agree about whether the recently perceived worldwide warming trend is because of greenhouse gases, due to some other cause, or whether it is simply a wider variation in the normal heating and cooling trends they have been studying. Unchecked, the greenhouse effect may lead to significant global warming, with profound effects upon our lives and our environment. Human impact on greenhouse effect is real; it has been measured and detected. The rate at which the greenhouse effect is intensifying is now more than five times what it was during the last century (Hansen et al. 1989).

Supporters of the global warming theory base their assumptions on man’s altering of the Earth’s normal and necessary greenhouse effect. The human activities they blame for increases of greenhouse gases include burning of fossil fuels, deforestation, and use of certain aerosols and refrigerants. These gases have increased how much heat remains trapped in the earth's atmosphere, gradually increasing the temperature of the whole globe.

From information based on recent or short-term observation, many scientists note that the last decade has been the warmest since temperature recordings began in the late nineteenth century. They see that the general rise in temperature over the last century coincides with the Industrial Revolution and its accompanying increase in fossil fuel use. Other evidence supports the global warming theory. In places that are synonymous with ice and snow—the Arctic and Antarctica, for example—we see evidence of receding ice and snow cover.

Trying to pin down definitively whether or not changing our anthropogenic activities could have any significant effect on lessening global warming, though, is difficult. Scientists look at temperature variations over thousands and even millions of years, taking a long-term view at Earth's climate. The variations in Earth's climate are wide enough that they cannot definitively show that global warming is anything more than another short-term variation. Historical records that have shown the earth's temperature does vary widely, growing colder with ice ages and then warming again, and because we cannot be certain of the causes of those climate changes, we cannot be certain of what appears to be the current warming trend.

Still, debate abounds for the argument that our climate is warming and our activities are part of the equation. The 1980s saw nine of the twelve warmest temperatures ever recorded, and the earth's average surface temperature has risen approximately 0.6ºC (1ºF) in the last century (USEPA, 1997). *Time* magazine (1998) reports that scientists are increasingly convinced that because of the buildup in the atmosphere of carbon dioxide and other gases produced in large part by the burning of fossil fuels, the earth is getting hotter. Each month from January through July 1998, for example, set a new average global temperature record, and if that trend continued, the surface temperature of the earth could rise by about 1.8º to 6.3ºF by 2100. At the same time, others offer as evidence that the '80s also saw 3 of the coldest years: 1984, 1985, and 1986.

Assuming that we are indeed seeing long-term global warming, we must determine what causes it. But again, we face the problem that scientists cannot be sure of the greenhouse effect's precise causes. Our current, possible trend in global warming may simply be part of a much longer trend of warming since the last ice age. We have learned much in the past two centuries of science, but little is actually known about the causes of the worldwide global cooling and warming that sent the earth through major and smaller ice ages. The data we need reaches back over millennia. We simply do not possess enough long-term data to support our theories.

Currently, scientists can point to six factors they think could be involved in long-term global warming and cooling.

1. Long-term global warming and cooling could result if changes in the earth's position relative to the sun occur (i.e., the earth's orbit around the sun), with higher temperatures when the two are closer together and lower when farther apart.
2. Long-term global warming and cooling could result if major catastrophes (meteor impacts or massive volcanic eruptions), which throw pollutants into the atmosphere that can block out solar radiation, occur.
3. Long-term global warming and cooling could result if changes in albedo (reflectivity of earth's surface) occur. If the earth's surface were more reflective, for example, the amount of solar radiation radiated back toward space instead of absorbed would increase, lowering temperatures on earth.
4. Long-term global warming and cooling could result if the amount of radiation emitted by the sun changes.
5. Long-term global warming and cooling could result if the shape and relationship of the land and oceans change.
6. Long-term global warming and cooling could result if the composition of the atmosphere changes.

"If the composition of the atmosphere changes." This final factor, of course, defines our present concern: have human activities had a cumulative impact large enough to affect the total temperature and climate of Earth? Right now, we cannot be sure. The problem concerns us, and we are alert to it, but we are not certain, because, again, we do not know what we do not know about global warming or climate change.

However, we can expect winters to be longer, if global warming is occurring, and summers hotter. Over the next hundred years, sea level will rise as much as a foot or so. Is this bad? Depends upon where you live. However, keep in mind that not only could sea level rise 1 foot over the next hundred years, it could continue to do so for many hundreds of years.

Another point to consider is that we have routine global temperature measurements for only about hundred years. Even these are unreliable, because instruments and methods of observation changed over that course of time.

The only conclusion we can safely draw about climate and climate change is that we do not know if drastic changes are occurring. We could be at the end of a geological ice age. Evidence indicates that during interglacials, a period of temperatures increase occurs before they plunge. Are we ascending the peak temperature range?

We have no way to tell. To what extent does our human activity impact climate? Have anthropogenic effects become so marked that we have affected the natural cycle of ice ages (which lasted for roughly the last five million years)? Maybe we just have a breathing spell of a few centuries before the next advance of the glaciers. Many have raised the issue: If this is the case, if we are at the apogee of the present inter-glacial, then we have to ask ourselves a few questions: Is global warming the lesser of two evils when compared to the alternative, global cooling? If we are headed into another glacial freeze, in this era of expanding population and decreasing resources, where will we get the energy to keep all of us warm?

Global Warming Potential: The ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide. FCF-12, for example, has a GWP of 8,500, while water has a GWP of zero.

Glovebag: A polyethylene or polyvinyl chloride bag-like enclosure affixed around an asbestos-containing source (most often thermal system insulation) permitting the material to be removed while minimizing release of airborne fibers to the surrounding atmosphere.

Glycolysis: One of three phases of the catabolism of glucose to carbon and water process.

Goggles: A wraparound, protective device that fits the face, surrounding the eyes in order to shield them from impact, splash and vapor hazards. Goggles are available non-vented or with direct or indirect vents.

Gooseneck: A portion of a water service connection between the distribution system water main and a meter. Sometimes called a pigtail.

Gout: A metabolic disease marked by a painful inflammation of the joints, deposits of uric acid salts in and around the joints, and usually an excessive amount of uric acid in the blood.

Grab Sample: An individual discrete sample collected over a period of time not exceeding fifteen minutes.

Gradient of Head: The gradient of the head is a mathematical term which refers to the vector denoted by h or grad h, whose magnitude is equal to the maximum rate of change to head and whose direction is that in which the maximum rate of increase occurs. The hydraulic gradient and the gradient of the head are equal but of opposite sign.

Grain Loading: The rate at which particles are emitted from a pollution source. Measurement is made by the number organisms per cubic foot of gas emitted.

Gram: The basic unit of weight in the metric system; equal to 1/1000th of a kilogram; approximately 28.5 grams equal one ounce.

Granular Activated Carbon (GAC) Treatment: A filtering system often use din small water system sand individual homes to remove organics. Also used by municipal water treatment plans. GAC can be highly effective in lowering elevated levels of radon in water.

Grasscycling: Source reduction activities in which grass clippings are left on the lawn after mowing.

Grassed Infiltration Area: Area with vegetative cover where runoff water infiltrates into the soil.

Grassed Waterway: Natural or constructed watercourse or outlet that is shaped or graded and established in suitable vegetation of the disposal of runoff water without erosion.

Graticule: Is the spherical coordinate system based on lines of altitude and longitude.

Gravimetry: The use of precisely measured gravitational force to determine mass differences that can be correlated to subsurface geology.

Gravity: The force of attraction that arises between objects by virtue of their masses. On Earth, gravity is the force of attraction between any object in the earth's gravitational field and the earth itself.

Gravity Settlers: Used for the removal of solid and liquid waste materials from gaseous streams. Consists of an enlarged chamber in which the horizontal gas velocity is slowed, allowing particles to settle out by gravity.

Gravity Thickener: *Gravity thickening* is most effective on primary sludge. In operation, solids are withdrawn from primary treatment (and sometimes-secondary treatment) and pumped to the thickener. The solids buildup in the thickener forms a solids blanket on the bottom. The weight of the blanket compresses the solids on the bottom and "squeezes" the water out. By adjusting the blanket thickness the percent solids in the underflow (solids withdrawn from the bottom of the thickener) can be increased or decreased. The supernatant (clear water) which rises to the surface is returned to the wastewater flow for treatment.

Daily operations of the thickening process include pumping, observation, sampling and testing, process control calculations, maintenance and housekeeping.

Note: The equipment employed in thickening depends on the specific thickening processes used.

Equipment used for gravity thickening consists of a thickening tank, which is similar in design to the settling tank used in primary treatment. Generally the tank is circular and provides equipment for continuous solids collection. The collector mechanism uses heavier construction than that in a settling tank because the solids being moved are more concentrated. The gravity thickener pumping facilities (i.e., pump and flow measurement) are used for withdrawal of thickened solids.

Performance of gravity thickeners (i.e., the solids concentrations achieved) typically results in producing 8–10 percent solids from primary underflow, 2–4 percent solids from waste activated sludge, 7–9 percent solids from trickling filter residuals and 4–9 percent from combined primary and secondary residuals.

The performance of gravity thickening processes depends on various factors, including

- type of sludge
- condition of influent sludge
- temperature
- blanket depth
- solids loading
- hydraulic loading
- solids retention time
- hydraulic detention time

Gray Water: Domestic wastewater composed of wash water from kitchen, bathroom, and laundry sinks, tubs, and washers.

Graying Workforce: Increasing attention is paid to the safety and health of older workers and the relationship between work and aging. Wegman (2000) points out the important issues:

- How age affects workers' abilities to meet job demands;
- How job-related factors affect the aging process;
- How to help older workers maintain and update working skills and knowledge;
- How age determines retirement decisions;
- How better to use the expertise and wisdom of older workers;
- How to design work to enable people to retire in optimal health.

According to *Maturity Works* (2003)

- 16 million Americans age 55 and older work or are seeking work;
- Between 2000 and 2010, the fastest growing age group will be those between 55 and 64;
- In the age group of 70 to 74, one in eight is employed full- or part-time.

Even though no proven correlation exists between worker aging and job performance, safety engineers should be aware of the effects of aging on workers. For example, natural aging can affect worker hearing, eyesight, strength, flexibility, and reflexes. In addition, older workers may have fitness problems; lack endurance, stamina, and agility; and have balance and hand-eye coordination problems. Another serious safety concern may be the aging workers' loss of gripping strength. For example, the typical thirty-year-old has right hand gripping strength of approximately 99 pounds, while the typical sixty-year-old may have a right hand gripping strength of only 85 pounds. This loss of gripping strength because of the natural aging process could lead to serious safety concerns in the workplace. Natural increases in blood pressure problems, in cancer/heart condition risks; and in burnout risks also are concerns for the safety engineer as workers age. The safety engineer must also be aware of the other changes in workers caused by the natural aging process. Older workers may also experience extreme heat and cold sensitivity problems, for example. More importantly, many older workers take prescribed medications; the effects of these drugs could affect their work.

Not all the news that is related to natural aging is bad, of course. While true that the average worker 55 and older usually gains weight and wrinkles, it is also true that older workers usually have a wealth of experience. Older workers are usually wiser, have more self-control, greater confidence, and the desire to instruct or mentor. They are also more stable and have strong values. According to AARP (1998), older workers tend to be more reliable than younger workers, and tend to have a higher level of commitment to the organization than younger workers do. Again, notwithstanding the preceding facts and statistics, extensive research has found no direct, measurable relationship between age and on the job performance.

According to U.S. Bureau of Labor Statistics (2003),

- older workers tend to take twice as long to recover from injuries;
- older workers are one third less likely than younger workers to be hurt severely enough to miss work;
- older workers are more likely to die of injuries than younger workers.

The goal of safety professionals and workers alike should be to minimize the work-related consequences of any chronic health conditions as well as the risk of on the job injury. Compliance with OSHA requirements is a minimum first step. Employer-sponsored health and wellness programs for workers of all ages can enhance health status and performance. Implementation of an ergonomics program can also enhance health status and performance and result in cost savings for employers.

Based on over hundred studies, OSHA in (undated) reports states that programs and interventions studied resulted in an average reduction of 67 percent in musculoskeletal injury rates and 74 percent reduction in lost workdays. The number of workers' compensation claims fell by an average of 74 percent and the cost of claims by 71 percent.

Environmental professionals can gain insight into where workforce interventions and risk management strategies might prove fruitful from age audits of their workforce, as well as from assessments of workers' compensation records (Douglas 2000). Appropriate intervention strategies can be developed for the entire workplace, or for categories of workers (e.g., assembly line workers) at particular risk rather than directed toward specific age groups or individuals. In job placement, safety engineers, in conjunction with human resource practitioners, especially need to consider matching work tasks with a worker's personal characteristics and skills, thus improving workplace conditions for all age groups.

Green Pricing/Marketing: In the case of renewable electricity, green pricing represents a market solution to the various problems associated with regulatory valuation of the non-market benefits of renewables. Green pricing programs allow electricity customers to express their willingness to pay for renewable energy development through direct payments on their monthly utility bills.

Green Zone: An area where contamination with chemical, biological, radiological, or nuclear (CBRN) agents is unlikely. This zone covers the area beyond the expected significant dispersal range of the initial event and secondary contamination range caused by traffic and emergency responders.

Greenhouse Effect: The trapping of heat in the atmosphere. Incoming short-wavelength solar radiation penetrates the atmosphere, but the longer-wavelength outgoing radiation is absorbed by water vapor, carbon dioxide, ozone, and several other gases in the atmosphere and is reradiated to the earth, causing an increase in atmospheric temperature.

Greenhouse Gas: Gases that trap the heat of the sun in the earth's atmosphere, producing the greenhouse effect. The two major greenhouse gases are water vapor and carbon dioxide. Other greenhouse gases include methane, ozone, chlorofluorocarbons, and nitrous oxide.

Greensand: Used as a water softener.

Greywater: Wastewater from clothes washing machines, showers, bathtubs, hand washing, lavatories, and sinks.

Grid: The layout of an electrical distribution system.

Grid Sampling: In grid sampling, an imaginary grid system is placed over the study area. The grids may be numbered, and random numbers are generated to determine which grids should be sampled. This type of sampling method allows for quantitative analysis because the grids are all of a certain size. For example, to sample a stream for benthic macroinvertebrates, grids that are 0.25 m^2 may be used. Then, the weight or number of benthic macroinvertebrates per square meter can be determined.

Grinder Pump: A mechanical device that shreds solids and raises sewage to a higher elevation through pressure sewers.

Grit: In wastewater treatment, heavy inorganic solids, such as sand, gravel, eggshells, or metal filings.

Grit Channel: Unit treatment process designed to remove grit from wastewater stream.

Gross Alpha/Beta Particle Activity: The total radioactivity due to alpha or beta particle emission as inferred from measurements on a dry sample.

Ground (electrical): Ground or the earth may be the reference point in an electrical circuit from which voltage are measured, or a common return path for electric current, or a direct physical connection to the earth.

Ground Cover: Plants grown to keep soil from eroding.

Ground Fault Circuit Interrupter (GFCI): Ground Fault Circuit Interrupters (GFCIs) are designed to open the circuit before a fault path through the operator can cause harm, at levels as low as five milliamps (5 Ma). A GFCI compares current normally flowing through the power distribution wire and the grounded neutral wire of a circuit. The current flowing through one must pass through the other for the circuit to work. If current is not equal, some electrical energy is flowing to ground through other than the normal route, perhaps through a person. When the current is not equal, the GFCI detects this current differential and shuts off the current.

Though GFCIs protect normal 115 volt circuits where users can form a ground with energized equipment, they do not work on line-to-line connections found in distribution of 220 volts and higher. GFCIs are required by the NEC for outdoor receptacles or circuits and for bathrooms and other locations.

Grounding and Bonding: 1. An essential aspect of a safe electrical system. Everything that might come in contact with a live system should be maintained at ground potential. Protective grounding must be capable of conducting the maximum fault current that could flow at the point of ground for the time necessary to clear the fault. 2. Grounding and bonding control the electrical potential between two bodies. If a difference of potential occurs between two bodies, a conductor between them allows charge or current to flow. That flow may be dangerous, particularly as a source of ignition.

R. H. Lee in *Electrical Grounding: Safe or Hazardous* (162, 1969) and W. Hammer in *Occupational Safety Management and Engineering* (pp. 362-363, 1989) provide important information on grounding and bonding. NOTE: The information provided in the following assumes that the reader has some fundamental knowledge of electrical terms and their meaning.

The earth acts as an infinite store from which electrons (current flow) can be drawn, or to which they can return. Providing a path from where it exists to earth can eliminate any undesirable excess or deficiency. Gaining electrons can then neutralize positive ions in a system; electrons can be conducted to earth (called "earthing" in some countries). In the United States the term "grounding" is preferred, and the path to earth or the earth itself is a "ground." In some instances (such as in electronic equipment), a massive metallic body acts as the reservoir of electrons and ions (the ground) in place of the earth.

Grounds can be designed and installed into a system or they can be accidental. Unless noted otherwise, the word "ground" used here indicates one of design. Installed grounds are basically safety mechanisms to prevent (1) overloading of circuits and equipment which would destroy them or shorten their lives, (2) shock to personnel, and (3) arcing or sparking that might act as an ignition source.

Grounds may protect a system, equipment, or personnel. Certain designs used on high-voltage transmission lines are sophisticated types which follow the standards set by the American Institute of Electrical Engineers or other codes. The ground systems and standards of the National Electrical Code (NEC), which apply to buildings and related facilities, are more common.

Safety engineers should know several terms used in the NEC that are related to grounding and bonding. System ground refers to an electric circuit and is designed to protect conductors (wires/wiring) for a transmission, distribution or wiring system.

The term voltage to ground is often used in electrical codes. It indicates the maximum voltage in a grounded circuit measured between the ground wire and a wire that is not grounded. Where a ground is not used, voltage to ground indicates the maximum voltage between any two wires. The wire that connects the circuit to earth is the grounding wire or ground; the wire to which it is connected is the grounded wire.

Probably the simplest way in which to illustrate the principles of grounding is to use a typical three-wire system as an example. In a three-wire system, current generally flows along two wires—the third is neutral. In distribution systems for building and related facilities, the neutral wire is always the one grounded when grounding is installed. High-voltage transmission lines sometimes ground all three wires, but this is less common. The types of grounding systems that have been used on transmission lines include:

- Solid grounds: The neutral wire is grounded without any impedance that might restrict current flow.
- Resistance grounds: The neutral wire is connected to ground through high resistance at a transformer.
- Reactance grounds: The neutral wire is connected to ground through impedance that is principally reactance.
- Capacitance grounds: Each line of a circuit is connected to a capacitor; the other side of each capacitor is grounded.
- Resonant grounds: This is a tuned, parallel system that uses capacitance grounds and a ground from a transformer neutral through an induction coil.

Solid grounds are the most commonly used, especially in interior electrical systems of buildings. Resistance and capacitance grounds are designed into most electronic equipment. These types of grounds involve circuitry comparable to two-wire systems in which it is necessary to maintain potentials within prescribed limits.

One purpose of grounding the neutral in a three-wire system is to activate over-current protection devices before damage is done when a fault occurs. Should one of the two wires that normally carry current be broken or accidentally grounded, current will flow through the neutral, through the installed ground, and back to the power source. This short circuit opens the protection devices and de-energize the affected portion of the system. Where the neutral is not grounded, accidental grounding of one of the other wires will cause an increase in voltage to ground of the remaining system. The definitions of voltage to ground for grounded and ungrounded systems will illustrate this point. According to these, a 220-volt three-wire grounded neutral system will have a voltage between any two wires. The excessively high voltages may cause burnout of equipment, burning or breakdown of insulation, arcing and sparking, and shock to personnel in contact with metal energized through the breaks.

Other possibilities exist by which an excessively high voltage can be produced that would create similar hazards if the system is not grounded. A fault in a step-down transformer could result in the distribution system potential, or part of it greater than normal being applied to a building wiring system. An accidental connection between the two systems would produce the same result. Where grounds existed, the overcurrent protection devices de-energize and safeguard the system.

Equipment grounds: may be used on the metal parts of a wiring system, such as the conduit, armor, switch boxes, and connected apparatus other than the wire, cable, or other circuit components. They may also be provided for equipment such as metal tables and cabinets that might come in contact with an energized circuit or source of electrical charges. Equipment on which undesirable charges may be induced or generated should also be grounded.

The metal of electrical equipment may come in contact with an energized circuit whose insulation is deteriorated or cut, or through which arcing can take place. A person may then touch the metal surface, inadvertently receiving a shock. The degree of shock depends on whether the equipment was grounded. If it was not, the person in contact with the metal would act as a ground, the current passing through his body. If the equipment was grounded, the person might or might not receive a shock at all. If current did pass through this body, the amount would be inversely proportional to the resistance of his body compared to that of the equipment ground. If the resistance of his body were high enough, no current would pass.

Bonding ensures that all major parts of a piece of equipment are linked to provide a continuous path to ground. A bond is a mechanical connection that provides a low-resistance path to current flow between two surfaces that are physically separated or that may become separated. A bond can be permanent, such as one in which the connection is welded or brazed to the two surfaces, or it may be semi-permanent, bolted or clamped where required.

Where permanent types are used, the parts themselves can be joined and narrow gaps filled with weld or brazing metal. Where separation is wider, a strip of metal can be welded or brazed at both ends across the gap. Bonds connecting one vibrating part to another part that may or may not vibrate should be of a flexible material that will not fail under vibration. Corrosion because of the joining of dissimilar metals may cause the electrical resistance across the bond to increase. This is especially noticeable in humid or corrosive atmospheres. The types of metal for the bond and its fastenings must therefore be selected with care.

Grounding and bonding requirements

Grounds and bonds should:

- Be permanent wherever possible.
- Have ample capacity to conduct any possible current flow. (Note: a ground should not normally be designed to be part of a current-carrying circuit.)
- Have as low impedance as possible.
- Be continuous, and wherever possible, be made directly to the basic structure rather than through other bonded parts.
- Be secured so that vibration, expansion, contraction or other movement will not break the connection, or loosen so that the resistance varies.
- Have connections located in protected areas, and where accessible for inspection or replacement.
- Not impede movement of movable components.
- Not be compression-fastened through nonmetallic materials.
- Not have dissimilar metals in contact.
- Have metals selected to minimize corrosion.

Grounding is not always advantageous in all cases; some electrical systems are safer ungrounded.[3] Some electrical systems (necessarily of limited extent), must be left ungrounded for safety reasons. For example, the electrical system of a hospital operating room is purposely ungrounded because a spark from an insulation failure would otherwise ignite the anesthesia-permeated atmosphere. When ungrounded, an insulation failure “to ground” produces no current low and hence no spark, no ignition and no explosion. Electric blasting caps present a similar condition; a short-circuit current returning through the earth could fire the caps if their two connecting wires touched the earth more than a few inches apart.

Groundwater: Water filling all the unblocked pores of underlying material below the water table. This water is part of the precipitation that falls on land infiltrates the land surface, percolates downward through the soil under the force of gravity, and becomes groundwater. Groundwater, like surface water, is extremely important to the hydrologic cycle and to our water supplies. Almost half of the people in the United States drink public water from groundwater supplies. Overall, more water exists as groundwater than surface water in the United States, including the water in the Great Lakes. But sometimes, pumping it to the surface is not economical, and in recent years, pollution of groundwater supplies from improper disposal has become a significant problem.

We find groundwater in saturated layers called aquifers under the earth’s surface. Three types of aquifers exist: unconfined, confined, and springs.

Aquifers are made up of a combination of solid material such as rock and gravel and open spaces called pores. Regardless of the type of aquifer, the groundwater in the aquifer is in a constant state of motion. This motion is caused by gravity or by pumping.

The actual amount of water in an aquifer depends upon the amount of space available between the various grains of material that make up the aquifer. The amount of space available is called porosity. The ease of movement through an aquifer is dependent upon how well the

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[3] R.H. Lee, 1971. Electrical Safety In Industrial Plants, *IEEE Spectrum*, June.

pores are connected. For example, clay can hold a lot of water and has high porosity, but the pores are not connected, so water moves through the clay with difficulty. The ability of an aquifer to allow water to infiltrate is called permeability.

The aquifer that lies just under the earth's surface is called the zone of saturation, unconfined aquifer. The top of the zone of saturation is the water table. An unconfined aquifer is only contained on the bottom and is dependent on local precipitation for recharge. This type of aquifer is often called a water table aquifer.

Unconfined aquifers are a primary source of shallow well water. These wells are shallow (and not desirable as a public drinking water source). They are subject to local contamination from hazardous and toxic materials—fuel and oil, and septic tanks and agricultural runoff providing increased levels of nitrates and microorganisms. These wells may be classified as groundwater under the direct influence of surface water (GUDISW), and therefore require treatment for control of microorganisms.

A confined aquifer is sandwiched between two impermeable layers that block the flow of water. The water in a confined aquifer is under hydrostatic pressure. It does not have a free water table.

Confined aquifers are called artesian aquifers. Wells drilled into artesian aquifers are called artesian wells and commonly yield large quantities of high quality water. An artesian well is any well where the water in the well casing would rise above the saturated strata. Wells in confined aquifers are normally referred to as deep wells and are not generally affected by local hydrological events.

A confined aquifer is recharged by rain or snow in the mountains where the aquifer lies close to the surface of the earth. Because the recharge area is some distance from areas of possible contamination, the possibility of contamination is usually very low. However, once contaminated, confined aquifers may take centuries to recover.

Groundwater naturally exits the earth's crust in areas called springs. The water in a spring can originate from a water table aquifer or from a confined aquifer. Only water from a confined spring is considered desirable for a public water system.

Generally, groundwater possesses high chemical, bacteriological, and physical quality. When pumped from an aquifer composed of a mixture of sand and gravel, if not directly influenced by surface water, groundwater is often used without filtration. It can also be used without disinfection if it has a low coliform count. However, as mentioned, groundwater can become contaminated. When septic systems fail, saltwater intrudes, improper disposal of wastes occurs, improperly stockpiled chemicals leach, underground storage tanks lead, hazardous materials spill, fertilizers and pesticides are misplaced, and when mines are improperly abandoned, ground water can become contaminated.

To understand how an underground aquifer becomes contaminated, you must understand what occurs when pumping is taking place within the well.

When groundwater is removed from its underground source (i.e., from the water-bearing stratum) via a well, water flows toward the center of the well. In a water table aquifer, this movement causes the water table to sag toward the well. This sag is called the cone of depression. The shape and size of the cone depends on the relationship between the pumping rate and the rate at which water can move toward the well. If the rate is high, the cone is shallow, and its growth stabilizes. The area that is included in the cone of depression is called the cone of influence, and any contamination in this zone will be drawn into the well.

Groundwater, Confined: Groundwater under pressure significantly greater than atmospheric with its upper limit the bottom of a bed with hydraulic conductivity distinctly lower than that of the material in which the confined water occurs.

Groundwater Discharge: Groundwater entering near coastal waters which has been contaminated by landfill leachate, deep well injection of hazardous wastes, septic tanks, etc.

Groundwater Disinfection Rule: A 1996 amendment of the Safe drinking water Act requiring EPA to promulgate national primary drinking water regulations requiring disinfection as for all public water system, including surface water and groundwater systems.

Groundwater Recharge: Inflow of water to a groundwater reservoir from the surface. Infiltration of precipitation and its movement to the water able is one form of natural recharge. Also, the volume of water added by this process.

Groundwater Table: Surface between the zone of saturation and the zone of aeration; the surface of an unconfined aquifer.

Groundwater Unconfined: Water in an aquifer that has a water table that is exposed to the atmosphere.

Groundwater Under the Direct Influence of Surface Water (GUDISW): Water under the direct influence of surface water (GUDISW) is not classified as a groundwater supply. A supply designated as GUDISW must be treated under the state's surface water rules rather than the groundwater rules.

The Surface Water Treatment Rule of the Safe Drinking Water Act requires each site to determine which groundwater supplies are influenced by surface water (i.e., when surface water can infiltrate a groundwater supply and could contaminate it with Giardia, viruses, turbidity, and organic material from the surface water source). To determine whether a groundwater supply is under the direct influence of surface water, USEPA has developed procedures that focus on significant and relatively rapid shifts in water quality characteristics, including turbidity, temperature, and pH. When these shifts can be closely correlated with rainfall or other surface water conditions, or when certain indicator organisms associated with surface water are found, the source is said to be under the direct influence of surface water.

Growth Curve (Bacteria): Plotting of bacterial growth cycles. The curve is divided into four phases designated as lag, exponential, stationary, and death. The lag phase, characterized by little or no growth, corresponds to an initial period of time when bacteria are first inoculated into a fresh medium. After the bacteria have adjusted to their new environment, a period of rapid growth (the exponential phase) follows, During this time, conditions are optimal and the population doubles with great regularity. As the bacteria food supply begins to be depleted, or as toxic metabolic products accumulate, the population enters the no-growth, or stationary phase. Finally, as the environment becomes more and more hostile, the death phase is reached and the population declines.

Guano: A substance composed chiefly of the dung of sea birds or bats, accumulated along certain coastal areas or in caves, and used as fertilizer.

Guar: Organic powder thickener typically used to make viscous fracturing fluids, completely soluble in hot and cold water insoluble in oils, grease and hydrocarbons.

Gum Bed: In environmental science, surface oil seeps that have congealed.

H

ha: Hectare; an area 100 meters square, or about 2.5 acres.

Haber-Bosch Process: In *materials engineering*, widely used industrial process for the synthesis of ammonia by direct combination of nitrogen and hydrogen in the presence of iron catalysts.

Habitat: The place or type of place where an organism or community of organisms naturally or normally thrives.

Habitat Indicator: A physical attribute of the environment measured to characterize conditions necessary to support an organism, population, or community in the absence of pollutants; e.g., salinity of estuarine waters or substrate type in steams or lakes.

Half-Life ($t_{1/2}$): Length of time required for a radioactive substance to lose on-half of its activity by radioactive decay.

Halo: Bromine-containing compounds with long atmospheric lifetimes whose breakdown in the stratosphere causes depletion of ozone. Halons are used in firefighting.

Hammer Mill: A high-speed machine that uses hammers and cutters to crush, grind, chip, or shred solid waste.

Handheld Devices: Handhelp devices offer low cost, ease of use, and portable convenience. While contemporary laptops can have all the power and hard disk capacity of an office PC, a handheld device is a palmtop whose weight is measured in ounces, not pounds. Limited to one or a few dedicated purposes, the rechargeable batteries last three to four times longer than a PC's. Dedicated handhelds (the UPS guy's delivery pad, for example, or a bar-code reader) are less attractive to casual theft than laptops, too. Handheld devices are a highly effective addition to mobile working practices, especially for data collection. Administrators and sales staff (and others) love their PDAs for the huge amount of useful data such devices can make portable.

The combination of low cost, portability and high functionality makes handheld computing equipment more and more attractive for companies with the need for a mobile workforce. However, many IT departments haven't fully incorporated handhelds into computer and data security programs. A handheld computing component that addresses personnel, technical, and security issues should be included for facilities that issue such equipment.

Handheld equipment's small size doesn't necessarily mean low capacity. I-Pods (now used mostly for music but capable of a startling array of functions for other purposes) can hold 30 gigabytes of memory in a case about the size of but much thinner than a pack of cigarettes. The large data storage capacity of both laptops and handhelds means that staff members have the potential of carrying large amounts of company information around with them. Best practice is to upload data to the server on a regular basis (determined by value of the data and opportunity), not storing it for long periods of time, so that any loss is mostly equipment loss, not data loss. Collecting the data again can be impossible (for time-sensitive measurements, for example) or difficult (would that UPS driver have to go back and collect all those signatures again?). The involved costs are hard to accurately calculate.

Other than loss or theft, the biggest problem areas for handhelds are in file transfer and synchronization. Tools that enable all devices to synchronize to a single server means that information available to mobile users can be easily monitored. Password protection on many devices is two-level—a password for the device and one for individual applications or files is common.

So far, handheld devices are not heavily affected by computer viruses. Currently, only a few Trojans affect them, most of them irritating but harmless—like randomly switching backlights on and off, or post nasty and hard to irradicate screen messages. However, sooner or later, creating more troublesome handheld-directed trouble will occur to hackers, so keeping an eye out for information on new vulnerabilities is important. Many hardware vendors have established partnerships with leading anti-virus organizations already.

Equipment can be infected by malicious code through email attachments or during synchronization with infected systems. Anti-virus software at all synchronization points on the network cuts down the possibility of mobile workers infecting the corporate system and vice versa. In fact, some operating system can be made resistant to virus attacks, though this can restrict the functionality of the device—in general, the more you increase the security, the more you restrict what the user can do. (Some of the previous information came from *A Guide to Rolling Out Handhelds in the Corporate Environment).*

HAP: Hazardous air pollutant.

Hard Water: Alkaline water containing dissolved salts that interfere with some industrial processes and prevent soap from sudsing.

Hardening: The process of identifying and fixing vulnerabilities on a system.

Hardness: 1. The property in steel that resists indentation or penetration. 2. A water quality parameter. Water that does not lather easily with soap, and produces scale in pots, pans, and kettles, caused by the presence of certain salts of calcium and magnesium in the water supply

Hauler: Garbage collection company that offers complete refuse removal service; may will also collect recyclables.

Hazard: The potential for an activity, condition, circumstance, or changing conditions or circumstances to produce harmful effects. Also an unsafe condition.

Hazard Analysis: A systematic process for identifying hazards and recommending corrective action.

Hazard Analysis Methodologies: Several methodologies (as described by the Center for Chemical Process Safety [CCPS]) or hazard evaluation procedures are available to complete the process hazard analysis. In an appendix to the PSM Standard, OSHA discussed several of these methods of process hazard analysis. That discussion, which may be helpful for those doing job hazard analyses, follows:

What-if—for relatively uncomplicated processes, review the process from raw materials to product. At each handling or processing step, "what if" questions are formulated and answered, to evaluate the effects of component failures or procedural errors on the process.

Checklist—for more complex processes, the "what if" study can be best organized through using a "checklist," and assigning certain aspects of the process to the committee members with the greatest experience or skill in evaluating those aspects. The committee members audit operator practices and job knowledge in the field, study the suitability of equipment and materials of construction, review the chemistry of the process and control systems, and audit the operating and maintenance records. Generally, a checklist evaluation of a process precedes use of the more sophisticated methods described below, unless the process has been operated safely for many years and has been subjected to periodic and thorough safety inspections and audits.

What if/Checklist—the what-if/checklist is a broadly based hazard assessment technique that combines the creative thinking of a selected team of specialists with the methodical focus of a prepared checklist. The result is a comprehensive hazard analysis that is extremely useful in training operating personnel on the hazards of the particular operation.

HAZOP and Operability Study (HAZOP): HAZOP is a formally structured method of systematically investigating each element of a system for all of the ways in which important parameters can deviate from the intended design conditions to create hazards and operability problems. The hazard and operability problems are typically determined by a study of the piping and instrument diagrams (or plant model) by a team of personnel who critically analyze effects of potential problems arising in each pipeline and each vessel of the operation.

Pertinent parameters are selected (for example, flow, temperature, pressure, and time), and then the effect of deviations from design conditions of each parameter is examined. A list of keywords, for example, "more of," "less of," "part of," is selected for use in describing each potential deviation.

The system is evaluated as designed and with deviations noted. All causes of failure are identified. Existing safeguards and protection are identified. An assessment is made weighing the consequences, causes, and protection requirements involved.

Hazard Assessment: A qualitative evaluation of potential hazards in the interrelationships between and among the elements of a system, upon the basis of which the occurrence probability of each identified hazard is rated.

Hazard Categories: The consequences of unmitigated releases of radioactive and/or hazardous material are evaluated and classified by the following hazard categories:

A. CATEGORY 1. The hazard analysis shows the potential for significant offsite consequences.
B. CATEGORY 2. The hazard analysis shows the potential for significant onsite consequences.
C. CATEGORY 3. The hazard analysis shows the potential for only significant localized consequences (DOE O 5480.31).

Hazard Classes: Non-nuclear facilities will be categorized as high, moderate, or low hazards based on the following:

A. High—hazards with a potential for onsite and offsite impacts to large numbers of person or for major impacts to the environment.
B. Moderate—hazards which present considerable potential onsite impacts to people or the environment, but at most only minor offsite impacts.
C. Low—hazards which present minor onsite and negligible offsite impacts to people and the environment (DOE O 5481.1B).

Hazard Communication Standard (HazCom): An OSHA workplace standard found in 29 CFR 1910.1200 that requires all employers to become aware of the chemical hazards in their workplace and relay that information to their employees. In addition, a contractor conducting work at a client's site must provide chemical information to the client regarding the chemicals that are brought onto the work site.

The Bhopal incident, the ensuing chemical spill, and the resulting tragic deaths and injuries are well known. However, not all of the repercussions—the lessons learned—from this incident are as well known. After Bhopal arose a worldwide outcry. "How could such an incident occur? Why wasn't something done to protect the inhabitants? Weren't there safety measures taken or in place to prevent such a disaster from occurring?"

Hazard Evaluation: A component of risk evaluation that involves gathering an devaluating data on the types of health injuries or diseases that may be produced by a chemical and on the conditions of exposure under which such health effects are produced.

Hazard Identification: The pinpointing of material, system, process, and plant characteristics that can produce undesirable consequences through the occurrence of an accident.

Hazard Identification: Providing information on which facilities have extremely hazardous substance, what those chemicals are, how much there is at each facility, how the chemicals are stored, and whether they are used at high temperatures.

Hazard Index: The sum of more than one hazard quotient for multiple contaminants or specific multiple exposure pathways, or both.

Hazard Quotient: The ratio of estimated site-specific exposure to a single chemical from a site over a specified period to the estimated daily exposure level, at which no adverse health effects are likely to occur.

Hazard Ratio: A term used to compare an animal's daily dietary intake of a pesticide to its LD 50 value. A ratio grater than 1.0 indicates that he animal is likely to consume a dose amount which would kill 50 percent of animals of the same species.

Hazards Analysis: Procedures used to (1) identify potential sources of release of hazardous materials from fixed facilities or transportation accidents; (2) determine the vulnerability of a geographical area to a release of hazardous materials; and (3) compare hazards to determine which preset greater or lesser risks to a community.

Hazardous Air Pollutants: Air pollutants which are not covered by ambient air quality standards but which, as defined in the Clean Air Act may present a threat of adverse human health effects or adverse environmental effects. Such pollutants include asbestos, beryllium, mercury, benzene, coke over emissions, radionuclides, and vinyl chloride.

Hazardous and Solid Waste Act and Amendments (HSWA): Part of RCRA that emphasizes the development and use of alternative and innovative treatment technologies that result in permanent destruction of wastes or reduction in toxicity, mobility, and volume. Land disposal is greatly restricted under the 1984 RCRA amendments.

Hazardous Chemicals: An explosive, flammable, poisonous, corrosive, reactive, or radioactive chemical requiring special care in handling because of hazards it poses to public health and the environment. Chemicals are hazardous if they are:

- **Ignitable**—capable of burning or causing a fire
- **Corrosive**—capable of eating away materials and destroying living tissue when contact occurs
- **Explosive and/or reactive**—can cause an explosion or release poisonous fumes when exposed to air, water or other chemicals
- **Toxic**—poisonous, either immediately (acutely toxic) or over a long period of time (chronically toxic)

- **Radioactive**—can damage and destroy cells and chromosomal material (know to cause cancer, mutations and fetal harm)

Chemicals can also be characterized by their physical hazards:

- **Combustible liquid**—means any liquid having a flashpoint at or above 100ºF (37.8ºC), but below 200ºF (93.3ºC).
- **Compressed gas**—means a gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70ºF (21.1ºC); a gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130ºF (54.4ºC) regardless of the pressure at 70ºF, or a liquid having a vapor pressure exceeding 40 psi at 100ºF (37.8ºC).
- **Explosive**—means a chemical that causes a sudden release of pressure, gas, and heat when subjected to sudden shock, pressure or high temperature.
- **Flammable**—means a chemical that falls into one of the following categories:
    - **Aerosol, flammable**—means an aerosol that yields a flame when ignited;
    - **Gas, flammable**—means a gas that at ambient temperature and pressure, forms a flammable mixture with air at a concentration of thirteen percent by volume or less, or a gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than twelve percent by volume, regardless of the lower limit;
    - **Liquid, flammable**—means any liquid having a flashpoint below 100ºF (37.8ºC); or
    - **Solid, flammable**—means a solid, other than an explosive, that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat form manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard.
- **Oxidizer**—means a chemical other than an explosive that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.
- **Organic peroxide**—means an organic compound that contains the bivalent **–O-O-** structure and which may be considered to be a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms has been replaced by an organic radical. Organic peroxides are oxidizers and fuels in one, and are therefore unstable and potentially explosive. "Peroxidizable" means a chemical which will form organic peroxide when exposed to air.
- **Pyrophoric**—means a chemical that will ignite spontaneously or explode in air at a temperature of 130ºF (54.4ºC) or below.
- **Unstable (reactive)**—means a chemical which in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense or will become self-reactive under conditions of shocks, pressure, or temperature.
- **Water-reactive**—means a chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

Hazardous Exposure: Exposure, including potential exposure, to any toxic substance, harmful physical agent, ergonomic stress, or harmful biological agent that poses or may pose a recognized hazard to the health of employees.

Hazardous Material: 1. Any material possessing a relatively high potential for harmful effects upon persons. 2. A substance in a quantity or form posing an unreasonable risk to health, safety, and/or property when transported in commerce; a substance that by its nature, containment, and reactivity has the capability for inflicting harm during an accident occurrence; characterized as toxic, corrosive, flammable, reactive, an irritant, or a strong sensitizer, and thereby poisonous. A threat to health and the environment when improperly managed.

Hazardous Materials Table: The Hazardous Materials Table, or HMT, is the backbone of the Hazardous Materials Regulations. Understanding and knowing how to use the Hazardous Materials Table is the first step toward compliance with the Hazardous Materials Regulations.

Hazardous Ranking System: The principal screening tool used by EPA to evaluate risks to public health and the environment associated with abandoned or uncontrolled hazardous waste sites. The HRS calculates a score based on the potential of hazardous substances spreading from the site through the air, surface water, or ground water, and on other factors such as density and proximity of human population. This core is the primary factor in deciding if the site should be on the Nation Priorities List and, if so, what ranking it should have compared to other sites on the list.

Hazardous Substance: 1. Any substance which has the potential for causing injury by reason of its being explosive, flammable, toxic, corrosive, oxidizing, irritating, or otherwise harmful to personnel. 2. A USEPA term used for certain listed chemicals that when released into the environment above a certain amount must be reported.

Hazardous Substance Release and Health Effects Database (HazDat): The scientific and administrative database system developed by ATSDR to management data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

Hazardous Waste: A solid, liquid, or gaseous waste that may cause or significantly contribute to serious illness or death, or that poses a substantial threat to human health or the environment when the waste is improperly managed.

Hazardous Waste Handling: The most alarming of all man's assaults upon the environment is the contamination of air, earth, rivers, and sea with dangerous and even lethal materials. This pollution is for the most part irrecoverable; the chain of evil it initiates not only in the world that must support life but in living tissues is for the most part irreversible. In this now universal contamination of the environment, chemicals are the sinister, and little–recognized partners of radiation in changing the very nature of the world—the very nature of life.

—Rachel Carson, 1962.

In 1990, R. B. Smith reported that the United States Environmental Protection Agency (EPA) estimated that the United States generates 570 million tons of hazardous waste annually. This waste includes toxic, biologic, and radioactive waste. But the broader human interaction, the safety and health considerations we have with wastes most concerns the safety engineer. These may overlap and directly interface with the classic environmental spans of control alluded to by Rachel Carson.

Rachel Carson combined the insight and sensitivity of a poet with the realism and observations of a scientist in ways no environment writer had before in her classic and highly influential book, *Silent Spring.* To us, today, with the impact of that critically important, visionary work proven true, that Rachel Carson was ostracized, vilified, laughed at, and lambasted (particularly by chemical manufacturers) for that work, that the work was at first disregarded strikes us as puzzling.

While those with vested interest in the book's failure worked to disparage it, Rachel Carson was not disregarded by those who understood. Examined with an unbiased eye, her message was clear: the chemicals we use commonly, in quantity, if not properly handled, treated, and disposed, not only pose a short term threat to human life, they pose a long-term threat to the environment as a whole. Her plea is also clear: to end the poisoning of earth. With the clarity of vision provided by 20/20 hindsight, we now see (and have known for many years) that Rachel Carson was well ahead of her time. The concerns that *Silent Spring* addressed in 1962, while based on limited data, have since been confirmed.

In this chapter we discuss the hazards of handling hazardous materials—especially hazardous wastes, all of which should be the focus of the safety engineer. We illustrate the nature of hazardous waste, the problem, and the possible consequences.

America: A Throwaway Society

America as a whole has lost the habit of earlier generations to "use it up, wear it out, make it do, or do without." A new American characteristic—one that might be further described as habit, trend, custom, practice, or tendency—is to discard those objects we no longer want, whether or not they still have useful life. We have become a "throwaway society."

While many of us conscientiously recycle our bottles, cans, newspapers and plastic containers, we often simply discard other, larger items we have no more use for, simply because throwing them away is easier than finding a venue to recycle or reuse them. When an item loses its value to us because it is broken, shabby, no longer fashionable, or no longer needed for whatever reason, discarding it should not be an insurmountable problem. But it is—especially whenever the item we throw away is a hazardous substance, one that is persistent, nonbiodegradable, and poisonous.

What is the magnitude of the problem with hazardous substance and waste disposal? Let's take a look at a few facts.

- Hazardous substances—including industrial chemicals, toxic waste, pesticides, and nuclear waste—are entering the marketplace, the workplace, and the environment in unprecedented amounts.
- The United States produces almost 300 million metric tons of hazardous waste each year—with a present population of 260,000,000+, this amounts to more than one ton for every person in the country.
- Through pollution of the air, the soil, and water supplies, hazardous wastes pose both short- and long-term threats to human health and environmental quality.

What Is a Hazardous Substance?

Hazardous wastes can be informally defined as a subset of all solid and liquid wastes that are disposed of on land rather than being shunted directly into the air or water, and which have the potential to adversely affect human health and the environment. We often believe that hazardous wastes result mainly from industrial activities, but households also play a role in the generation and improper disposal of substances that might be considered hazardous wastes. Hazardous wastes (via Bhopal and other disastrous episodes) have been given much attention, but surprisingly little is known of their nature and of the actual scope of the problem. In this section, we examine definitions of hazardous materials, substances, wastes, etc., and attempt to bring hazardous wastes into perspective both as a major environmental and as a safety and health concern.

Unfortunately, defining a hazardous substance is largely a matter of choice between the definitions offered by the various regulatory agencies and pieces of environmental legislation, each defining it somewhat differently. Many of the different terms are used interchangeably. Even experienced professional Certified Hazardous Materials Managers have been known to interchange these terms, even though they are generated by different official sources, and have somewhat different meanings, dependent upon the nature of the problem being addressed. To understand the scope of the dilemma in defining a hazardous substance let's take a look at the terms that are in common use today, used interchangeably, and often thought to mean the same thing.

Hazardous Material

A hazardous material is a substance (gas, liquid, or solid) capable of causing harm to people, property, and the environment. The United States Department of Transportation (DOT) uses the term *hazardous materials* to cover nine categories identified by the United Nations Hazard Class Number System, including:

- Explosives
- Gases (compressed, liquefied, dissolved)
- Flammable Liquids
- Flammable Solids
- Oxidizers
- Poisonous Materials
- Radioactive Materials
- Corrosive Materials
- Miscellaneous Materials

Hazardous Substances

The term *hazardous substance* is used by the USEPA for chemicals that, if released into the environment above a certain amount, must be reported, and depending on the threat to the environment, for which federal involvement in handling the incident can be authorized. USEPA lists hazardous substances in its 40 CFR Part 302, Table 302.4.

The Occupational Safety and Health Administration (OSHA) uses the term hazardous substance in 29 CFR 1910.120 (which resulted from Title I of SARA and covers emergency response) differently than does the EPA. Hazardous substances (as defined by OSHA) cover every chemical regulated by both DOT and the EPA.

Extremely Hazardous Substances

Extremely hazardous substance is a term used by the EPA for chemicals that must be reported to the appropriate authorities if released above the threshold reporting quantity (RQ). The list of extremely hazardous substances is identified in Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986 (40 CFR Part 355). Each substance has a threshold reporting quantity.

Toxic Chemicals

EPA uses the term *toxic chemical* for chemicals whose total emissions or releases must be reported annually by owners and operators of certain facilities that manufacture, process, or otherwise use listed toxic chemicals. The list of toxic chemicals is identified in Title III of SARA.

Hazardous Wastes

EPA uses the term *hazardous wastes* for chemicals regulated under the Resource, Conservation and Recovery Act (RCRA-40 CFR Part 261.33). Hazardous wastes in transportation are regulated by DOT (49 CFR Parts 170-179).

For our purposes in this text, we define a hazardous waste as any hazardous substance that has been spilled or released to the environment. For example, chlorine gas is a hazardous material. When chlorine is released to the environment, it becomes a hazardous waste. Similarly, when asbestos is in place and undisturbed, it is a hazardous material. When it is broken, breached, or thrown away, it becomes a hazardous waste.

Hazardous Chemicals

OSHA uses the term *hazardous chemical* to denote any chemical that poses a risk to employees if they are exposed to it in the workplace. Hazardous chemicals cover a broader group of chemicals than the other chemical lists.

What a Hazardous Substance Is

For the purposes of this text, to form the strongest foundation for understanding the main topic of this chapter (hazardous waste handling) and because RCRA's definition for a hazardous substance can also be used to describe a hazardous waste, we use RCRA's definition.

RCRA defines a substance as hazardous if it possesses any of the following four characteristics: reactivity, ignitability, corrosiveness, or toxicity. Briefly,

- Ignitability refers to the characteristic of being able to sustain combustion, and includes the category of flammability (ability to start fires when heated to temperatures less than 140°F or less than 60°C).
- Corrosive substances (or wastes) may destroy containers, contaminate soils and groundwater, or react with other materials to cause toxic gas emissions. Corrosive materials provide a specific hazard to human tissue and aquatic life where the pH levels are extreme.
- Reactive substances may be unstable or have tendency to react, explode, or generate pressure during handling. Pressure-sensitive or water-reactive materials are included in this category.
- Toxicity is a function of the effect of hazardous materials (or wastes) that may come into contact with water or air and be leached into the groundwater or dispersed in the environment.

The toxic effects that may occur to humans, fish, or wildlife are our principal concerns here. Toxicity (until 1990) was tested using a standardized laboratory test called the extraction procedure (EP Toxicity Test). The EP Toxicity test was replaced in 1990 by the Toxicity Characteristics Leaching Procedure (TCLP), because the EP test failed to adequately simulate the flow of toxic contaminants to drinking water. The TCLP test is designed to identify wastes likely to leach hazardous concentrations of particular toxic constituents into the soils surrounding groundwater as a result of improper management.

TCLP extracts constituents from the tested waste in a manner designed to simulate the leaching actions that occur in landfills. The extract is then analyzed to determine if it possesses any of the toxic constituents listed in the Table. If the concentrations of the toxic constituents exceed the levels listed in the table, the waste is classified as hazardous.

Maximum Concentration of Contaminants for TCLP Toxicity Test

Contaminant	*Regulatory Level (mg/L)*
Arsenic	5.0
Barium	100.0
Benzene	0.5
Cadmium	1.0
Carbon tetrachloride	0.5
Chlordane	0.03
Chlorobenzene	100.0
Chloroform	6.0
Chromium	5.0
Cresol	200.0
2,4-D	10.0
1,4-Dichlorobenzene	7.5
1,5-Dichloroethane	0.5
2.4-Dinitrololuene	0.13
Endrin	0.02
Heptachlor	0.008
Hexachlorobnezene	0.13
Hexachloroethane	3.0
Lead	5.0
Lindane	0.4
Mercury	0.2
Methoxychlor	10.0
Methyl ethyl ketone	200.0
Nitrobenzene	2.0
Pentachlorophenol	100.0
Pyridine	5.0
Selenium	1.0
Silver	5.0
Tetrachloroethylene	0.7
Toxaphene	0.5
Trichloroethylene	0.5
2,4,5-Trchlorophenol	400.0
2,4,6-Trchlorophenol	2.0
2.4,5-TP (Silvex)	1.0
Vinyl chloride	0.2

Source: USEPA (1990), 40 CFR 261.24.

What Is a Hazardous Waste?

A general rule of thumb states that any hazardous substance that is spilled or released to the environment is no longer classified as a hazardous substance but as a hazardous waste. The EPA uses the same definition for hazardous waste as it does for hazardous substance. The four characteristics described in the previous section (reactivity, ignitability, corrosivity, or toxicity) can also be used to identify hazardous substances as well as hazardous wastes.

Note that the EPA lists substances that it considers hazardous wastes . These lists take precedence over any other method used to identify and classify a substance as hazardous (i.e., if a substance is listed in one of the EPA's lists described below, it is a hazardous substance, no matter what).

EPA Lists of Hazardous Wastes

EPA-listed hazardous wastes are organized into three categories: nonspecific source wastes, specific source wastes, and commercial chemical products. All listed wastes are presumed to be hazardous, regardless of their concentrations. EPA developed these lists by examining different types of wastes and chemical products to determine whether they met any of the following criteria:

- Exhibits one or more of the four characterizations of a hazardous waste.
- Meets the statutory definition of a hazardous waste.
- Are acutely toxic or acutely hazardous.
- Are otherwise toxic.

These lists are described briefly:

- Nonspecific source wastes are generic wastes commonly produced by manufacturing and industrial processes. Examples from this list include spent halogenated solvents used in degreasing and wastewater treatment sludge from electroplating processes, as well as dioxin wastes, most of which are "acutely hazardous" wastes because of the danger they present to human health and the environment.
- Specific source wastes are from specially identified industries such as wood preserving, petroleum refining, and organic chemical manufacturing. These wastes typically include sludges, still bottoms, wastewaters, spent catalysts, and residues, such as wastewater treatment sludge from pigment production.
- Commercial chemical products (also called "P" or "U" list wastes because their code numbers begin with these letters) include specific commercial chemical products, or manufacturing chemical intermedi-

ates. This list includes chemicals such as chloroform and creosote, acids such as sulfuric and hydrochloric, and pesticides such as DDT and kepone (40 CFR 261.31, 32, and 33).

Note that the EPA ruled that any waste mixture containing a listed hazardous waste is also considered a hazardous waste—and must be managed accordingly. This applies regardless of what percentage of the waste mixture is composed of listed hazardous wastes. Wastes derived from hazardous wastes (residues from the treatment, storage, and disposal of a listed hazardous waste) are considered hazardous waste as well (EPA, 1990).

Where Do Hazardous Wastes Come From?

Hazardous wastes are derived from several waste generators. Most of these waste generators are in the manufacturing and industrial sectors and include chemical manufacturers, the printing industry, vehicle maintenance shops, leather products manufacturers, the construction industry, metal manufacturing, and others. These industrial waste generators produce a wide variety of wastes, including strong acids and bases, spent solvents, heavy metal solutions, ignitable wastes, cyanide wastes, and many more.

Why Are We Concerned about Hazardous Wastes?

From the safety engineer's perspective, any hazardous waste release that could alter the environment and/or impact the health and safety of employees in any way is a major concern. The specifics of the safety engineer's concern lie in acute and chronic toxicity to organisms, bioconcentration, biomagnification, genetic change potential, etiology, pathways, change in climate and/or habitat, extinction, persistence, esthetics such as visual impact, and most importantly, the impact on the health and safety of employees.

We have stated consistently that when a hazardous substance or hazardous material is spilled or released into the environment, it becomes a hazardous waste. This is important because specific regulatory legislation has been put in place regarding hazardous wastes, responding to hazardous waste leak/spill contingencies, and for proper handling, storage, transportation, and treatment of hazardous wastes—the goal being, of course, protecting the environment—and ultimately, protecting the health and safety of our employees and the surrounding community.

Why are we so concerned about hazardous substances and hazardous wastes? This question is relatively easy to answer based on experience, publicity, and actual hazardous materials incidents, which have resulted in tragic consequences, to the environment, and to human life.

Hazardous Waste Legislation

Humans are strange in many ways. We may know that a disaster is possible, is likely, could happen, is predictable. But do we act before someone dies? Not often enough. We often ignore the human element—we forget the victim's demise. We simply do not want to think about it, because if we think about it, we must come face to face with our own mortality. The safety engineer, though, must think about it—constantly, and before such travesties occur—to prevent them from ever occurring.

Because of Bhopal and other similar (but less catastrophic) chemical spill events, the United States Congress (pushed by public concern) developed and passed certain environmental laws and regulations to regulate hazardous substances/wastes in the United States. This section focuses on the two regulatory acts most crucial to the current management programs for hazardous wastes. The first (mentioned several times throughout the text) is the Resource Conservation and Recovery Act (RCRA). Specifically, RCRA provides guidelines for prudent management of new and future hazardous substances/wastes. The second act (more briefly mentioned) is the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), otherwise known as Superfund, which deals primarily with mistakes of the past: inactive and abandoned hazardous waste sites.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) is the United States's single most important law dealing with the management of hazardous waste. RCRA and its amendment Hazardous and Solid Waste Act (HSWA-1984) deal with the ongoing management of solid wastes throughout the country—with emphasis on hazardous waste. Keyed to the waste side of hazardous materials, rather than broader issues dealt with in other acts, RCRA is primarily concerned with land disposal of hazardous wastes. The goal is to protect groundwater supplies by creating a "cradle-to-grave" management system with three key elements: a tracking system, a permitting system, and control of disposal.

1. Tracking system—a manifest document accompanies any waste that is transported from one location to another.
2. Permitting system—helps assure safe operation of facilities that treat, store, or dispose of hazardous wastes.
3. Disposal control system—controls and restrictions governing the disposal of hazardous wastes onto, or into, the land (Masters, 1991).

RCRA regulates five specific areas for the management of hazardous waste (with the focus on treatment, storage, and disposal). These are:

1. Identifying what constitutes a hazardous waste and providing classification of each.

2. Publishing requirements for generators to identify themselves, which includes notification of hazardous waste activities and standards of operation for generators.
3. Adopting standards for transporters of hazardous wastes.
4. Adopting standards for treatment, storage, and disposal facilities.
5. Providing for enforcement of standards through a permitting program and legal penalties for noncompliance (Griffin, 1989).

Arguably, RCRA is our single most important law dealing with the management of hazardous waste—it certainly is the most comprehensive piece of legislation that EPA has promulgated to date.

CERCLA

The mission of the Comprehensive Environmental Response, Compensation, and Liabilities Act of 180 (Superfund or SARA) is to clean up hazardous waste disposal mistakes of the past, and to cope with emergencies of the present. More often referred to as the Superfund Law, as a result of its key provisions a large trust fund (about $1.6 billion) was created. Later, in 1986, when the law was revised, this fund was increased to almost $9 billion. The revised law is designated as the Superfund Amendments and Reauthorization Act of 1986 (SARA). The key requirements under CERCLA are listed in the following. Briefly,

1. CERCLA authorizes the EPA to deal with both short-term (emergency situations triggered by a spill or release of hazardous substances), as well as long-term problems involving abandoned or uncontrolled hazardous waste sites for which more permanent solutions are required.
2. CERCLA set up a remedial scheme for analyzing the impact of contamination on sites under a hazard ranking system. From this hazard ranking system, a list of prioritized disposal and contaminated sites is compiled. This list becomes the National Priorities List (NPL) when promulgated. The NPL identifies the worst sites in the nation, based on such factors as the quantities and toxicity of wastes involved, the exposure pathways, the number of people potentially exposed, and the importance and vulnerability of the underlying groundwater.
3. CERCLA also forces those parties who are responsible for hazardous waste problems to pay the entire cost of cleanup.
4. Title III of SARA requires federal, state, and local governments and industry to work together in developing emergency response plans and reporting on hazardous chemicals. This requirement is commonly known as the Community Right-To-Know Act, which allows the public to obtain information about the presence of hazardous chemicals in their communities and releases of these chemicals into the environment.

OSHA

Moretz (1989) points out that OSHA's hazardous waste standard specifically addresses the safety of the estimated 1.75 million workers who deal with hazardous waste: hazardous waste workers in all situations, including treatment, storage, handling, and disposal; firefighters; police officers; ambulance personnel; and hazardous materials response team personnel.

Occupational Health Magazine summarizes the requirements of this standard:

- Each hazardous waste site employer must develop a safety and health program designed to identify, evaluate, and control safety and health hazards, and provide for emergency response.
- A trained and competent person must perform a preliminary evaluation of the site's characteristics prior to entry, to identify potential site hazards and to aid in the selection of appropriate employee protection methods.
- The employer must implement a site control program to prevent contamination of employees. At a minimum, the program must identify a site map, site work zones, site communications, safe work practices, and the location of the nearest medical assistance. Also required in particularly hazardous situations is the use of the two-person rule (buddy system) so that employees can keep watch on one another and provide quick aid if needed.
- Employees must be trained before they are allowed to engage in hazardous waste operations or emergency response that could expose them to safety and health hazards.
- The employer must provide medical surveillance at least annually and at the end of employment for all employees exposed to any particular hazardous substance at or above established exposure levels and/or those who wear approved respirators for thirty days or more on site.
- Engineering controls, work practices, and PPE, or a combination of these methods, must be implemented to reduce exposure below established exposure levels for the hazardous substances involved.
- Periodic air monitoring to identify and quantify levels of hazardous substances and to ensure that proper protective equipment is being used must be performed.
- The employer must set up an information program with the names of key personnel and their alternates responsible for site safety and health, and the requirements of the standard.
- The employer must implement a decontamination procedure before any employee or equipment leaves

an area of potential hazardous exposure; establish operating procedures to minimize exposure through contact with exposed equipment, other employees, or used clothing; and provide showers and change rooms where needed.
- An emergency response plan to handle possible on-site emergencies prior to beginning hazardous waste operations must be in place. Such plans must address personnel roles; lines of authority, training and communications; emergency recognition and prevention; safe places of refuge; site security; evacuation routes and procedures; emergency medical treatment; and emergency alerting.
- An off-site emergency response plan to better coordinate emergency action by local services and to implement appropriate control actions must be in place.

Hazardous Waste Safety Program
For the purposes of this text, hazardous waste handling includes work activities that include the collection, storage, treatment, disposal and clean up of hazardous waste materials. We also focus on standard industrial wastes and their handling. Industrial wastes include:

- Acids
- Abrasives
- Bases
- Animal products/by-products
- Biologic substances
- Carcinogenic substances
- Explosives
- Solvents
- Salts
- Pesticides
- Oils
- Combustible materials
- Metals
- Reactive materials
- Organic materials

The comprehensive site characterization and safety analysis is required to identify specific site hazards, and to determine the appropriate safety and health control measures needed to protect employees from the identified hazards.

As mentioned, the safety engineer must ensure that appropriate site control measures are implemented to control employee exposure to hazardous substances before cleanup work begins. As a minimum, site control should include:

- A site map;
- Site work zones;
- The use of a "buddy system";
- Site communications, including alerting means for emergencies;
- The standard operating procedures or safe work practices; and,
- Identification of the nearest medical assistance.

All employees working on site who have the potential for exposure to hazardous substances, health hazards, or safety hazards must receive appropriate training and obtain certification before they can be allowed to engage in hazardous waste operations that could expose them to hazardous substances and safety or health hazards.

Employees engaged in hazardous waste operations must be included in a company medical surveillance program.

Engineering controls, work practices, and personal protective equipment for employee protection must be implemented to protect employees from exposure to hazardous substances and safety and health hazards.

Monitoring must be performed to assure proper selection of engineering controls, work practices (such as confined space entry) and personal protective equipment (PPE) so that employees are not exposed to levels that exceed permissible exposure limits (or published exposure levels if there are no permissible exposure limits) for hazardous substances.

Decontamination procedures for all phases of decontamination must be developed and implemented.

An emergency response plan must be developed and implemented by all employers who engage in hazardous waste operations. The plan must be written and available for inspection by employees and appropriate regulatory agencies.

While the technology to handle, control, and remediate hazardous wastes and their consequences is constantly improving, the problem continues to grow with the growth of population and industry. As safety engineer, you may hold responsibility for such materials for your organization. Because it affects workers, the surrounding community and the environment, it presents the safety engineer with a special challenge and a critically important concern.

Hazardous Waste Landfill: An excavated or engineered site where hazardous waste is deposited and covered.

Hazardous Waste Minimization: Reducing the amount of toxicity of waste produced by a facility via source reduction or environmentally sound recycling.

Hazardous Wastestream: A gaseous or liquid wastestream that contains any type of hazardous substance.

Hazmat Employee: A person who is employed by a hazmat employer and who in the course of employment directly affects hazardous material transportation safety. This term includes an owner-operator of a motor vehicle which transports hazardous material in commerce. This term includes an individual, including a self-employed individual, employed by a Hazmat employer who, during the course of employment:

A. Loads, unloads, or handles hazardous materials.
B. Manufactures, tests, reconditions, repairs, modifies, marks, or otherwise represents containers, drums, or packagings as qualified for use in the transportation of hazardous materials.
C. Prepares hazardous materials for transportation.
D. Is responsible for safety of transporting hazardous materials.
E. Operates a vehicle used to transport hazardous materials (49 CFR 171.8).

Hazmat Incident: Actual or potential unplanned release of a hazardous material.

H_2S: Hydrogen sulfide.

HCl: Molecular formula for hydrochloric acid; can be used in diluted form in the hydraulic fracturing process to fracture limestone formations and to clean up perforations in coalbed methane fracturing treatments.

Head, Hydraulic: *Head* is defined as the vertical distance the water/wastewater must be lifted from the supply tank to the discharge, or as the height a column of water would rise due to the pressure at its base. A perfect vacuum plus atmospheric pressure of 14.7 psi would lift the water 34 feet. If the top of the sealed tube is opened to the atmosphere and the reservoir is enclosed, the pressure in the reservoir is increased; the water will rise in the tube. Because atmospheric pressure is essentially universal, we usually ignore the first 14.7-psi of actual pressure measurements, and measure only the difference between the water pressure and the atmospheric pressure; we call this *gauge pressure*. For example, water in an open reservoir is subjected to the 14.7 psi of atmospheric pressure, but subtracting this 14.7 psi leaves a gauge pressure of 0 psi. This shows that the water would rise 0 feet above the reservoir surface. If the gauge pressure in a water main were 120 psi, the water would rise in a tube connected to the main:

$$120 \text{ psi} \times 2.31 \text{ ft/psi} = 277 \text{ ft (rounded)}$$

The *total head* includes the vertical distance the liquid must be lifted (static head), the loss to friction (friction head), and the energy required to maintain the desired velocity (velocity head).

$$\text{Total Head} = \text{Static Head} + \text{Friction Head} + \text{Velocity Head}$$

- **Static Head—**is the actual **vertical** distance the liquid must be lifted.

  $$\text{Static Head} = \text{Discharge Elevation} - \text{Supply Elevation}$$

EXAMPLE
Problem:
The supply tank is located at elevation 118 feet. The discharge point is at elevation 215 feet. What is the static head in feet?

Solution:

$$\text{Static Head, ft} = 215 \text{ ft} - 118 \text{ ft} = 97 \text{ feet}$$

- **Friction Head—**is the equivalent distance of the energy that must be supplied to overcome friction. Engineering references include tables showing the equivalent vertical distance for various sizes and types of pipes, fittings, and valves. The total friction head is the sum of the equivalent vertical distances for each component.

  $$\text{Friction Head, ft} = \text{Energy Losses Due to Friction}$$

- **Velocity Head—**is the equivalent distance of the energy consumed in achieving and maintaining the desired velocity in the system.

  $$\text{Velocity Head, ft} = \text{Energy Losses to Maintain Velocity}$$

- **Total Dynamic Head (Total System Head)**

  $$\text{Total Head} = \text{Static Head} + \text{Friction Head} + \text{Velocity Head}$$

Pressure/Head
The pressure exerted by water is directly proportional to its depth or head in the pipe, tank or channel. If the pressure is known, the equivalent head can be calculated.

$$\text{Head, ft} = \text{Pressure, psi} \times 2.31 \text{ ft/psi}$$

EXAMPLE
Problem:
The pressure gauge on the discharge line from the influent pump reads 72.3 psi. What is the equivalent head in feet?

Solution:

$$\text{Head, ft} = 72.3 \times 2.31 \text{ ft/psi} = 167 \text{ ft}$$

Head/Pressure

If the head is known, the equivalent pressure can be calculated by

$$\text{Pressure, psi} = \frac{\text{Head, ft}}{2.31\ \text{ft/psi}}$$

EXAMPLE

Problem:

The tank is 22 feet deep. What is the pressure in psi at the bottom of the tank when it is filled with water?

Solution:

$$\text{Pressure, psi} = \frac{22\ \text{ft}}{2.31\ \text{ft/psi}} = 9.52\ \text{psi (rounded)}$$

Flow/Discharge Rate: Water in Motion

The study of fluid flow is much more complicated than that of fluids at rest, but it is important to have an understanding of these principles because the water in a waterworks and distribution system and in a wastewater treatment plant and collection system is nearly always in motion.

Discharge (or flow) is the quantity of water passing a given point in a pipe or channel during a given period. Stated another way for open channels: The flow rate through an open channel is directly related to the velocity of the liquid and the cross-sectional area of the liquid in the channel.

$$Q = A \times V$$

where

Q = Flow—discharge in cubic feet per second (cfs)

A = Cross-sectional area of the pipe or channel (ft^2)

V = water velocity in feet per second (fps or ft/sec)

EXAMPLE

Problem:

The channel is 6 feet wide and the water depth is 3 feet. The velocity in the channel is 4 feet per second. What is the discharge or flow rate in cubic feet per second?

Solution:

$$\text{Flow, cfs} = 6\ \text{ft} \times 3\ \text{ft} \times 4\ \text{ft/second} = 72\ \text{cfs}$$

Discharge or flow can be recorded as gallons/day (gpd), gallons/minute (gpm), or cubic feet (cfs). Flows treated by many waterworks or wastewater treatment plants are large, and often referred to in million gallons per day (MGD). The discharge or flow rate can be converted from cfs to other units such as gallons per minute (gpm) or million gallons per day (MGD) by using appropriate conversion factors.

EXAMPLE

Problem:

A pipe 12 inches in diameter has water flowing through it at 10 feet per second. What is the discharge in (a) cfs, (b) gpm, and (c) MGD? Before we can use the basic formula (5.13), we must determine the area A of the pipe. The formula for the area of a circle is

$$A = \pi \times \frac{D^2}{4} = \pi \times r^2$$

(π is the constant value 3.14159 or simply 3.14)

where

D = diameter of the circle in feet

r = radius of the circle in feet

Therefore, the area of the pipe is:

$$A = \pi \frac{D^2}{4} = 3.14 \times \frac{(1\ \text{ft})^2}{4} = 0.785\ \text{ft}^2$$

Now we can determine the discharge in cfs [part (a)]:

$$Q = V \times A = 10\ \text{ft/sec} \times 0.785\ \text{ft}^2 = 7.85\ \text{ft}^3\text{/sec or cfs}$$

For part (b), we need to know that 1 cubic foot per second is 449 gallons per minute, so 7.85 cfs x 449 gpm/cfs = 3525 gpm. (rounded)

Finally, for part (c), one million gallons per day is 1.55 cfs, so

$$\frac{7.85\ \text{cfs}}{1.55\ \frac{\text{cfs}}{\text{MGD}}} = 5.06\ \text{MGD}$$

Area/Velocity

The *law of continuity* states that the discharge at each point in a pipe or channel is the same as the discharge at any other point (if water does not leave or enter the pipe or channel). That is, under the assumption of steady state flow, the flow that enters the pipe or channel is the same flow that exits the pipe or channel. In equation form, this becomes

$$Q_1 = Q_2 \text{ or } A_1V_1 = A_2V_2$$

EXAMPLE

Problem:

A pipe 12 inches in diameter is connected to a 6-inch diameter pipe. The velocity of the water in the 12-inch pipe is 3 fps. What is the velocity in the 6-in. pipe?

Solution:

Using the equation $A_1V_1 = A_2V_2$, we need to determine the area of each pipe:

$$12 \text{ in.: } A = \pi \times \frac{D^2}{4}$$

$$= 3.14 \times \frac{(1 \text{ ft})^2}{4}$$

$$= 0.785 \text{ ft}^2$$

$$6 \text{ in.: } A = 3.14 \; \frac{(0.5)^2}{4}$$

$$= 0.196 \text{ ft}^2$$

The continuity equation now becomes

$$(0.785 \text{ ft}^2) \times \left(\frac{\text{ft}}{3 \text{ sec}}\right) = (0.196 \text{ ft}^2) \times V_2$$

Solving for V_2

$$V_2 = \frac{(0.785 \text{ ft}^2) \times (3 \text{ ft/sec})}{(0.196 \text{ ft}^2)}$$

$$= 12 \text{ ft/sec or fps}$$

Pressure/Velocity

In a closed pipe flowing full (under pressure), the pressure is indirectly related to the velocity of the liquid.

$$\text{Velocity}_1 \times \text{Pressure}_1 = \text{Velocity}_2 \times \text{Pressure}_2$$

or

$$V_1P_1 = V_2P_2$$

Conservation of Energy

Many of the principles of physics are important to the study of hydraulics. When applied to problems involving the flow of water, few of the principles of physical science are more important and useful to us than the *Law of Conservation of Energy*. Simply, the Law of Conservation of Energy states that energy can neither be created nor destroyed, but it can be converted from one form to another. In a given closed system, the total energy is constant.

Energy Head

As previously mentioned, there are two types of energy, kinetic and potential; three forms of mechanical energy exist in hydraulic systems: potential energy due to elevation, potential energy due to pressure, and kinetic energy due to velocity. Energy has the units of foot pounds (ft-lbs). It is convenient to express hydraulic energy in terms of *Energy Head*, in feet of water. This is equivalent to foot-pounds per pound of water (ft lb/lb = ft).

Energy Available

Energy available is directly proportional to flow rate and to the hydraulic head. As mentioned, the head is equivalent to stored potential energy. This is shown as

$$= mgh$$

where

m = the mass of water

g = the acceleration due to gravity (can be taken as 10ms^{-2}) in most applications

h = the head difference

With regards to piping, the pipe diameter must be large enough to take the volume of water flowing. Friction in the pipes will reduce the effective head of water and larger diameters are used, although cost then has a bearing. Ideally, the pipes should narrow as one proceeds downhill, however, friction losses are highest where the velocity is highest, and so there is usually little change in pipe diameter. Friction losses in piping are classified as either major head loss or minor head loss (Tovey 2005).

Major Head Loss

Major head loss consists of pressure decreases along the length of pipe caused by friction created as water encounters the surfaces of the pipe. It typically accounts for most of the pressure drop in a pressurized or dynamic water system. The components that contribute to major head loss: roughness, length, diameter, and velocity.

- **Roughness—**Even when new, the interior surfaces of pipes are rough. The roughness varies, of course, depending on pipe material, corrosion (tuberculation and pitting), and age. Because normal flow in a water pipe is turbulent, the turbulence increases with pipe roughness, which, in turn, causes pressure to drop over the length of the pipe.
- **Pipe Length—**With every foot of pipe length, friction losses occur. The longer the pipe, the more head loss. Friction loss because of pipe length must be factored into head loss calculations.
- **Pipe Diameter—**Generally, small diameter pipes have more head loss than large diameter pipes. This is the case because in large diameter pipes less of the water actually touches the interior surfaces of the pipe (encountering less friction) than in a small diameter pipe.
- **Water Velocity—**Turbulence in a water pipe is directly proportional to the speed (or velocity) of the flow. Thus, the velocity head also contributes to head loss.

Calculating Major Head Loss

Darcy, Weisbach, and others developed the first practical equation used to determine pipe friction in about 1850. The equation or formula now known as the *Darcy-Weisbach* equation for circular pipes is:

$$h_f = f\,\frac{LV^2}{D2g}$$

In terms of the flow rate Q, the equation becomes:

$$h_f = \frac{8fLQ^2}{\pi^2 gD^5}$$

where h_f = head loss, (ft)

f = coefficient of friction

L = length of pipe, (ft)

V = mean velocity, (ft/s)

D = diameter of pipe, (ft)

g = acceleration due to gravity, (32.2 ft/s^2)

Q = flow rate, (ft^3/s)

The Darcy-Weisbach formula as such was meant to apply to the flow of any fluid and into this friction factor was incorporated the degree of roughness and an element called the *Reynold's Number*, which was based on the viscosity of the fluid and the degree of turbulence of flow.

The Darcy-Weisbach formula is used primarily for determining head loss calculations in pipes. For making this determination in open channels, the *Manning Equation* was developed during the later part of the nineteenth century. Later, this equation was used for both open channels and closed conduits.

In the early 1900s, a more practical equation, the *Hazen-Williams* equation, was developed for use in making calculations related to water pipes and wastewater force mains:

$$Q = 0.435 \text{ x } CD^{2.63} \times S^{0.54}$$

where

Q = flow rate, (ft^3/s)

C = coefficient of roughness (C decreases with roughness)

D = hydraulic radius R, (ft)

S = slope of energy grade line, (ft/ft)

C Factor

C factor, as used in the Hazen-Williams formula, designates the coefficient of roughness. *C* does not vary appreciably with velocity, and by comparing pipe types and ages, it includes only the concept of roughness, ignoring fluid viscosity and Reynold's Number. Based on experience (experimentation), accepted tables of *C* factors have been established for pipe (Table). Generally, *C* factor decreases by one with each year of pipe age. Flow for a newly designed system is often calculated with a *C* factor of 100, based on averaging it over the life of the pipe system.

C Factors (Lindeburg 1986)

Type of Pipe	*C Factor*
Asbestos Cement	140
Brass	140
Brick Sewer	100
Cast Iron	
10 years old	110
20 years old	90
Ductile Iron, (cement lined)	140
Concrete or Concrete Lined	
Smooth, steel forms	140
Wooden forms	120
Rough	110
Copper	140
Fire Hose (rubber lined)	135
Galvanized Iron	120
Glass	140
Lead	130
Masonry Conduit	130
Plastic	150
Steel	
Coal-tar enamel lined	150
New unlined	140
Riveted	110
Tin	130
Vitrified	120
Wood Stave	120

Slope

Slope is defined as the head loss per foot. In open channels, where the water flows by gravity, slope is the amount of incline of the pipe, and is calculated as feet of drop per foot of pipe length (ft/ft). Slope is designed to be just enough to overcome frictional losses, so that the velocity remains constant, the water keeps flowing, and solids will not settle in the conduit. In piped systems, where pressure loss for every foot of pipe is experienced, slope is not provided by slanting the pipe but instead by pressure added to overcome friction.

Minor Head Loss

In addition to the head loss caused by friction between the fluid and the pipe wall, losses also are caused by turbulence created by obstructions (i.e., valves and fittings of all types) in the line, changes in direction, and changes in flow area.

Head Loss: That part of head energy which is lost because of friction as water flows.

Head, Static, *h [L]*: The static head is the height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. The static head is the sum of the elevation head, h_e, and the pressure head, h_p; that is, $h = h_e + h_p$. Under conditions to which Darcy's law may be applied, the velocity of groundwater is so small that the velocity head, $h_v = v^2/2g$, is negligible. *Head*, when used alone, is understood to mean static head. Inspection of equation 7 shows that the head is proportional to the fluid potential; therefore, the head is a measure of the potential.

Head, Total, *H [L]*: The total head of a liquid at a given point is the sum of three components: (1) elevation head, h_e, which is equal to the elevation of the point above a datum, (2) pressure head, h_p, which is the height of a column of static water that can be supported by the static pressure at the point, and (3) velocity head, h_v which is the height the kinetic energy of the liquid is capable of lifting the liquid.

Headspace: The vapor mixture trapped above a solid or liquid in a sealed vessel.

Headwaters: (1) Part of a stream or river proximate to its source. (2) The water upstream from a structure (powerhouse) or point on a stream. (3) The small streams that come together to form a river. Also may be thought of as any of an all parts of a river basin except the mainstream river and main tributaries.

Health Advisory Level: A non-regulatory heath-based reference level of chemical traces (usually in ppm) in drinking water at which there are no adverse health risks when ingested over various periods of time. Such levels are established for one day, 10 days, long-term and life-term exposure periods. They contain a wide margin of safety.

Health Assessments: An evaluation of available data on existing or potential risks to human health posed by a Superfund site. The Agency for Toxic Substances and Disease Registry (ATSDR) of the Department of Health and Human Services (DHHS) is required to perform such an assessment at every site on the National Priorities List.

Health Investigation: The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Hearing Conservation: The prevention of, or minimizing of noise-induced deafness through the use of hearing protection devices, the control of noise through engineering controls, annual audiometric tests, and employee training.

Hearing Conservation Program: In 1983, OSHA adopted a Hearing Conservation Amendment to OSHA 29 CFR 1910.95 that requires employers to implement hearing conservation programs in any work setting where employees are exposed to an eight-hour time-weighted average of 85 dBA and above (LaBar, 1989). Employers must implement hearing conservation procedures in settings where the noise level exceeds a time-weighted average of 90 dBA. They also must provide personal protective equipment for any employee who shows evidence of hearing loss, regardless of the noise level at his or her worksite.

In addition to concerns over noise levels, the OSHA Standard also addresses the issue of duration of exposure. LaBar explains the duration aspects of the regulation:

"Duration is another key factor in determining the safety of workplace noise. The regulation has a 50 percent 5 dBA logarithmic tradeoff. That is, for every 5-decibel increase in the noise level, the length of exposure must be reduced by 50 percent. For example, at 90 decibels (the sound level of a lawnmower or shop tools), the limit on 'safe' exposure is 8 hours. At 95 dBA, the limit on exposure is 4 hours, and so on. For any sound that is 106 dBA and above—this would include such things as a sandblaster, rock concert, or jet engine-— exposure without protection should be less than 1 hour, according to OSHA's rule."

The basic requirement of OSHA's Hearing Conservation Standard include:

1. Monitoring noise levels. Noise levels should be monitored on a regular basis. Whenever a new process is added, an existing process is altered, or new equipment is purchased, special monitoring should be undertaken immediately.
2. Medical surveillance. The medical surveillance component of the regulation specifies that employees who will be exposed to high noise levels be tested upon being hired and again at least annually.
3. Noise controls. The regulation requires that steps be taken to control noise at the source. Noise controls are required in situations where the noise level exceeds 90 dBA. Administrative controls are sufficient until noise levels exceed 100 dBA. Beyond 100 dBA, engineering controls must be used.
4. Personal protection. Personal protective devices are specified as the next level of protection when administrative and engineering controls do not reduce noise hazards to acceptable levels. They are to be used in addition to rather than instead of administrative and engineering controls.
5. Education and training. The regulation requires the provision of education and training to do the following: ensure that employees understand (1) how the ear

works, (2) how to interpret the results of audiometric tests, (3) how to select personal protective devices that will protect them against the types of noise hazards to which they will be exposed, and (4) how to properly use personal protective devices (LaBar, 1989).

Heat Balance: The constant trade-off that takes place when solar energy reaches the earth's surface and is absorbed, then must return to space to maintain earth's normal heat balance.

Heat Cramps: Performing hard physical labor in a hot environment can cause heat cramps, a type of heat stress that occurs as a result of salt and potassium depletion. Primary observable symptoms are muscle spasms in the arms, legs, and abdomen.

To prevent heat cramps, acclimatize workers to the hot environment gradually over a period of at least a week. Ensure that fluid replacement is accomplished with a commercially available carbohydrate-electrolyte replacement product that contains the appropriate amount of salt, potassium, and electrolytes.

Heat Disorders and Health Effects: According to OSHA (2003), heat stress can manifest itself in a number of ways, depending on the level of stress. The most common types of heat stress are heat stroke, heat exhaustion, heat cramps, heat rash, transient heat fatigue, chronic heat fatigue, and sunburn. These various types of heat stress can cause a number of undesirable bodily reactions, including prickly heat, inadequate venous return to the heart, inadequate blood flow to vital body parts, circulatory shock, cramps, thirst, and fatigue.

Heat (Energy in Transit): 1. A measure of energy in terms of quantity. 2. A condition of matter caused by the rapid movement of its molecules. Energy has to be applied to the material in sufficient amounts to create the motion, and may be applied by mechanical or chemical means. Heat is always moving from a material of higher temperature to one of a lower temperature.

Heat Exchanger: A device for transferring thermal energy from one fluid to another.

Heat Exhaustion: A type of heat stress that occurs as a result of water and/or salt depletion. When people sweat in response to exertion and environmental heat, they lose water, salt and electrolytes, the minerals needed for the body to maintain the proper metabolism and for cells to produce energy. Loss of electrolytes causes these functions to break down. Electrolyte imbalance is a problem with heat exhaustion and heat cramps. For this reason, using commercially produced drinks that contain water, salt, sugar, potassium, or electrolytes to replace those lost through sweating is important. Employees working in the heat should have water and electrolyte replacement drinks readily available, and drink them frequently.

Symptoms of heat exhaustion are headache, nausea, vertigo, weakness, thirst, and giddiness. Fortunately, this condition responds readily to prompt treatment. Heat exhaustion should not be dismissed lightly. One principal reason should be apparent to the safety engineer: fainting associated with heat exhaustion can be dangerous because the victim may be operating machinery, controlling an operation that should not be left unattended, or in physical danger from falling.

A victim of heat exhaustion should be moved to a cool (but not cold) environment and should rest lying down. Give fluids slowly but steadily by mouth until the urine volume indicates that the body's fluid level is once again in balance.

Heat Fatigue: Principle cause is the victim's lack of acclimatization. Well-conditioned, properly acclimatized employees will suffer this form of heat stress less frequently and less severely than poorly conditioned employees. Consequently, preventing heat fatigue involves physical conditioning and acclimatization, because removing the heat stress before a more serious heat-related condition develops is the only treatment for heat fatigue available.

Heat Flow: Movement of heat from within the earth to the surface, where it is dissipated into the atmosphere, surface water, and space by radiation.

Heat Index: The Heat Index combines temperature and humidity levels to determine how the combined conditions affect individuals. The formula for calculating the Heat Index is:

$$\begin{aligned}
HI &= 16.923 + (1.85212\times10^{1} * T) + (5.37941 * RH) - (1.00254\times10^{1} * T * RH)\\
&+ (9.41695\times10^{3} * T^{2}) + (7.28898\times10^{3} * RH^{2}) + (3.45372\times10^{4} * T^{2} * RH)\\
&- (8.14971\times10^{4} * T * RH^{2}) + (1.02102\times10^{5} * T^{2} * RH^{2}) - (3.8646\times10^{5} * T^{3})\\
&+ (2.91583\times10^{5} * RH^{3}) + (1.42721\times10^{6} * T^{3} * RH) + (1.97483\times10^{7} * T * RH^{3})\\
&- (2.18429\times10^{8} * T^{3} * RH^{2}) + (8.43296\times10^{10} * T^{2} * RH^{3}) - (4.81975\times10^{11} * T^{3} * RH^{3})
\end{aligned}$$

where:

HI = Heat Index
T = Temperature (° F)
RH = Relative Humidity (%)

Heat Island: Large metropolitan areas where heat generated has an influence on the ambient temperature (adds heat) in and near the area.

Heat Island Effect: A "dome" of elevated temperatures over an urban area caused by structural and pavement heat fluxes, and pollutant emissions.

Heat Index Chart (Temperature and Relative Humidity)

RH (%)	Temperature (° F)															
	90	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**	**103**	**104**	**105**
90	119	123	128	132	137	141	146	152	157	163	168	174	180	186	193	199
85	115	119	123	127	132	136	141	145	150	155	161	166	172	178	184	190
80	112	115	119	123	127	131	135	140	144	149	154	159	164	169	175	180
75	109	112	115	119	122	126	130	134	138	143	147	152	156	161	166	171
70	106	109	112	115	118	122	125	129	133	137	141	145	149	154	158	163
65	103	106	108	111	114	117	121	124	127	131	135	139	143	147	151	155
60	100	103	105	108	111	114	116	120	123	126	129	133	136	140	144	148
55	98	100	103	105	107	110	113	115	118	121	124	127	131	134	137	141
50	96	98	100	102	104	107	109	112	114	117	119	122	125	128	131	135
45	94	96	98	100	102	104	106	108	110	113	115	118	120	123	126	129
40	92	94	96	97	99	101	103	105	107	109	111	113	116	118	121	123
35	91	92	94	95	97	98	100	102	104	106	107	109	112	114	116	118
30	89	90	92	93	95	96	98	99	101	102	104	106	108	110	112	114

Note: Exposure to full sunshine can increase HI values by up to 15° F

Source: 8/24/10 Weather Images: http://www.weatherimages.org/data/heatindex.html

Heat Pump: A year-round heating and air-conditioning system employing a refrigeration cycle. In a refrigeration cycle, a refrigerant is compressed (as a liquid) and expanded (as a vapor) to absorb and reject heat. The heat pump transfers heat to a space to be heated during the winter period and by reversing the operation extracts (absorbs) heat from the same space to be cooled during the summer period. The refrigerant within the heat pump in the heating mode absorbs the heat to be supplied to the space to be heated from an outside medium (air, ground or ground water) and in the cooling mode absorbs heat from the space to be cooled to be rejected to the outside medium.

Heat Pump (Air Source): An air-source heat pump is the most common type of heat pump. The heat pump absorbs heat from the outside air and transfers the heat to the space to be heated in the heating mode. In the cooling mode the heat pump absorbs heat from the space to be cooled and rejects the heat to the outside air. In the heating mode when the outside air approaches 32ºF or less, air-source heat pumps loose efficiency and generally require a back-up (resistance) heating system.

Heat Pump (Geothermal): A heat pump in which the refrigeration exchanges heat (in a heat exchanger) with a fluid circulating through an earth connection medium (ground or ground water). The fluid is contained in a variety of loop (pipe) configurations depending on the temperature of the ground and the ground area available. Loops may be installed horizontally or vertically in the ground or submersed in a body of water.

Heat Rash: Heat rashes are the most common problem in hot work environments. This type of heat manifests itself as small raised bumps or blisters that cover a portion of the body and give off a prickly sensation that can cause discomfort. Caused by prolonged exposure to hot, damp conditions in which the body is continuously covered with sweat that does not evaporate because of the high humidity, in most cases, heat rashes will disappear when the affected individual returns to a cool environment.

Heat Resistant: A material having the quality of capability of withstanding heat for a specified period at a maximum given temperature without decomposing or losing its integrity.

Heating Value: The maximum amount of energy that is available from burning a substance.

Heat Stroke: A serious disorder resulting from exposure to excessive heat. Occurs when the body's system of temperature regulation fails and body temperature rises to critical levels. This condition is caused by a combination of highly variable factors, and its occurrence is difficult to predict. Heat stroke is very dangerous and should be dealt with immediately because it can be fatal. The primary signs and symptoms of heat stroke are confusion; irrational behavior; loss of consciousness; convulsions; a lack of sweating (usually); hot, dry skin; and an abnormally high body temperature, e.g., a victim of heat stroke will have a rectal temperature of 104.5°F or higher that will typically continue to climb.

If a worker shows signs of possible heat stroke, professional medical treatment should be obtained immediately. The worker should be placed in a shady area and the outer clothing should be removed. The worker's skin should be wetted and air movement around the worker should be increased to improve evaporative cooling until professional methods of cooling are initiated and the seriousness of the condition can be assessed. Fluids should be replaced as soon as possible. The medical outcome of an episode of heat stroke depends on the victim's physical fitness and the timing and effectiveness of first aid treatment.

Heavy Metals: A group of elements whose compounds are toxic to humans when found in the environment; examples are cadmium, mercury, copper, nickel, chromium, lead, zinc, and arsenic.

Hedonic Tone: Scale that ranges from –10, which is unpleasant, to +10, which is pleasant, to describe an odor.

Hemorrhage: Excessive bleeding.

Henry's Law: Governs the behavior of gases in contact with water.

HEPA Filters: High Efficiency Particulate Air filters.

Heptachlor: An insecticide that was banned on some food products in 1975 and in all of them 1978. It was allowed for use in seed treatment until 1983. More recently it was found in milk and other dairy products in Arkansas and Missouri, where dairy cattle were illegally fed treated seed.

Herbaceous: Non-woody type of vegetation, usually lacking permanent strong stems, such as grasses, cereals, and canola (rape).

Herbicide: Chemicals used to kill unwanted plants.

Heterotrophic Organism: 1. Organisms that are dependent on organic matter for foods. 2. A category of organism that obtains its energy by consuming the tissue of other organisms.

High-Density Polyethylene: A material used to make plastic bottles and other products that produces toxic fumes when burned.

High-Efficiency Particulate Air (HEPA) Filter: A filter capable of trapping and retaining at least 99.97 percent of 0.3 micrometer mono-dispersed particles (10 CFR 850.3).

High-Intensity Discharge: A generic term for mercury vapor, metal halide, and high pressure sodium lamps and fixtures.

High-Level Nuclear Waste Facility: Plant designed to handle disposal of used nuclear fuel, high-level radioactive waste, and plutonium waste.

High-Level Radioactive Waste (HLRW): Waste generated in core fuel of a nuclear reactor, found at nuclear reactors or by nuclear fuel processing; is a serious threat to anyone who comes near the waste without shielding.

High-Risk Community: A community located with the vicinity of numerous sites of facilities or other potential sources of environmental exposures/health hazards which may result in high levels of exposure to contaminants or pollutants.

High-Speed Shaft: Transmits force from the gearbox to the generator.

High-Temperature Collector: A solar thermal collector designed to operate at a temperature of 180 degrees Fahrenheit of higher.

High-to-Low-Dose Extrapolation: The process of prediction of low exposure risk to humans and animals from the measured high-exposure-high-risk data involving laboratory animals.

Highest Dose Tested: The highest dose of a chemical or substance tested in a study.

Hoists and Jacks: OSHA under general industry safety standards 29 CFR 1910.244 and 1910.308 and the construction standards 29 CFR 1926.305 and 1926.554 cover jacks, overhead hoists, and monorail hoists.

Holding Pond: Storage, usually earthen where lot runoff, lagoon effluent, and other dilute wastes are stored before final disposal. It is not designed for treatment.

Holding Time: The maximum amount of time a sample may be stored before analysis.

Homeland Security: Federal cabinet-level department created to protect the United States of America and her citizens as a result of 9/11. The new Department of Homeland Security (DHS) has three primary missions: prevent terrorist attacks within the United States, reduce America's vulnerability to terrorism, and minimize the damage from potential attacks and natural disasters.

Homogeneous Area: In accordance with Asbestos Hazard and Emergency Response Act (AHERA) definitions, an area of surfacing materials, thermal surface insulation, or miscellaneous material that is uniform in color and texture.

Homologous: Similar in position, structure, function, or characteristics.

Hood: A device that encloses, captures, or receives emitted contaminants.

Hood and Duct Dimensions: Can be estimated from plans, drawings, and specifications. Measurements can be made with measuring tape. If a duct is constructed of 2.5 or 4-foot sections, the sections can be counted (elbows and tees should be included in the length).

Hood Capture Efficiency: Ratio of the emissions captured by a hood and directed into a control of disposal device, expressed as a percent of all emissions.

Hood Entry Loss (H_e): The static pressure lost (in inches of water) when air enters a duct through a hood. The majority of the loss usually is associated with a vena contracta formed in the duct.

Hood-Face Velocities: Outside the hood or at the hood face velocities can be estimated with velometers, smoke tubes, and swinging-vane anemometers, all of which are portable, are reliable, and require no batteries.

a. The minimum velocity that can be read by an anemometer is 50 feet per minute (fpm). The meter should always be read in the upright position, and only the tubing supplied with the equipment should be used.
b. Anemometers often cannot be used if the duct contains dust or mist because air must actually pass through the instrument for it to work. The instrument requires periodic cleaning and calibration at least once per year. Hot-wire anemometers should not be used in airstreams containing aerosols.
c. Hood-face velocity measurement involves the following steps:

- mark off imaginary areas
- measure velocity at center of each area
- average all measured velocities

d. Smoke is useful for measuring face velocity because it is visible. Nothing convinces management and employees more quickly that the ventilation is not functioning properly than to show smoke drifting away from the hood, escaping the hood, or traveling into the worker's breathing zone, Smoke can be used to provide a rough estimate of face velocity:

   Squeeze off a quick blast of smoke. Time the smoke plume's travel over a two-foot distance. Calculate the velocity in feet per minute. For example, if it takes to seconds for the smoke to travel two feet, the velocity is 60 fpm.

Velocity = Distance/Time or V = D/T

Hood Static Pressure (SP_h): The sum of the duct velocity pressure and the hood entry loss; hood static pressure is the static pressure required to accelerate air at rest outside the hood into the duct at velocity. Should be measured about 4-6 duct diameters downstream in a straight section of the hood take-off duct. The measurement can be made with a pitot tube or by a static pressure tap into the duct sheet metal.

a. Pressure gauges come in a number of varieties, the simplest being the U-tube manometer.
b. Inclined manometers offer greater accuracy and greater sensitivity at low pressures than U-tube manometers. However, manometers rarely can be used for velocities less than 800 fpm (i.e. velocity pressures less than 0.05" w.g.). Aneroid-type manometers use a calibrated bellows to measure pressures. They are easy to read and portable but require regular calibration and maintenance.

Horsepower and Work: *Horsepower* is a common expression for power. One horsepower is equal to 33,000 foot pounds of work per minute. This value is determined, for example, for selecting to pump or combination of pumps to ensure an adequate pumping capacity. Pumping capacity depends upon the flow rate desired and the feet of head against which the pup must pump (a.k.a., effective height).

Calculations of horsepower are made in conjunction with many industrial operations. The basic concept from which the horsepower calculation is derived is the concept of work. *Work* involves the operation of a force (lb) over a specific distance (ft). The *amount of work* accomplished is measured in foot-pounds:

$$(\text{ft})\,(\text{lb}) = \text{ft-lb}$$

The *rate of doing work (power)* involves a time factor. Originally, the rate of doing work or power compared the power of a horse to that of a steam engine. The rate at which a horse could work was determined to be about 550 ft-lb/sec (or expressed as 33,000 ft-lb/min). This rate has become the definition of the standard unit called horsepower.

1. Horsepower

$$\text{Horsepower, hp} = \frac{\text{Power, ft-lb/min}}{\text{33,000 ft-lb/min/HP}}$$

When the major use of horsepower calculation is to determine the proper pumping station operation, the horsepower calculation can be modified as shown below.

a) Water Horsepower (Whp)

The amount of power required to move a given volume of water is specified as total head and is known as *water horsepower (Whp).*

$$\text{Whp} = \frac{\text{Pump Rate, gpm} \times \text{Total Head, ft} \times 8.34\ \text{lb/gal}}{33{,}000\ \text{ft-lb/min/HP}}$$

Example Problem:

A pump must deliver 1,210 gpm to total head of 130 feet. What is the required water horsepower?

Solution:

$$\text{Whp} = \frac{1{,}210\ \text{gpm} \times 130\ \text{ft} \times 8.34\ \text{lb/gal}}{33{,}000\ \text{ft-lb/min/HP}} = 40\ \text{Whp}$$

b) Brake Horsepower (bhp)

Brake horsepower (bhp) refers to the horsepower supplied to the pump from the motor. As power moves through the pump, additional horsepower is lost from slippage and friction of the shaft and other factors; thus, pump efficiencies range from about 50 percent to 85 percent and pump efficiency must be taken into account.

$$\text{Bhp} = \frac{\text{Whp}}{\text{Pump \% Efficiency}}$$

Example Problem:

Under the specified conditions, the pump efficiency is 73 percent. If the required water horsepower is 40 hp, what is the required brake horsepower?

Solution:

$$\text{Bhp} = \frac{40\ \text{Whp}}{0.73} = 55\ \text{Bhp}$$

c) Motor Horsepower

Motor horsepower (Mhp) is the horsepower the motor must generate to produce the desired brake and water horsepower.

$$\text{Mhp} = \frac{\text{Brake Horsepower, Bhp}}{\text{Motor \% Efficiency}}$$

Example Problem:

The motor is 93 percent efficient. What is the required motor horsepower when the required brake horsepower is 49.0 Bhp?

Solution:

$$\text{Mhp} = \frac{49\ \text{Bhp}}{0.93} = 53\ \text{Mhp}$$

Host: 1. In genetics, the organism, typically a bacterium, into which a gene from another organism is transplanted. 2. In medicine, an animal infected or parasitized by another organism. 3. Any computer that has full two-way access to other computers on the Internet, or a computer with a web server that serves the pages for one or more Web sites.

Hot Standby: A backup system configured in such a way that it may be used if the system goes down.

Hot Work: Work involving electric or gas welding, cutting, brazing, or similar flame or spark-producing operations.

In the performance of hot work in the workplace, various OSHA standards require the following:

> The employer shall issue a hot work permit for hot work operations conducted on or near a covered process [including confined spaces].
>
> The permit shall document that the fire prevention and protection requirements in 29 CFR § 1910.252(a) [Fire Prevention and Protection] have been implemented prior to beginning the hot work operations; it shall indicate the date(s) authorized for hot work; and identify the object on which hot work is to be performed. The permit shall be kept on file until completion of the hot work operations.
>
> —29 CFR 1910.119,.134,.252. Code of Federal Regulations, 1995

When confined space entry is to be made into an entry-by-permit-only confined space, often an important interface between these various standards must exist, especially in the need to ensure safe entry. In addition to ensuring that any type of hot work to be performed in confined spaces is accomplished in a safe manner by using hot work permit requirements, other workplace operations might require the use of hot work permit procedures. For example, under OSHA's 29 CFR 1910.119 (Process Safety Management), any time hot work is to be performed on, near, or around covered chemical processes, a hot work permit must be used. Many companies require the use of hot work permits any time hot work is to be performed anywhere within the organization, outside normal operations and processes. "Normal operations and processes" might be defined as work normally performed in a welding, brazing or hot torch cutting shop, or hot work performed as part of a assembly line process, such as that conducted by robots on automobile assembly lines.

"Outside normal operations and processes" might be described as performing hot work in work areas where hot work is not typically performed—for example, in office, storage, and/or production areas.

Typically, the organizational safety person is responsible for implementing and managing the hot work permitting procedure. The primary elements required to be incorporated into a viable hot work permit system include a standard operating procedure consisting of (1) a written procedure, (2) a permit, (3) worker training, and (4) fire watch provisions.

A hot work permitting procedure works primarily to ensure that work areas and all adjacent areas to which sparks and heat might be spread (including floors above and below and on opposite sides of walls) are inspected during the work and again thirty minutes after the work is completed, to ensure they are fire safe. For example, during the inspection, work areas and surrounding areas should be inspected to ensure that:

- Sprinklers are in service;
- Cutting and welding equipment is in good repair;
- Floors are swept clean of combustibles;
- Combustible floors are wetted down, and covered with damp sand, metal or other shields;
- No combustible material or flammable liquids are within 35 feet of the work;
- Combustibles and flammable liquids within 35 feet of work are protected with covers, guards or metal shields;
- All wall and floor openings within 35 feet of work are covered;
- Covers are suspended beneath the work to collect sparks;
- For work on walls or ceilings, ensure construction is of noncombustible materials;
- Combustibles must be moved away from opposite side of wall;
- For work on or in enclosed tanks, containers, ducts, etc., equipment must be cleaned of all combustibles and purged of flammable vapors;
- Fire watch is provided during and until thirty minutes after operation;
- Assigned fire watch is properly trained and equipped.

Hot Zone: The area immediately around the incident site. Appropriate protective clothing and equipment must be worn by all personnel in the hot zone. Awareness Level and operational Level trained personnel are not permitted in the hot zone.

Household Hazardous Waste: Hazardous products used and disposed of by residential as opposed to industrial consumers. Includes paints, strains, varnishes, solvents, pesticides, and other materials or products containing volatile chemicals that can catch fire, react or explode, or are corrosive or toxic.

Household Waste (Domestic Waste): Solid waste, composed of garbage and rubbish, which normally originates in a private home or apartment house. Domestic waste may contain a significant amount of toxic or hazardous waste.

Human Equivalent Dose: A dose which, when administered to humans, produces an effect equal to that produced by a dose in animals.

Human-Error Factor: People cause the biggest risks to information systems, whether deliberate or accidental. In fact, people—the users themselves, are a commonly overlooked possible breach in any security infrastructure. They'll write down passwords and leave them in obvious places. They'll set their software to remember passwords. They'll open email with strange attachment file endings and cute taglines, and the resulting avalanche of virally induced spamming will bring down the whole system, and help to spread the infection at top speed throughout the world. Educating them on the implications of their actions is ongoing, an integral part of employee training. IT staff and safety personnel should work together to educate administrations and the workforce in computer and data protection. Training and worker education helps to control a wide range of problems. For example, as safety engineer, you should know that the workers in your organization have been trained to follow IT instructions on updating viral protection regularly, that they know better than to open up suspicious email, that they are aware that a random stranger on-site could be seeking vulnerable equipment or data, and that passwords must never be shared with anyone outside a verified IT staff member. In short, one of the best protections for computer security are users who are thinking.

Human Factor Engineering (used in the United States) **Ergonomics**: (Europe): For practical purposes, the terms are synonymous, and focus on human beings and their interaction with products, equipment, facilities, procedures, and environments used in work and everyday living. The emphasis is on human beings (as opposed to engineering, where the emphasis is more strictly on technical engineering considerations) and how the design of things influences people. Human factors, then, seek to change the things people use and the environments in which they use these things to better match the capabilities, limitations, and needs of people (Sanders and McCormick, 1993).

Human Health Risk: The likelihood that a given exposure or series of exposures may have damaged or will damage the health of individuals.

Humidity: The amount of water vapor in a given volume of the atmosphere (absolute humidity), or the ratio of the amount of water vapor in the atmosphere to the saturation value at the same temperature (relative humidity).

Humus: Dark, high carbon residue from plant decomposition. Similar residues are in composted manure and well-digested sludge.

HVAC (Heating, Ventilation, and Air-Conditioning) System: Ventilating systems designed primarily to control temperature, humidity, odors, and air quality.

Hydraulic Conductivity: Rate of flow of water in gallons per day through a cross section of one square foot of soil at the prevailing temperature (gpd/ft^2). In the SI system, the units are m^3/day/m^2 or m/day.

Hydraulic Diffusivity, T/S or K/S_s [L^2T^{-2}]: The hydraulic diffusivity is the parameter T/S or K/S_s. It is the conductivity of the saturated medium when the unit volume of water moving is that involved in changing the head a unit amount in a unit volume of medium. By analogy with Maxwell's nomenclature in heat conduction theory (thermometric conductivity), it may be considered potentiometric conductivity. Similar diffusivities, having dimensions L^2T^{-1}, characterize the flow of heat and of electricity by conduction and the movement of a dissolved substance in a liquid by diffusion. The parameter arises from the fundamental differential equation for liquid flow in a porous medium. In any isotropic homogenous system the time involved for a given head change to occur at a particular point in response to a greater change in head at another point is inversely proportional to the diffusivity. As a common example the cone of depression affects moderately distant well by measure able amounts in a short time in confined groundwater bodies for which the diffusivities are commonly large and only after a longer time in unconfined water bodies for which the diffusivities are commonly much smaller.

Hydraulic Fracturing: A well stimulation method in which liquid under high pressure is pumped down a well to fracture the reservoir rock adjacent to the wellbore. Propping agents are used to keep the fractures open.

Hydraulic Gradient: 1. Rate of change in total head per unit of distance of flow in a given direction. 2. The difference in hydraulic head divided by the distance along the fluid flow path. Groundwater moves through an aquifer in the direction of the hydraulic gradient.

Hydraulic Stimulation: A stimulation technique performed using fluid.

Hydrocarbon: A chemical containing only carbon and hydrogen atoms. Crude oil is a mixture largely of hydrocarbons.

Hydrocompaction: The process of volume decrease and density increase that occurs when certain moisture-deficient deposits compact as they are wetted for the first time since burial. The vertical downward movement of the land surface that results from this process has also been termed "shallow subsidence" and "near-surface subsidence."

Hydrogen Sulfide (H_2S): Gas emitted during organic decomposition. Also a by-product of oil refining and burning. Smells like rotten eggs and, in heavy concentration, can kill or cause illness.

Hydrogeological Cycle: The natural process recycling water from the atmosphere down to (and through) the earth and back to the atmosphere again.

Hydrogeology: The geology of ground water, with particular emphasis on the chemistry and movement of water.

Hydrologic Condition: Description of the moisture present in a soil by amount, location, and configuration.

Hydrological Cycle: The means by which water is circulated in the biosphere. Cooling in the atmosphere and precipitation over both land and oceans counterbalances evapotranspiration from the land mass plus evaporation from the oceans.

Hydrology: The science dealing with the properties, distribution, and circulation of water.

Hydrolysis: The decomposition of organic compounds by interaction with water.

Hydrolyze: To subject to or undergo hydrolysis.

Hydronic: A ventilation system using heated or cooled water pumped through a building.

Hydrophilic: Having a strong affinity for water.

Hydrophobic: Having a strong aversion of for water.

Hydropneumatic: A water system, usually small, in which a water pump is automatically controlled by the pressure in a compressed air tank.

Hydropower[1]

> When we speak of water, we are speaking of that endless quintessential cycle that predates all other cycles. Water is our most precious natural resource; we can't survive without it. There is no more water today than there was yesterday; that is, no more this calendar year than 100 million years ago. The water present today is the same water used by all the animals that ever lived, by cave dwellers, Caesar, Cleopatra, Christ, da Vinci, John Snow, Teddy Roosevelt, and the rest of us—again there is not one drop more or one drop less of water than there has always been. This life-giving cycle, though it is a unique blend of thermal and mechanical aspects, is dependent on solar energy and gravity for its existence Nothing on earth is truly infinite in supply, but the energy available from water sources, in practical terms, comes closest to that ideal.
>
> —F.R. Spellman

When we look at rushing waterfalls and rivers, we may not immediately think of electricity. But hydroelectric (water-powered) power plants are responsible for lighting many of our homes and neighborhoods. *Hydropower* is the harnessing of water to perform work. The power of falling water has been used in industry or thousands of years. The Greeks used water wheels for grinding wheat into flour more than 2,000 years ago. Besides grinding flour, the power of the water was used to saw wood and power textile mills and manufacturing plants.

The technology for using falling water to create hydroelectricity has existed for more than a century. The evolution of the modern hydropower turbine began in the mid-1700s, when a French hydraulic and military engineer, Bernard Forest de Belidor wrote a four volume work describing using a vertical-axis versus a horizontal-axis machine.

Water turbine development continued during the 1700s and 1800s. In 1880, a brush arc light dynamo driven by a water turbine was used to provide theatre and storefront lighting in Grand Rapids, Michigan; and in 1881, a brush dynamo connected to a turbine in a flour mill provided street lighting at Niagara Falls, New York. These two projects used direct-current (DC) technology.

Alternating current (AC) is used today. That breakthrough came when the electric generator was coupled to the turbine, which resulted in the worlds, and the Unites States', first hydroelectric plant located on the Fox River in Appleton, Wisconsin, in 1882. The U.S. Library of Congress (2009) lists the Appleton hydroelectric power plant as one of the major accomplishments of the Gilded Age (1878–1889). Soon, people across the United States were enjoying electricity in homes, schools, and offices, reading by electric lamp instead of candlelight or kerosene. Today, we take electricity for granted, not able to imagine life without it.

Ranging in size from small systems (100 kilowatts to 30 megawatts) for a home or village to large projects (capacity greater than 30 megawatts) producing electricity for utilities, hydropower plants are of three types: impoundment, diversion, and pumped storage. Some hydropower plants use dams and some do not. Many dams were built for other purposes and hydropower was added later. In the United States, there are about 80,000 dams of which only 2,400 produce power. The other dams are for recreation, stock/farm ponds, flood control, water supply, and irrigation. The sizes of hydropower plants are described below.

Impoundment

The most common type of hydroelectric power plant is an impoundment facility. An impoundment facility, typically a large hydropower system, uses a dam to store river water in a reservoir. This type of facility works best in mountainous or hilly terrain where high dams can be built and deep reservoirs can be maintained. Potential energy available in a reservoir depends on the mass of water contained in it, as well as on overall depth of the water. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. The water may be released either to meet changing electricity needs or to maintain a constant reservoir level.

Diversion

A diversion, sometimes called run-of-river, facility channels all or a portion of the flow of a river from its natural course through a canal or penstock, and the current through this medium is used to drive turbine. It may not require the use of a dam. This type of system is best suited for locations where a river drops considerably per unit of horizontal distance. The ideal location is near a natural waterfall or rapids. The chief advantage of a diversion system is the fact that, lacking a dam, it has far less impact on the environment than an impoundment facility (Gibilisco 2007).

Pumped Storage

When the demand for electricity is low, a pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

Hydropower Basic Concepts[2]

Air Pressure (@ Sea Level) = 14.7 pounds per square inch (psi)

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[1] Adapted from F.R. Spellman (2011). *The Science of Renewable Energy*. Boca Raton, FL: CRC Press.

[2] Much of the information in this section is adapted from F.R. Spellman (2008). *The Science of Water*. Boca Raton: CRC Press.

The relationship shown above is important because our study of hydropower basics begins with air. A blanket of air, many miles thick surrounds the earth. The weight of this blanket on a given square inch of the earth's surface will vary according to the thickness of the atmospheric blanket above that point. As shown above, at sea level, the pressure exerted is 14.7 pounds per square inch (psi). On a mountaintop, air pressure decreases because the blanket is not as thick.

$$1 \text{ ft}^3 \text{ H}_2\text{O} = 62.4 \text{ lb}$$

The relationship shown above is also important: both cubic feet and pounds are used to describe a volume of water. There is a defined relationship between these two methods of measurement. The specific weight of water is defined relative to a cubic foot. One cubic foot of water weighs 62.4 pounds. This relationship is true only at a temperature of 4°C and at a pressure of one atmosphere [known as standard temperature and pressure (STP)—14.7 lbs. per square inch at sea level containing 7.48 gallons]. The weight varies so little that, for practical purposes, this weight is used from a temperature 0°C to 100°C. One cubic inch of water weighs 0.0362 pounds. Water one foot deep will exert a pressure of 0.43 pounds per square inch on the bottom area ($12 \text{ in} \times 0.0362 \text{ lb/in}^3$). A column of water two feet high exerts 0.86 psi, one 10 feet high exerts 4.3 psi, and one 55 feet high exerts

$$55 \text{ ft} \times 0.43 \text{ psi/ft} = 23.65 \text{ psi}$$

A column of water 2.31 feet high will exert 1.0 psi. To produce a pressure of 50 psi requires a water column

$$50 \text{ psi} \times 2.31 \text{ ft/psi} = 115.5 \text{ ft}$$

Remember: The important points being made here are:

1. $1 \text{ ft}^3 \text{ H}_2\text{O} = 62.4 \text{ lb}$
2. A column of water 2.31 ft high will exert 1.0 psi

Another relationship is also important:

$$1 \text{ gallon H}_2\text{O} = 8.34 \text{ pounds}$$

One cubic foot of water weighs 62.4 lbs.

At standard temperature and pressure, one cubic foot of water contains 7.48 gallons. With these two relationships, we can determine the weight of one gallon of water. This is accomplished by

$$\text{wt. of gallon of water} = 62.4 \text{ lb} \div 7.48 \text{ gal} = 8.34 \text{ lb/gal}$$

Thus,

$$1 \text{ gallon H}_2\text{O} = 8.34 \text{ pounds}$$

Note: Further, this information allows cubic feet to be converted to gallons by simply multiplying the number of cubic feet by 7.48 gal/ft^3.

EXAMPLE
Problem:
Find the number of gallons in a reservoir that has a volume of 855.5 ft^3.

Solution:

$$855.5 \text{ ft}^3 \times 7.48 \text{ gal/ft}^3 = 6{,}399 \text{ gallons (rounded)}$$

Note: The term *head* is discussed later but for now it is important to point out that it is used to designate water pressure in terms of the height of a column of water in feet. For example, a 10-foot column of water exerts 4.3 psi. This can be called 4.3-psi pressure or 10 feet of head.

Stevin's Law
Stevin's Law deals with water at rest. Specifically, the Law states: "The pressure at any point in a fluid at rest depends on the distance measured vertically to the free surface and the density of the fluid." Stated as a formula, this becomes

$$p = w \times h$$

where
p = pressure in pounds per square foot (psf)
w = density in pounds per cubic foot (lb/ft^3)
h = vertical distance in feet

EXAMPLE
Problem:
What is the pressure at a point 18 feet below the surface of a reservoir?

Solution:

Note: To calculate this, we must know that the density of the water, *w*, is 62.4 pounds per cubic foot.

$$\begin{aligned} p &= w \times h \\ &= 62.4 \text{ lb/ft}^3 \times 18 \text{ ft} \\ &= 1123 \text{ lb/ft}^2 \text{ or } 1123 \text{ psf} \end{aligned}$$

Water practitioners generally measure pressure in pounds per square **inch** rather than pounds per square **foot**; to convert, divide by 144 in^2/ft^2 (12 in × 12 in = 144 in^2):

$$P = \frac{1123 \text{ psf}}{144 \text{ in}^2/\text{ft}^2} = 7.8 \text{ lb/in}^2 \text{ or psi (rounded)}$$

Properties of Water

The table shows the relationship between temperature, specific weight and density of water.

Density and Specific Gravity

When we say that iron is heavier than aluminum, we say that iron has greater density than aluminum. In practice, what we are really saying is that a given volume of iron is heavier than the same volume of aluminum.

Note: What is density? *Density* is the *mass per unit volume* of a substance.

Suppose you had a tub of lard and a large box of cold cereal, each having a mass of 600 grams. The density of the cereal would be much less than the density of the lard because the cereal occupies a much larger volume than the lard occupies. The density of an object can be calculated by using the formula:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Perhaps the most common measures of density are pounds per cubic foot (lb/ft^3) and pounds per gallon (lb/gal).

- **1 cu ft of water weights 62.4 lbs—Density = 62.4 lb/cu/ft**
- **gallon of water weighs 8.34 lbs—Density = 8.34 lb/gal**

The density of a dry material, such as cereal, lime, soda, and sand, is usually expressed in pounds per cubic foot. The density of a liquid, such as liquid alum, liquid chlorine, or water, can be expressed either as pounds per cubic foot or as pounds per gallon. The density of a gas, such as chlorine gas, methane, carbon dioxide, or air, is usually expressed in pounds per cubic foot.

The density of a substance like water changes slightly as the temperature of the substance changes. This occurs because substances usually increase in volume (size—they expand) as they become warmer. Because of this expansion with warming, the same weight is spread over a larger volume, so the density is lower when a substance is warm than when it is cold.

Note: What is specific gravity? Specific gravity is the weight (or density) of a substance compared to the weight (or density) of an equal volume of water. [Note: The specific gravity of water is 1.]

This relationship is easily seen when a cubic foot of water, which weighs 62.4 lbs as shown earlier, is compared to a cubic foot of aluminum, which weights 178 pounds. Aluminum is 2.7 times as heavy as water. It is not that difficult to find the specific gravity of a piece of metal. All you have to do is to weigh the metal in air, then weigh it under water. Its loss of weight is the weight of an equal volume of water. To find the specific gravity, divide the weight of the metal by its loss of weight in water.

$$\text{Specific Gravity} = \frac{\text{Weight of Substance}}{\text{Weight of Equal Volume of Water}}$$

EXAMPLE

Problem:

Suppose a piece of metal weighs 150 pounds in air and 85 pounds under water. What is the specific gravity?

Solution:

Step 1: 150 lb subtract 85 lb = 65 lb loss of weight in water

Step 2:

$$\text{specific gravity} = \frac{150}{65} = 2.3$$

Water Properties (Temperature, Specific Weight, and Density)

Temperature (°F)	*Specific Weight (lb/ft^3)*	*Density (slugs/ft^3)*	*Temperature (°F)*	*Specific Weight (lb/ft^3)*	*Density (slugs/ft^3)*
32	62.4	1.94	130	61.5	1.91
40	62.4	1.94	140	61.4	1.91
50	62.4	1.94	150	61.2	1.90
60	62.4	1.94	160	61.0	1.90
70	62.3	1.94	170	60.8	1.89
80	62.2	1.93	180	60.6	1.88
90	62.1	1.93	190	60.4	1.88
100	62.0	1.93	200	60.1	1.87
110	61.9	1.92	210	59.8	1.86
120	61.7	1.92			

The specific gravity of water is one (1), which is the standard, the reference that all other liquid or solid substances are compared. Specifically, any object that has a specific gravity greater than one will sink in water (rocks, steel, iron, grit, floc, sludge). Substances with a specific gravity of less than 1 will float (wood, scum, gasoline). Considering the total weight and volume of a ship, its specific gravity is less than one; therefore, it can float.

The most common use of specific gravity in water operations is in gallons-to-pounds conversions. In many cases, the liquids being handled have a specific gravity of 1.00 or very nearly 1.00 (between 0.98 and 1.02), so 1.00 may be used in the calculations without introducing significant error. However, in calculations involving a liquid with a specific gravity of less than 0.98 or greater than 1.02, the conversions from gallons to pounds must consider specific gravity. The technique is illustrated in the following example.

EXAMPLE
Problem:
There are 1,455 gal of a certain liquid in a basin. If the specific gravity of the liquid is 0.94, how many pounds of liquid are in the basin?

Solution:
Normally, for a conversion from gallons to pounds, we would use the factor 8.34 lb/gal (the density of water) if the substance's specific gravity were between 0.98 and 1.02. However, in this instance the substance has a specific gravity outside this range, so the 8.34 factor must be adjusted.

Multiply 8.34 lb/gal by the specific gravity to obtain the adjusted factor:

Step 1: (8.34 lb/gal) (0.94) = 7.84 lb/gal (rounded)
Step 2: Then convert 1,455 gal to pounds using the corrected factor:

$$(1{,}455 \text{ gal})\,(7.84 \text{ lb/gal}) = 11{,}407 \text{ lb (rounded)}$$

Force and Pressure
Water exerts force and pressure against the walls of its container, whether it is stored in a tank or flowing in a pipeline. There is a difference between force and pressure, though they are closely related. Force and pressure are defined below.

Force is the push or pull influence that causes motion. In the English system, force and weight are often used in the same way. The weight of a cubic foot of water is 62.4 pounds. The force exerted on the bottom of a one-foot cube is 62.4 pounds. If we stack two cubes on top of one another, the force on the bottom will be 124.8 pounds.

Pressure is a force per unit of area. In equation form, this can be expressed as:

$$P = \frac{F}{A}$$

where
P = pressure
F = force
A = area over which the force is distributed

Pounds per square inch or pounds per square foot are common expressions of pressure. The pressure on the bottom of the cube is 62.4 pounds per square foot. It is normal to express pressure in pounds per square inch (psi). This is easily accomplished by determining the weight of one square inch of a cube one foot high. If we have a cube that is 12 inches on each side, the number of square inches on the bottom surface of the cube is 12 × 12 = 144 in^2. Dividing the weight by the number of square inches determines the weight on each square inch.

$$\text{psi} = \frac{62.4 \text{ lb/ft}}{144 \text{ in}^2} = 0.433 \text{ psi/ft}$$

This is the weight of a column of water one-inch square and one foot tall. If the column of water were two feet tall, the pressure would be 2 ft x 0.433 psi/ft = 0.866.

1 foot of water = 0.433 psi

With the above information, feet of head can be converted to psi by multiplying the feet of head times 0.433 psi/ft.

EXAMPLE
Problem:
A tank is mounted at a height of 90 feet. Find the pressure at the bottom of the tank.

Solution:

$$90 \text{ ft} \times 0.433 \text{ psi/ft} = 39 \text{ psi (rounded)}$$

To convert psi to feet, you would divide the psi by 0.433 psi/ft.

EXAMPLE
Problem:
Find the height of water in a tank if the pressure at the bottom of the tank is 22 psi.
Solution:

$$\text{height in feet} = \frac{22 \text{ psi}}{0.433 \text{ psi/ft}} = 51 \text{ ft (rounded)}$$

Reservoir Stored Energy

One of the major components of a hydro-electric dam is the area behind the dam, its reservoir. The water temporarily stored there is called gravitational potential energy. The water is in a stored position above the rest of the dam facility so as to allow gravity to carry the water down to the turbines. Because this higher altitude is different than where the water would naturally be, the water is considered to be at an altered equilibrium. The result is stored energy of position; that is, gravitational potential energy. The water has the potential to do work because of the position it is in. Gravity will force the water to fall to a lower position through the intake and the control gate. Installed within the dam, when the control gate is opened, the water from the reservoir goes through the intake and becomes translational kinetic energy as it falls through the next main part of the system, the penstock. Translational kinetic energy is the energy due to motion from one location to another. The water is moving (falling) from the reservoir towards the turbines through the penstock; the water is carried through the penstock's long shaft towards the turbines where the kinetic energy becomes mechanical energy. The force of the water is used to turn the turbines that turn the generator shaft. The generators convert the energy of water into electricity and then step-up transformers increase the voltage produced to higher voltage levels.

As mentioned, potential energy stored in the reservoir is converted into kinetic energy at the inlet to the water turbine. Thus we can equate:

$$mgh = \frac{1}{2} mV^2$$

where

m = mass of water

g = acceleration due to gravity (can be taken as $10mm^{-2}$) in most applications

h = head difference

V = velocity of water at the inlet

EXAMPLE[3]

Problem:

A reservoir has an area of 1 sq km, and the difference between the crest of the dam and the inlet to a hydro station is 10m. The station runs at an overall efficiency of 80 percent, and is situated 305m below the crest of the dam. The rainfall is 1000mm per annum, the catchment area of the reservoir is 10 times the area of the reservoir, and the run is 50 percent. What should the rated output of the turbine be if its maximum output is designed to be 5 times the mean output at the site? What is the maximum time the station could operate at full power during a sustained drought?

Solution:

Mean head between max and min levels = 305 – 10/2 = 300m

Average annual flow into reservoir

= 50% of 10 times area multiplied by rainfall

$= 0.5 \times 10 \times 1000 \times 1000 \times 1 = 5{,}000{,}000 \text{ m}^3$

Mean energy generated per annum at 80% efficiency

$= [mgh \times 0.8]$

$= 5{,}000{,}000 \times 1000 \times 10 \times 300 \times 0.8$

$= 12{,}000{,}000$ MJ

Rated output (i.e., mean power)

$= 12{,}000{,}000/60 \times 60 \times 24 \times 365 = 0.381$ MW

So max power out = 5 × 0.381 = 190 MW

and time at max power assuming reservoir falls by 10m

$$= \frac{\text{area x depth} \times \text{density} \times gh \times 0.8}{\text{max power}}$$

$$= \frac{1000 \times 1000 \times 10 \times 1000 \times 300 \times 0.8}{1900000 \times 60 \times 60 \times 24}$$

= 146.2 days

Advanced Hydropower Technology

The United States Department of Energy (USDOE) and its associated technical activities support the development of technologies that will enable existing hydropower power to generate more electricity with less environmental impact. This will be done by: 1) developing new turbine systems that have improved overall performances, 2) developing new methods to optimize hydropower operations at the unit, plant, and reservoir system levels, and 3) conducting research to improve the effectiveness of the environmental mitigation practices required at hydropower projects.

USDOE (2008) reports that the main objective of its research into advanced hydropower technology is to develop new system designs and operation modes that will enable both better environmental performance and competitive generation of electricity. The products of DOE's research will allow hydropower projects to generate cleaner electricity. DOE-sponsored projects will develop and demonstrate new equipment and operational techniques that will optimize water-use efficiency, increase

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[3] Example modified from Tovey, *2005.ENV-2E02 Energy Resources—Lecture Notes*, p.109. Accessed 03/01//10 @ www2.env.ac.uk.gmmc/energy.

generation and improve environmental performance and mitigation practices existing plants. On-going research efforts contributing to the success of these objectives will enable up to a 10 percent increase in the hydropower generation at existing dams; these objectives include:

- Testing a new generation of large turbines in the filed to demonstrate that these turbines are commercially viable, compatible with today's environmental standards, capable of balancing environmental, technical, operational, and cost considerations.
- Developing new tools to improve water use efficiency and operations optimization within hydropower units, plants and river systems with multiple hydropower facilities.
- Identifying improved practices that can be applied at hydropower plants to mitigate for environmental effects of hydro development and operation.

Hydropower Generation: Dissolved Oxygen Concerns

In regard to the benefits derived from the use of hydropower—it is a clean fuel source; it is a fuel source that is domestically supplied; it relies on the water cycle and thus is a renewable power source; it is generally available as needed; it creates reservoirs that offer a variety of recreational opportunities, notably fishing, swimming, and boating; and they supply water where needed and assist in flood control—many of them are well known and often taken for granted.

Coins are two-sided, of course, and so are the facts about hydropower; that is, with the good side of anything there generally is an accompanying bad side. Many view this to be the case with hydropower. The bad side or disadvantages of hydropower include the impact on fish populations (e.g., salmon) if they can't migrate upstream past impoundment dams to spawning grounds or if they can't migrate downstream to the ocean. Hydropower can also be impacted by drought in that when water is not available, the plant can't produce electricity. Hydropower plants also compete with other uses for the land.

Other lesser known negatives of hydropower plants concern their impact on water flow and quality; hydropower plants can cause low water levels that impact riparian habitats. Water quality is also affected by hydropower plants. The low dissolved oxygen levels in the water, a problem that is harmful to riparian (riverbank) habitats, can result when reservoirs stratify (develop layers of water of different temperatures. Stratification could affect the water temperature with resultant effects on dissolved oxygen levels, nutrient levels, productivity and the bio-availability of heavy metals. During the summer, stratification, a natural process, can divide the reservoir into distinct vertical strata, i.e., a warm, well-mixed upper layer (epilimnion) overlying a cooler, relativity stagnant lower layer (hypolimnion). Plant and animal respiration, bacterial decomposition of organic matter, and chemical oxidation can all act to progressively remove DO from hypolimnetic waters. This decrease in hypolimnetic DO is not generally offset by the renewal mechanisms of atmospheric diffusion, circulation, and photosynthesis that operate in the epilmnion (Spellman 1996; Spellman 2008). In temperate regions, the decline in hypolimnetic DO concentrations begins at the onset of stratification (spring or summer) and continues until either anaerobic conditions predominate or reoxygenation occurs during the fall turnover of the water body.

There are numerous structural, operational, and regulatory techniques that a hydropower operator can use to resolve a low DO issue. Levels of DO can be increased through modifications in dam operations. These include such techniques as fluctuating the timing and duration of flow releases, spilling or sluicing water, increasing minimum flows, flow mixing, turbine aeration, and, at some sites, injection of air or oxygen in weir aeration have proven effective. The most effective strategy for addressing the DO problem is dependent on the site-specific situation.

Hydropower offers advantages over the other energy sources but faces unique environmental challenges. As mentioned, the advantages of using hydropower begin with that fact that hydropower does not pollute the air like power plants that burn fossil fuels, such as coal and natural gas. Moreover, hydropower does not have to be imported into the United States like foreign oil does; it is produced in the United States. Because hydropower relies on the water cycle, driven by the sun, it's a renewable resource that will be around for at least as long as humans. Hydropower is controllable; that is, engineers can control the flow of water through the turbines to produce electricity on demand. Finally, hydropower impoundment dams create huge lake areas for recreation, irrigation of farm lands, reliable supplies of potable water, and flood control.

Again, as mentioned, hydropower also has some disadvantages. For example, fish populations can be impacted if fish cannot migrate upstream past impoundment dams to spawning grounds or if they cannot migrate downstream to the ocean. Many dams have installed fish ladders or elevators to aid upstream fish passage. Downstream fish passage is aided by diverting fish from turbine intakes using screens or racks or even underwater lights and sounds, and by maintaining a minimum spill flow past the turbine. Hydropower can also impact water quality and flow. Hydropower plants can cause lo dissolved oxygen (DO) levels in the water, a problem that is harmful to riparian (riverbank) habitats and is addressed using various aeration techniques, which oxygenate the water. Maintaining minimum flows of water downstream of a hydropower installation is also critical for the survival of riparian habitats. Hydropower is also susceptible to drought. When water is not available, the hydropower plants can't produce electricity. Finally, construction of new hydropower facilities impact investors and others by competing with other uses of the land. Preserving local flora and fauna and historical or cultural sites is often more highly valued than electricity generation.

Hydroscopic: Readily taking up and retaining water or moisture.

Hydrosphere: The portion of the earth's surface covered by the oceans, seas, and lakes.

Hydrostatic Pressure: Very important principles that always apply for hydrostatic pressure.[4]

1. The pressure depends only on the depth of water above the point in question (not on the water surface area).
2. The pressure increases in direct proportion to the depth.
3. The pressure in a continuous volume of water is the same at all points that are at the same depth.
4. The pressure at any point in the water acts in all directions at the same depth.

Hydrothermal Reservoir: An aquifer, or subsurface water that has sufficient heat, permeability, and water to be exploited without stimulation or enhancement.

Hydro Turbines: According to EERE (2005), there ate two main types of hydro turbines: Impulse and reaction. The type of hydropower turbine selected for a project is based on the height of standing water—as mentioned, this is referred to as "head"—and the flow, or volume of water, at the site. Cost, efficiency desired, and how deep the turbine must be set are other deciding factors.

Impulse Turbine

The impulse turbine uses the velocity of the water to move the runner and discharges to atmospheric pressure. The water stream hits each bucket on the runner. There is no suction on the down side of the turbine, and water flows out the bottom of the turbine housed after hitting the runner. An impulse turbine is generally suitable for high head, low flow applications.

Reaction Turbine

A reaction turbine develops power from the combined action of pressure and moving water. The runner is placed directly in the water stream flowing over the blades rather than striking each individually. Reaction turbines are generally used for sites with lower head and higher flows than compared with impulse turbines.

Hydrothermal: Pertaining to hot water.

Hypersensitivity Diseases: Diseases characterized by allergic responses to pollutants; disease most clearly associated with indoor air quality are asthma; rhinitis, and pneumonic hypersensitivity.

Hypertension: Abnormally elevated blood pressure.

Hyperventilation: Excessive rate and depth of respiration.

Hypha (sing.), **Hyphae** (pl): In fungi, a tubular cell that grows from the tip and may form many branches.

Hypoglycemia: Low blood levels of sugar (glucose).

Hypotension: Abnormally low blood pressure.

Hypothermia: Exceptionally high body temperature.

Hypoxemia: Oxygen deficiency in the blood.

Hypoxia: A phenomenon that occurs in aquatic environments as dissolved oxygen (DO) becomes reduced in concentration to appoint detrimental to aquatic orgasms living in the system.

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[4] Adaptation from Nathanson, J.A., *Basic Environmental Technology: Water Supply, Waste Management, and Pollution Control*, 2nd ed. Upper Saddle River, New Jersey: Prentice Hall, 21–22, 1997.

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Ideal Gas Law: A hypothetical gas that obeys the gas laws exactly in regards to temperature, pressure, and volume relationships.

Identification Code or EPA I.D. Number: The unique code assigned to each generator, transporter, and treatment, storage, or disposal facility by regulating agencies to facilitate identification and tracking of chemicals or hazardous waste.

Idle Cropland: Land in cover and soil improvement crops, and cropland on which no crops were planted. Some cropland is idle each year for various physical and economic reasons. Acreage diverted from corps to soil-conserving uses (if not eligible for and used as cropland pasture) under federal farm programs is included in this component. Cropland enrolled in the Federal Conservation Reserve Program (CRP) is included in the idle cropland.

IDLH (Immediately Dangerous to Life and Health): Any condition that poses an immediate threat to life, or that is likely to result in acute or immediately severe health effects.

Ignitability: One of the characteristics used to classify a substance as hazardous.

Ignition Temperature: The temperature at which a given fuel bursts into flame.

Illumination: The amount of light flux a surface receives per unit area. May be expressed in lumens per square foot or in foot-candles.

Imhoff Cone: A clear, cones-shaped container used to measure the volume of settleable solids in a specific volume of water.

Immediately Dangerous to Life and Health (IDLH): The maximum level to which a healthy individual can be exposed to a chemical for thirty minutes and escape without suffering irreversible health effects or impairing symptoms. Used as a “level of concern.”

Imminent Hazard: One that would likely result in unreasonable adverse effects on humans or the environment or risk unreasonable hazard to an endangered species during the time required for a pesticide registration cancellation proceeding.

Imminent Threat: A high probability that exposure is occurring.

Immiscibility: The inability of two or more substances or liquids to readily dissolve into one another, such as soil and water.

Immune Response: The series of cellular events by which the immune system reacts to challenge by an antigen (10 CFR 850.3).

Immune System: The cells, tissues, and organs that help the body to resist infection and disease by producing antibodies and/or altered cells that inhibit the multiplication of the infectious agent.

Impact Strength: The ability of a metal to resist loads that are applied suddenly and often at high velocity.

Impaction: In air pollution control technology, a particle collection process whereby the center of mass of a particle diverging from a fluid strikes a stationary object and is collected by the stationary object.

Impermeable: Not easily penetrated. The property of a material or soil that does not allow, or allows only with get difficulty, the movement or passage of water.

Impermeable Layer: A layer of solid material, such as rock or clay, which does not allow water to pass through.

Imports: Municipal solid waste and recyclables that have been transported to a state or locality for processing or final disposition (but that did not originate in the state or locality).

Impoundment: A lake classification; an artificially man-made lake made by trapping water from rivers and watersheds.

Impulse Noise: A noise characterized by rapid rise time, high peak value, and rapid decay.

in. w.g. (inches of water): A unit of pressure. One inch of water is equal to 0.0735 in. of mercury, or 0.036 psi. Atmospheric pressure at standard conditions is 407 in. w.g.

Incapacitating Agent: An agent that produces temporary physiological and/or mental effects via action on the central nervous system. Effects may persist for hours or days, but victims usually do not require medical treatment, although treatment may speed recovery.

Incidence: The number of new cases of disease in a defined population over a specific time period.

Incident: 1. An undesired event that, under slightly different circumstances, could have resulted in personal harm or property damage; any undesired loss of resources. 2. An adverse network event in an information system or network or the threat of the occurrence of such an event.

Incident Command Post: A facility located at a safe distance from an emergency site, where the incident commander, key staff, and technical representatives can make decisions and deploy emergency manpower and equipment.

Incident Command System (ICS): The organizational arrangement wherein one person, normally the fire chief of the impacted district, is in charge of an integrated, comprehensive emergency response organization and the emergency incident, site, backed by an Emergency Operations center staff with resources, information, and advice.

Incident Energy: The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. One of the units used to measure incident energy is calories per centimeter squared (cal/cm^2).

Incident Handling: An action plan for dealing with intrusions, cyber-theft, denial of service, fire, floods, and other security-related events, comprised of a six-step process: Preparation, Identification, Containment, Eradication, Recovery, and Lessons Learned.

Incident Light: Light that shines onto the face of a solar cell or module.

Incineration: The application of high temperatures (800 to 3000ºF) to break down organic wastes into simpler forms and to reduce the volume of waste needing disposal. Energy can be recovered from incineration heat.

Incineration at Sea: Disposal of waste by burning at sea on specially-designed incinerator ships.

Incinerator: A furnace for burning waste under controlled conditions.

Inclusion: Storage granules often seen within bacterial cells.

Incompatible Waste: A waste unsuitable for mixing with another waste or material because it may react to form a hazard.

Indemnification: In the pesticide program, legal requirement that EPA pay certain end-users, dealers, and distributors for the cost of stock on hand at the time a pesticide registration is suspended.

Indeterminate Public Health Hazard: The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Indicator: In biology, any biological entity or processes, or community, whose characteristics show the presence of specific environmental conditions. 2. In chemistry, a substance that shows a visible change, usually of color, at a desired point in aa chemical reaction. 3. A device that indicates the result of a measurement; e.g., a pressure gauge or a moveable scale.

Indicator Tube: Glass tube with both ends sealed that measures a wide range of gases.

Indirect Discharge: Introduction of pollutants from a non-domestic source into a publicly owned waste-treatment system. Indirect discharges can be commercial or industrial facilities whose wastes enter local sewers.

Indirect Source: Any facility or building, property, road, or parking area that attracts motor vehicle traffic and indirectly, causes pollution.

Indoor Air: The breathable air inside a habitable structure or conveyance.

Indoor Air Pollution: Chemical, physical, or biological contaminants in indoor air.

Indoor Air Quality (IAQ): The study, examination, and control of air quality related to temperature, humidity, and airborne contaminants. The effect, good or bad, of the contents of the air inside a structure on its occupants. While usually temperature (too hot and cold), humidity (too dry or too damp), and air velocity (draftiness or motionless) are considered "comfort" rather than indoor air quality issues, IAQ refers to such problems as asbestosis, sick building syndrome, biological aerosols, ventilation issues concerning dusts, fumes, and so forth.

According to Byrd (2003), Indoor Air Quality (IAQ) refers to the effect, good or bad, of the contents of the air inside a structure on its occupants. Usually, temperature (too hot or too cold), humidity (too dry or too damp), and air velocity (draftiness or motionlessness) are considered "comfort" rather than indoor air quality issues, unless they are extreme, not within normal range. They may make someone uncomfortable, but they won't make a person ill. Nevertheless, most Safety Engineers must take these factors into account in investigating air quality situations.

Byrd (2003) points out that good IAQ is the quality of air, which has no unwanted gases or particles in it at concentrations, which will adversely affect someone. Poor IAQ occurs when gases or particles are present at an excessive concentration so as to affect the satisfaction of health of occupants.

In the workplace, poor IAQ may only be annoying to one person, however, at the extreme, it could be fatal to all of the occupants in the workplace. The concentration of the contaminant is crucial. Potentially infectious, toxic, allergenic, or irritating substances are always present in the air. Note that a threshold level below which no effect occurs is nearly always a factor.

Air quality is affected by the presence of various types of contaminants in the air. Some are in the form of gases, and are generally classified as toxic chemicals. Types of interest include: combustion products (carbon monoxide, nitrogen dioxide); volatile organic compounds (formaldehyde, solvents, perfumes and fragrances, etc.); and semi-volatile organic compounds (pesticides). Other pollutants are particulate form, including various forms of animal dander, etc.; soot; particles from buildings, furnishings, and occupants, including such diverse elements as fiberglass, gypsum powder, paper dust, lint from clothing, carpet fibers, etc.; dirt (sandy and earthy material), etc.

Burge and Hoyer (1998) point out many specific sources for contaminants that result in adverse health effects in the workplace. These include the workers themselves (contagious diseases, carriage of allergens, and other agents on clothing); building compounds (VOCs, particles, fibers); contamination of building components (allergens, microbial agents, pesticides); and outdoor air (microorganisms, allergens, and chemical air pollutants).

When workers complain of IAQ problems, the safety professional is called upon to determine if the problem really is an IAQ problem. If he or she determines that some form of contaminant is present in the workplace, proper remedial action is required. This usually includes removing the source of the contamination.

Indoor Climate: Temperature, humidity, lighting, air flow, and noise levels in a habitable structure or conveyance. Indoor climate can affect indoor air pollution.

Induced Seismicity: Induced seismicity refers to typically minor earthquakes and tremors that are caused by human activity that alters the stresses and strains on the earth's crust. Most induced seismicity is of an extremely low magnitude, and in many cases, human activity is merely the trigger for an earthquake that would have occurred naturally in any case.

Industrial Health Hazards: NIOSH and OSHA's *Occupational Health Guidelines for Chemical Hazards*, DHHS (NIOSH) Publication No. 81-123 (Washington, DC: Superintendent of Documents, U.S. Government Printing Office, current edition) illustrates quite clearly that the number of known industrial poisons is quite large, and also that their effects and means of control are generally understood. Generally, determining if a substance is hazardous or not is simple, if the following is known: (1) what the agent is and what form it is in; (2) the concentration; and (3) the duration and form of exposure.

However, practicing safety engineers and industrial hygienists come face to face with one problem rather quickly. Many new compounds of somewhat uncertain toxicity are introduced into the workplace each year. Another related problem occurs when manufacturers develop chemical products with unfamiliar trade names, and do not properly labeled them to indicate the chemical constituents of the compounds (of course, under OSHA's Hazard Communication Standard, this practice is illegal).

One of the primary categories of industrial health hazards that the safety engineer must deal with is airborne contaminants. Two main forms of airborne contaminants are of chief concern: particulates, and gases or vapors. Particulates include dusts, fumes, smoke, aerosols, and mists, classified additionally by size and chemical makeup, and sometimes by shape.

Dusts are solid particles of matter produced by grinding, crushing, handling, detonation, rapid impact, etc. Size may range from 0.5 to 100 mm (micron: 1 mm = 1/25000 inch), with most (over 90 percent) airborne dust in the 0.5-5-mm range. Dusts do not tend to flocculate except under electrostatic forces.

Fumes are solid particles of matter formed by condensation of vapors. Heating or volatilizing metals (welding) or other solids usually produces them. Size usually ranges from 0.01 to 0.5 microns. Fumes flocculate and sometimes coalesce.

Gases are normally formless fluids (a state of matter separate from solids and liquids) that occupy the space of an enclosure and that can change to liquid or solid states only by the combined effects of increased pressure and decreased temperatures. Gases diffuse.

Mists are fine liquid droplets suspended in or falling through air. Mist is generated by condensation from the gaseous to liquid state, or by breaking up liquid into fine particles through atomizing, spraying, mechanized agitation, splashing or foaming.

Smoke is the visible carbon or soot particles (generally less than 0.1 micron in size) resulting from the incomplete combustion of carbonaceous materials such as oil, tobacco, coal, and tar.

Vapor is the gaseous phase of a substance that is liquid or solid at normal temperature and pressure. Vapors diffuse.

Aerosols are a suspension of solid particles or liquid droplets in a gaseous medium, distributed in a finely divided state through the gas, usually air. Particles within aerosols are usually less than 1 micron (0.001 mm) in diameter, and are more uniformly distributed than in a spray.

Industrial atmospheric contaminants exist in virtually every workplace. Sometimes they are readily apparent to workers, because of their odor, or because they can actually be seen. Safety engineers, however, cannot rely on odor or vision to detect or measure airborne contaminants. They must rely on measurements taken by detection and sampling devices. Many different commercially available instruments permit the detection and concentration evaluation of many different contaminants. Some of these instruments are so simple that nearly any worker can learn to properly operate them. A note of caution, however; the untrained worker may receive an instrument reading that seems to indicate a higher degree of safety than may actually exist. Thus, the qualitative and quantitative measurement of atmospheric contaminants generally is the job of the safety engineer. Any samples taken should also be representative—samples should be taken of the actual air the workers breathe, at the point they breathe them, in their breathing zone—between the top of the head and the shoulders.

Industrial Hygiene: The American Industrial Hygiene Association (AIHA) defines industrial hygiene as "that science and art devoted to the anticipation, recognition, evaluation, and control of those environmental factors or stresses—arising in the workplace—which may cause sickness, impaired health and well-being, or significant discomfort and inefficiency among workers or among citizens of the community."

What is an industrial hygienist? A well-trained, well-prepared industrial hygienist (IH) is equipped to deal with virtually any situation that arises (Ogle, 2003).

Safety engineering and industrial hygiene have commonly been thought to be separate entities (especially by safety professionals and industrial hygienists). In fact, over the years, a considerable amount of debate and argument has risen between those in the safety and industrial hygiene professions on many areas concerning safety and health issues in the workplace—and on exactly who is best qualified to administer a workplace safety program.

Historically, the safety professional had the upper hand in this argument—that is, prior to the enactment of the OSH Act. Until OSHA went into effect, industrial hygiene was not a topic that many thought about, cared about, or had any understanding of. Safety was safety—and job safety included health—and that was that.

After the OSH Act, however, things changed. In particular, people began to look at work injuries and work diseases differently. In the past, they were regarded as separate problems. The primary reason for this view was obvious—and not so obvious. The obvious was work-related injury. Work injuries occurred suddenly and their agent (i.e., the electrical source, chemical, machine, tool, work or walking surface, or whatever unsafe element caused the injury) usually was readily obvious.

Not so readily obvious were the workplace agents that caused illnesses (occupational diseases). Why? Because most occupational diseases develop rather slowly, over time. In asbestos exposure, for example, workers who abate (remove) asbestos-containing materials without the proper training (awareness) and personal protective equipment are subject to exposure. Typically, asbestos exposure may be a one time exposure event (the silver bullet syndrome) or the exposure may go on for years. No matter the length of exposure, one thing is certain; with asbestos contamination, pathological change occurs slowly—some time will pass before the worker notices a difference in pulmonary function. Disease from asbestos exposure has a latency period that may be as long as twenty to thirty years before the effects are realized. The point? Any exposure to asbestos, short term or long term, may eventually lead to a chronic disease (in this case, restrictive lung disease) that is irreversible (e.g., asbestosis). Of course, many other types of workplace toxic exposures can affect workers' health. The prevention, evaluation, and control of such occurrences are the roles of the industrial hygienist.

Thus, because of the OSH Act, and also because of increasing public awareness and involvement by unions in industrial health matters, the role of the industrial hygienist has continued to grow over the years. Certain colleges and universities have incorporated industrial hygiene majors into environmental health programs.

Industrial Hygiene Stressors: Industrial hygienists focus on evaluating the healthfulness of the workplace environment, either for short periods or for a work-life of exposure. When required, the industrial hygienist recommends corrective procedures to protect health, based on solid quantitative data, experience, and knowledge. The control measures he or she often recommends include: isolation of a work process, substitution of a less harmful chemical or material, and/or other measures designed solely to increase the healthfulness of the work environment.

To ensure a healthy workplace environment and environs, the industrial hygienist focuses on the recognition, evaluation, and control of chemical, physical, or biological and ergonomic stressors that can cause sickness, impaired health, or significant discomfort to workers.

The key word was stressors, or simply, stress—the stress caused by the workplace external environmental demands placed upon a worker. Increases in external stressors beyond a worker's tolerance level affect his or her on-the-job performance.

The industrial hygienist must not only understand that workplace stressors exist, but also that they are sometimes cumulative (additive). For example, studies have shown that some assembly line processes are little affected by either low illumination or vibration; however, when these two stressors are combined, assembly-line performance deteriorates.

Other cases have shown just the opposite effect. For example, the worker who has had little sleep and then is exposed to a work area where noise levels are high actually benefits (to a degree, depending on the intensity of the noise level and the worker's exhaustion level) from increased arousal level; a lack of sleep combined with a high noise level is compensatory (Ferry, 1990).

To recognize environmental stressors and other factors that influence worker health, the industrial hygienist must be familiar with work operations and processes. An essential part of the new industrial hygienist's employee orientation process should include orientation on all pertinent company work operations and processes. Obviously, the newly hired industrial hygienist who has not been fully indoctrinated on company work operations and processes not only is not qualified to study the environmental affects of such processes, but also suffers from another disability—lack of credibility with supervisors and workers. This point cannot be emphasized strongly enough.

NOTE: Woe be it to the rookie industrial hygienist or safety engineer who has the audacity (and downright stupidity) to walk up to any supervisor (or any worker with experience at task) and announce that he or she is going to find out everything that is unhealthy (and thus injurious to workers) about the work process—without having any idea how the process operates, what it does, or what it is all about. We do not recommend this scenario—as an industrial hygienist (or as a safety engineer), you must understand the work operations and processes to the point that you could almost operate the system efficiently and safely yourself.

What are the workplace stressors the industrial hygienist should be concerned with? According to Pierce (1984), the industrial hygienist should be concerned with those workplace stressors that are likely to accelerate the aging process, cause significant discomfort and inefficiency, or may be immediately dangerous to life and health. Several stressors fall into these categories; the most important ones include:

- Chemical stressors—gases, dusts, fumes, mists, liquids, or vapors.
- Physical stressors—noise, vibration, extremes of pressure and temperature, and electromagnetic and ionizing radiation.
- Biological stressors—bacteria, fungi, molds, yeasts, insects, mites, and viruses.
- Ergonomic stressors—repetitive motion, work pressure, fatigue, body position in relation to work activity, monotony/boredom, and worry.

Industrial Noise Control: Only recently has noise has been recognized as a significant industrial health problem. In fact, now, workers' compensation laws in all states recognize hearing losses due to industrial noise as an occupational disease.

The obvious question is "What is noise?" Simply put, noise is any unwanted sound. The safety engineer is concerned about noise (or any workplace sound) that exceeds OSHA regulated levels and may be injurious to workers—that could cause hearing damage.

Hearing damage risk criteria for exposure to noise are found in OSHA's 29 CFR 1910.95 (Hearing Conservation Standard) and are stated in the Table 40.

The safety engineer's primary concern when starting a noise reduction or control program is first to determine if any "noise-makers" in the facility exceed the OSHA limits for worker exposure—exactly which machines or processes produce noise at unacceptable levels. Making

Permissible Noise Exposures

Permissible Noise Exposures* Duration per day, hours	Sound Level dBA** Slow Response
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25	115

* When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions C1/T1 + C2/T2 + Cn/Tn exceeds unity, then the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level.

** Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

*** Measured on the A weighting scale of a standard sound level meter is slow response mode.

SOURCE: U.S. Department of Labor, Part 1910. *Occupational Safety and Health Standards*, subpart G., section 1910.95. Washington, D.C.: Occupational Safety and Health Administration, 1995.

this determination is accomplished by conducting a noise level survey of the plant or facility.

When conducting the noise level survey, the safety engineer should use an ANSI-approved sound-level meter (a device used most commonly to measure sound pressure). Sound is measured in decibels. One decibel is one-tenth of a bel (a unit of measure in electrical-communication engineering) and is the minimum difference in loudness that is usually perceptible.

The sound level meter consists of a microphone, an amplifier and an indicating meter that responds to noise in the audible frequency range of about 20 to 20,000 Hz. Sound level meters usually contain "weighting" networks designated "A", "B", or "C". Some meters have only one weighting network; others are equipped with all three. The A-network approximates the equal loudness curves at low sound pressure levels, the B-network is used for medium sound pressure levels, and the C-network is used for high levels.

In conducting a routine workplace sound level survey, using the A-weighted network (referenced dBA) in the assessment of the overall noise hazard has become common practice. The A-weighted network is the preferred choice because it is thought to provide a rating of industrial noises that indicates the injurious effects such noise has on the human ear (gives a frequency response similar to that of the human ear at relatively low sound pressure levels).

With an approved and freshly calibrated (always calibrate test equipment prior to use) sound level meter in hand, the safety engineer is ready to begin the sound level survey. In doing so, the safety engineer is primarily interested in answering the following questions: (1) What is the noise level in each work area? (2) what equipment or process is generating the noise? (3) which employees are exposed to the noise? and (4) how long are they exposed to the noise?

In answering these questions, safety engineers record their findings as they move from workstation to workstation, following a logical step-by-step procedure. The first step involves using the sound level meter set for A-scale slow response mode to measure an entire work area. When making such measurements, restrict the size of the space being measured to less than 1,000 square feet. If the maximum sound level does not exceed 80 dBA, it can be assumed that all workers in this work area are working in an environment with a satisfactory noise level.

Note: The key words in the preceding statement are "maximum sound level." To assure an accurate measurement, the safety engineer must ensure that all "noise-makers" are actually in operation when measurements are taken. Measuring an entire work area does little good when only a small percentage of the noisemakers are actually in operation.

The next step depends on the readings recorded when the entire work area was measured. For example, if the measurements indicate sound levels greater than 80 dBA, another set of measurements needs to be taken at each worker's workstation. The purpose here, of course, is to determine two things: which machine or process is making noise above acceptable levels (i.e., >80 dBA), and which workers are exposed to these levels. Remember that the worker who operates the machine or process might not be the only worker exposed to the noisemaker. You need to inquire about other workers who might, from time to time, spend time working in or around the machine or process. Our experience in conducting workstation measurements has shown us noise levels usually fluctuate. If this is the case, you must record the minimum and maximum noise levels. If you discover that the noise level is above 90 (dBA) (and it remains above this level), you have found a noisemaker that exceeds the legal limit (90 dBA). However, if your measurements indicate that the noise level is never greater than 85 (dBA) (OSHA's action level), the noise exposure can be regarded as satisfactory.

If workstation measurements indicate readings that exceed the 85 dBA level, you must perform another step. This step involves determining the length of time of exposure for workers. The easiest, most practical way to make this determination is to have the worker wear a noise dosimeter, which records the noise energy to which the worker was exposed during the workshift.

What happens next?

You must then determine if the worker is exposed to noise levels that exceed the permissible noise exposure levels listed in the Table. The key point to remember is that your findings must be based on a time-weighted average (TWA). For example, from the Table you will notice that a noise level of 95 dBA is allowed up to four hours per day.

NOTE: This parameter assumes that the worker has good hearing acuity with no loss. If the worker has documented hearing loss, then exposure to 95 dBA or higher may be unacceptable under any circumstances without proper hearing protection.

So exactly what does 4-hour maximum exposure per day mean? It means that, cumulatively, a worker cannot be exposed for more than 4 hours of noise at the 95-dBA level. Cumulative maximum exposures are used because all noisemakers are not necessarily continuous; instead, they may be intermittent or impact-type noise makers. Consider this—a worker who runs a machine operates the machine 8 hours each day. When the machine is running, it continuously produces 95 dBA. Obviously, this worker must be protected from the 95-dBA noisemaker, because his or her exposure will be over an 8-hour period—which is not allowed under OSHA. Another worker operates a machine that produces 95-dBA noise, but the operator only operates it for a few minutes at a time, with several minutes without the machine running in between operations. The worker is exposed to noise from other workstations, at varying levels. This is considered intermittent operation, with intermittent noise generation—and possibly intermittent exposure (depending upon the level of noise). Is this worker exposed to noise levels above the Permissible Exposure Limit of 4 hours maximum (i.e., without hearing protection)?

It depends. To make this determination we must calculate the daily noise dose. We can accomplish by using the equation below.

$$E_m = C_1/T_1 + C_2/T_2 + C_3/T_3 + \ldots C_n/T_n$$

where

E_m = mixed exposure
C = total time of exposure at a specified noise level
T = total time of exposure permitted at that level

For purposes of illustration let's assume that the worker's intermittent noise levels expose him or her to the following noise levels during the workday:

85 dBA for 2.75 hours
90 dBA for 1 hour
95 dBA for 2.25 hours
100 dBA for 2 hours

Has the worker received an excessive exposure during the workday?

To answer this question we use the equation below and plug in the parameters. From our calculation, if we find that the sum of the fractions equals or exceeds 1, then the mixed exposure is considered to exceed the limit value. Daily noise dose (D) is expressed as a percentage of $E_m = 1$, the mixed exposure is equivalent to a noise dose of 100 percent. Keep in mind that noise levels below 90 dBA are not considered in the calculation of daily noise.

So, again, has our worker received an excessive exposure during her workday?

Let's find out:

$$Dose = \frac{0}{0} + \frac{1}{8} + \frac{2.8}{4} + \frac{2}{2} = 169\%$$

The sum exceeds 1; therefore, obviously, the results indicate that the employee has received an excessive exposure during her workday.

NOTE: A final word on noise exposure. From the Table, you can see that the highest sound level listed is 115 dBA. Any exposure above this level is not permissible for any length of time.

When the safety professional investigates the possibility of using engineering controls to control noise, the first thing he or she recognizes is that reducing and/or eliminating all noise is virtually impossible. And this should not be the focus in the first place . . . eliminating or reducing the "hazard" is the goal. While the primary hazard may be the possibility of hearing loss, the distractive effect (or its interference with communication) must also be considered. The distractive effect of excessive noise can certainly be classified as hazardous whenever the distraction might affect the attention of the worker. The obvious implication of noise levels that interfere with communications is emergency response. If ambient noise is at such a high level that workers can't hear fire or other emergency alarms, this is obviously a hazardous situation.

So what does all this mean? The safety engineer must determine the "acceptable" level of noise. Then he or she can look into applying the various noise control measures. These include making alterations in engineering design (obviously this can only be accomplished in the design phase) or making modifications after installation. Unfortunately, this latter method is the one the safety engineer is usually forced to apply—and also the most difficult, depending upon circumstances.

Let's assume that the safety professional is trying to reduce to a safe level noise levels generated by an installed air compressor. Obviously, the first place to start is at the source: the air compressor. Several options are available for the safety engineer to employ at the source. First, the safety engineer would look at the possibility of modifying the air compressor to reduce its noise output. One option might be to install resilient vibration mounting devices. Another might be to change the coupling between the motor and the compressor.

If the options described for use at the source of the noise are not feasible or are only partially effective, the next component the safety engineer would look at is the path along which the sound energy travels. Increasing the distance between the air compressor and the workers could be a possibility. Another option might be to install acoustical treatments on ceilings, floors, and walls. The best option available (in this case) probably is to enclose the air compressor, so that the dangerous noise levels are contained within the enclosure, and the sound leaving the space is attenuated to a lower, safer level. If total enclosure of the air compressor is not practicable, then erecting a barrier or baffle system between the compressor and the open work area might be an option.

The final engineering control component the safety engineer might incorporate to reduce the air compressor's noise problem is to consider the receiver (the worker). An attempt could be made to isolate the operator by providing a noise reduction or soundproof enclosure or booth for the operator.

Industrial Pollution Prevention: Combination of industrial source reduction and toxic chemical use substitution.

Industrial Process Waste: Residues produced during manufacturing operations.

Industrial Sludge: Semi-liquid residue or slurry remaining from treatment of industrial water and wastewater.

Industrial Source Reduction: Practices that reduce the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment. Also reduces the threat to public health and the environment associated with such releases. Term includes equipment or technology modifications, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.

Industrial Toxicology: Normally, we give little thought to the materials (chemical substances, for example) we are exposed to on a daily, almost constant basis, unless they interfere with our lifestyles, irritate us, or noticeably physically affect us. Most of these chemical substances do not present a hazard—under ordinary conditions. However, keep in mind that all chemical substances have the potential for being injurious at some sufficiently high concentration and level of exposure. The industrial hygienist understands this, and to prevent the lethal effects of over-exposure for workers must have an adequate understanding and knowledge of general toxicology.

What is toxicology? Toxicology is a very broad science, which studies the adverse effects of chemicals on living organisms. It deals with chemicals used in industry, drugs, food, and cosmetics, as well as those occurring naturally in the environment. Toxicology is the science that deals with the poisonous or toxic properties of substances. The primary objective of industrial toxicology is the prevention of adverse health effects in workers exposed to chemicals in the workplace. The industrial hygienist's responsibility is to consider all types of exposure and the subsequent effects on living organisms. Following the prescribed precautionary measures and limitations placed on exposure to certain chemical substances by the industrial toxicologist is the worker's responsibility. The industrial hygienist uses toxicity information to prescribe safety measures for protecting workers.

To gain a better appreciation for what industrial toxicology is all about, you must understand some basic terms and factors—many of which contribute to determining the degree of hazard particular chemicals present. You must also differentiate between toxicity and hazard. Toxicity is the intrinsic ability of a substance to produce an unwanted effect on humans and other living organisms when the chemical has reached a sufficient concentration at a certain site in the body. Hazard is the probability that a substance will produce harm under specific conditions. The industrial hygienist and other safety professionals employ the opposite of hazard—safety—that is, the probability that harm will not occur under specific conditions. A toxic chemical—used under safe conditions—may not be hazardous.

Basically, all toxicological considerations are based on the dose-response relationship, another toxicological concept important to the industrial hygienist. In its simplest terms, the dose of a chemical to the body resulting from exposure is directly related to the degree of harm. This relationship means that the toxicologist is able to determine a threshold level of exposure for a given chemical—the highest amount of a chemical substance to which one can be exposed with no resulting adverse health effect. Stated another way, chemicals present a threshold of effect, or a no-effect level.

Threshold levels are critically important parameters. For instance, under the OSH Act, threshold limits have been established for the air contaminants most frequently found in the workplace. The contaminants are listed in three tables in 29 CFR 1910 subpart Z—Toxic and Hazardous Substances. The threshold limit values listed in these tables are drawn from values published by the American Conference of Governmental Industrial

Hygienists (ACGIH) and from the "Standards of Acceptable Concentrations of Toxic Dusts and Gases," issued by the American National Standards Institute (ANSI).

An important and necessary consideration when determining levels of safety for exposure to contaminants is their effect over a period of time. For example, during an eight-hour work shift, a worker may be exposed to a concentration of Substance A [with a 10 ppm (parts per million—analogous to a full shot glass in a swimming pool) TWA (time-weighted average), 25 ppm ceiling and 50 ppm peak] above 25 ppm (but never above 50 ppm) only for a maximum period of 10 minutes. Such exposure must be compensated by exposures to concentrations less than 10 ppm, so that the cumulative exposure for the entire 8-hour work shift does not exceed a weighted average of 10 ppm. Formulas are provided in the regulations for computing the cumulative effects of exposures in such instances. The computed cumulative exposure to a contaminant may not exceed the limit value specified for it.

Although air contaminant values are useful as a guide for determining conditions that may be hazardous and may demand improved control measures, the industrial hygienist must recognize that the susceptibility of workers varies.

Even though it is essential not to permit exposures to exceed the stated values for substances, even careful adherence to the suggested values for any substance will not assure an absolutely harmless exposure. Thus, the air contaminant concentration values should only serve as a tool for indicating harmful exposures, rather than the absolute reference on which to base control measures.

For a chemical substance to cause or produce a harmful effect, it must reach the appropriate site in the body (usually via the bloodstream) at a concentration (and for a length of time) sufficient to produce an adverse effect. Toxic injury can occur at the first point of contact between the toxicant and the body, or in later, systemic injuries to various organs deep in the body (Hammer 1989). Common routes of entry are ingestion, injection, skin absorption, and inhalation. However, entry into the body can occur by more than one route (e.g., inhalation of a substance that can be absorbed through the skin).

Ingestion of toxic substances is not a common problem in industry—most workers do not deliberately swallow hazardous or toxic substances they handle on the job. However, ingestion does sometimes occur either directly or indirectly. Industrial exposure to harmful substance through ingestion may occur when workers eat lunch, drink coffee, chew tobacco, apply cosmetics, or smoke in a contaminated work area. The substances may exert their toxic effect on the intestinal tract or at specific organ sites.

Injection of toxic substances may occur just about anywhere in the body where a needle can be inserted, but is a rare event in the industrial workplace.

Skin absorption or contact is an important route of entry in terms of occupational exposure. While the skin may act as a barrier to some harmful agents, other materials may irritate or sensitize the skin and eyes, or travel through the skin into the bloodstream, thereby impacting on specific organs.

Inhalation is the most common route of entry for harmful substances in industrial exposures. Nearly all airborne substances can be inhaled. Dusts, fumes, mists, gases, vapors, and other airborne substances may enter the body via the lungs and may produce local effects on the lungs, or may be transported by the blood to specific organs in the body.

Upon finding a route of entry into the body, chemicals and other substances may exert their harmful effects on specific organs of the body, such as the lungs, liver, kidneys, central nervous system, and skin. These specific organs are termed target organs and will vary with the chemical of concern.

The toxic action of a substance can be divided into short-term (acute) and long-term (chronic) effects. Short-term adverse (acute) effects are usually related to an

Comparison of Selected Chemical Agents and Their Harmful Effects Resulting from Overexposure

Agent Type	*Major Route of Entry*	*Acute/Chronic Effects*
Asbestos	Inhalation	Chronic: asbestosis, mesothelioma, lung cancer
Arsenic	Skin absorption	Acute: skin irritation, conjunctivitis, sensitization dermatitis Chronic: possible epidermal cancer
Cadmium	Inhalation	Acute: chest pain, shortness of breath, pulmonary edema, digestive effects
Lead	Inhalation	Chronic: gastrointestinal disturbance, anemia due to red blood cell effects, kidney disease and reproductive effects
Aromatic Solvents	Inhalation	Acute: central nervous system effects, depression, narcotic effects Chronic: liver, blood system disorders
Sulfur dioxide	Skin absorption	Dermatitis (chronic or acute)
	Inhalation	Acute: eye and respiratory irritation Chronic: bronchitis

accident where exposure symptoms (effects) may occur within a short time period following either a single exposure or multiple exposures to a chemical. Long-term adverse (chronic) effects usually occur slowly after a long period of time, following exposures to small quantities of a substance (as lung disease may follow cigarette smoking). Chronic effects may sometimes occur following short-term exposures to certain substances.

The Table shows the harmful effects that can result from overexposure to some chemical agents.

Industrial Ventilation (IV): The equipment or operation associated with the supply or exhaust of air by natural or mechanical means to control occupational hazards in the industrial setting.

The purpose of industrial ventilation is essentially to (under control) recreate what occurs in natural ventilation. Natural ventilation results from differences in pressure. Air moves from high-pressure areas to low pressure areas. This difference in pressure is the result of thermal conditions. We know that hot air rises, which (for example) allows smoke to escape from the smokestack in an industrial process, rather than disperse into areas where workers operate the process. Hot air rises because air expands as it is heated, becoming lighter. The same principle is in effect when air in the atmosphere becomes heated. The air rises and is replaced by air from a higher-pressure area. Thus, convection currents cause a natural ventilation effect through the resulting winds.

Along with controlling or removing toxic airborne contaminants from the air, installed ventilation systems perform several other functions within the workplace. These functions include:

1. Ventilation is often used to maintain an adequate oxygen supply in an area. In most workplaces, this is not a problem because natural ventilation usually provides an adequate volume of oxygen; however, some work environments (deep mining and thermal processes which use copious amounts of oxygen for combustion) the need for oxygen is the major reason for an installed ventilation system.
2. An installed ventilation system can remove odors from a given area. This type of system (as you might guess) has applications in such places as athletic locker rooms, restrooms, and kitchens. In performing this function, the noxious air may be replaced with fresh air, or odors may be masked with a chemical masking agent.
3. One of the primary uses of installed ventilation is one that we are familiar with—providing heat, cooling, and humidity control.
4. A ventilation system can remove undesirable contaminants at their source, before they enter the workplace air (e.g., from a chemical dipping or stripping tank). Obviously, this technique is an effective way to ensure that certain contaminants never enter the breathing zone of the worker—exactly the kind of function safety engineering is intended to accomplish.

A mechanical fan is the heart of any ventilation system, but like the human heart, certain ancillaries are required to make it function as a system. Ventilation is no different. Four major components make up a ventilation system.

1. The fan forces the air to move.
2. An inlet or some type of opening allows air to enter the system.
3. An outlet must be provided for air to leave the system.
4. A conduit or pathway (ducting) not only directs the air in the right direction, but also limits the amount of flow to a predetermined level.

An important concept regarding ventilation systems is the difference between exhaust and supply ventilation. An *exhaust ventilation system* removes air and airborne contaminants from the workplace. Such a system may be designed to exhaust an entire work area, or it may be placed at the source to remove the contaminant prior to its release into the workplace air. The second type of ventilation system is the *supply system,* which (as the name implies) adds air to the work area, usually to dilute work area contaminants to lower the concentration of these contaminants. However, a supplied-air system does much more; it also provides movement to air within the space (especially when an area is equipped with both an exhaust and supply system—a usual practice, because it allows movement of air from inlet to outlet and is important in replenishing exhausted air with fresh air).

Air movement in a ventilation system is a result of differences in pressure. Note that pressures in a ventilation system are measured in relation to atmospheric pressure. In the workplace, the existing atmospheric pressure is assumed to be the zero point. In the supply system, the pressure created by the system is *in addition* to the atmospheric pressure that exists in the workplace (i.e., a positive pressure). In an exhaust system, the objective is to lower the pressure in the system below the atmospheric pressure (i.e., a negative pressure).

When we speak of increasing and decreasing pressure levels within a ventilation system, what we are really talking about is creating small differences in pressure—small when compared to the atmospheric pressure of the work area. For this reason, these differences are measured in terms of *inches of water* or *water gauge*, which results in the desired sensitivity of measurement. Air can be assumed to be incompressible, because of the small-scale differences in pressure.

Industrial Vibration Control: Vibration is often closely associated with noise, but is frequently overlooked as a potential occupational health hazard. Vibration is defined as the oscillatory motion of a system around an equilibrium position. The system can be in a solid, liquid, or gaseous state, and the oscillation of the system can be periodic or random, steady state or transient, continuous or intermittent (NIOSH, 1973). Vibrations of the human body (or parts of the human body) are not only annoying, they also affect worker performance, and sometimes causing blurred vision and loss of motor control. Excessive vibration can cause trauma, which results when external vibrating forces accelerate the body or some part so that amplitudes and restraining capacities by tissues are exceeded.

Vibration results in the mechanical shaking of the body or parts of the body. These two types of vibration are called whole-body vibration (affects vehicle operators) and segmental vibration (occurs in foundry operations, mining, stonecutting, and a variety of assembly operations, for example). Vibration originates from mechanical motion, generally occurring at some machine or series of machines. This mechanical vibration can be transmitted directly to the body or body part or it may be transmitted through solid objects to a worker located at some distance away from the actual vibration.

The effect of vibration on the human body is not totally understood; however, we do know that vibration of the chest may create breathing difficulties, and that an inhibition of tendon reflexes is a result of vibration. Excessive vibration can cause reduced ability on the part of the worker to perform complex tasks, and indications of potential damage to other systems of the body also exist.

More is known about the results of segmental vibration (typically transmitted through hand to arm), and a common example is the vibration received when using a pneumatic hammer—a jackhammer. One recognized indication of the effect of segmental vibration is impaired circulation to the appendage, a condition known as Raynaud's Syndrome, also known as "dead fingers" or "white fingers." Segmental vibration can also result in the loss of the sense of touch in the affected area. Some indications that decalcification of the bones in the hand can result from vibration transmitted to that part of the body exist. In addition, muscle atrophy has been identified as a result of segmental vibration.

As with noise, the human body can withstand short-term vibration, even though this vibration might be extreme. The dangers of vibration are related to certain frequencies that are resonant with various parts of the body. Vibration outside these frequencies is not nearly as dangerous as vibration that results in resonance.

Control measures for vibration include substituting some other device (one that does not cause vibration) for the mechanical device that causes the vibration. An important corrective measure (often overlooked) that helps in reducing vibration is proper maintenance of tools, or support mechanisms for tools, including coating the tools with materials that attenuate vibrations. Another engineering control often employed to reduce vibration is the application of balancers, isolators, and damping devices/materials that help to reduce vibration.

Industrial Waste: Unwanted material from an industrial operation, may be liquid, sludge, solid, or hazardous waste.

Industrial Wastewater: Liquid wastes produced by industry.

Industrial Water Use: Water used for industrial purposes in such industries as steel, chemical, paper, and petroleum refining. Nationally, water for industrial uses comes mainly (80 percent) from self-supplied sources, such as a local wells or withdrawal points in a river, but some water comes from public-supplied sources, such as the country/city water department.

Industrial Wood: All commercial Roundwood products except Fuelwood.

Inert: Not readily reactive with other elements; forming few or no chemical compounds.

Inert Ingredient: Pesticide components such as solvents, carriers, dispersants, and surfactants that are not active against target pests. Not all inert ingredients are innocuous.

Inertial Separator: A device that uses centrifugal force to separate waste particles.

Infectious Agent: Any organism, such as a pathogenic virus, parasite, or bacterium, that is capable of invading body tissues, multiplying, and causing disease.

Infectious Waste: Hazardous waste capable of causing infections in humans, including contaminated animal waste; human blood and blood products; isolation waste; pathological waste; and discarded sharps (needles, scalpels, or broken medical instruments).

Inflammation: A local response to cellular injury that is marked by redness, heat, pain, swelling, cellular and blood vessel changes, and often loss of function that serves as a mechanism initiating the elimination of noxious agents and of damaged tissue.

Inflammatory: Accompanied with, or tending to cause, inflammation.

Infiltration: 1. Process of water entering soil through the surface. 2. The technique of applying large volumes of wastewater to land to penetrate the surface ad percolate through the underlying soil.

Infiltration Capacity: Maximum rate soil can absorb rainfall.

Infiltration Galleries: Technique used in in-situ biodegradation process to reintroduce conditioned groundwater to the soil or aquifer.

Infiltration Rate: Rate at which water enters soil under a given condition, expressed as depth of water per unit time, usually inches per hour.

Inflow: Entry of extraneous rain water into a sewer system from sources other than infiltration, such as basement drains, manholes, storm drains, and street washing.

Influent: A liquid entering a container or process.

Information Collection Request (ICR): A description of information to be gathered in connection with rules, proposed rules, surveys, and guidance documents that contain information-gathering requirements. The ICR describes what information is needed, why it is needed, how it will be collected, and how much collecting it will cost. The ICR is submitted by the EPA to the Office of Management and Budget (OMB) for approval.

Information File: In the Superfund program, a file that contains accurate, up-to-date documents on a Superfund site. The file is usually located in a public building (school, library, or city hall) convenient for local residents.

Infrared Radiation: Invisible electromagnetic radiation of wavelength between about 0.75 micrometers and 1 mm—between the limit of the red end of the visible spectrum and the shortest microwaves.

Inhalation: The act of drawing in breath.

Ingestion: Entry of a foreign substance into the body through the mouth.

Ingress Filtering: Filtering inbound traffic.

Inhalable Particles: All dust capable of entering the human respiratory tract.

Inhalation Exposure: This exposure route involves breathing chemicals either as vapors (e.g., toluene in glue; formaldehyde in new carpets) or particulates (e.g., smog).

Inhaled chemicals will pass through the nose and mouth into the respiratory tract, which includes the trachea, bronchi, bronchioles, and alveoli. The bronchi, bronchioles, and alveoli comprise the lungs. The size of the airways decreases from the trachea to the alveoli. This decreasing size, along with the many angles formed by branching airways, prevents many particles containing chemicals from reaching the alveoli. Oxygen and carbon dioxide are exchanged in the blood across the alveoli. However, chemicals in the gas form (i.e., vapors) will not lodge in the airways and can reach the alveoli, along with the oxygen taken in through breathing. These vapors can then enter the bloodstream and be transported to organs where toxicity is manifested. Carbon monoxide, toluene, and formaldehyde are examples of vapors that can pass across the alveoli into the lungs through inhalation. Carbon monoxide replaces oxygen in red blood cells, leading to asphyxiation. Toulene enters the central nervous system and causes anesthetic effects. Formaldehyde can impact respiration, especially in asthmatic children. It has also been shown to cause nose tumors in lab mice.

Many particulates are too large to reach the alveoli; they will be deposited in larger airways (e.g., bronchi). This includes the particulate matter components of smog (the vapor components of smog are not similarly affected). Only particles smaller than about 10 microns in diameter are likely to reach the alveoli. One micron is 0.000001 of a meter. Our airways are line with small hairs, called cilia, which beat up to the mouth (i.e., the opposite direction of inhaled air). The purpose of these cilia is to move deposited particulates up away from the alveoli and towards the mouth. These particles can then be ingested, where they can be eliminated from the body or absorbed from the gut. Very small particles may reach the alveoli and pass into the blood.

This demonstrates that we are physiologically adapted to remove contaminants from our air passages before they reach the lung and bloodstream. The hairs in our nose are our first defense against particulates; cilia represent a secondary defense mechanism. For people with impaired respiratory systems (e.g. smokers, asthmatics), the cilia may be damaged or covered with mucus, preventing them from removing particulates before they reach the alveoli.

Therefore, the risk from inhalation exposure will be increased if the airways are damaged.

Even though we have these defense mechanisms, many chemicals exert their toxic effects directly on the lungs (e.g., Paraquat). These chemicals are the ones from which we are most at risk from inhalation exposure. Paraquat is a herbicide that was historically used to eliminate pests from plants, including marijuana plant. Paraquat sprayed on plants that are then smoked is directly transported to the lungs. In the lungs, Paraquat binds to fatty molecules in cell membranes of the lungs, which leads to the replacement of lung tissue with fibrous tissue that is not elastic. Therefore, the lungs fail to expand and contract, and death from respiratory failure ensues. This effect takes only a few days to occur, and there is no cure for this type of exposure.

As little as one teaspoon can cause this effect. This illustrates that inhalation exposure, depending on the chemical and the amount, can lead to very serious toxic effects.

Inhibited: Containing a small amount of another substance included to prevent the first material from reacting with itself or other things in its environment.

Inhibitor: An agent that slows or interferes with a chemical reaction; a substance that reduces the activity of another substance (as an enzyme).

Initial Compliance Period (Water): The first full three-year compliance period which begins at least eighteen months after promulgation.

Injectate: In relation to the coalbed methane industry, this is the fracturing fluid injected into a coalbed methane well.

Injection: The process of returning spent geothermal fluids to the subsurface. Sometimes referred to as reinjection.

Injection Well: In groundwater remediation, used to raise the level of the water table and to push a contaminated plume away from a potable water system (well).

Injection Zone: A geological formation receiving fluid through a ell.

In-Line Filtration: Pre-treatment method in which chemicals are mixed by the flowing water; commonly used in pressure filtration installations. Eliminates need for flocculation and sedimentation.

In situ: In its original place; unmoved unexcavated; remaining a the site or in the subsurface.

***In-situ* Biodegradation:** Uses naturally occurring microorganisms in soil to degrade contaminants to another form.

***In-situ* Flushing:** Introduction of large volumes of water, at times supplemented with cleaning compounds, into soil, waste, or ground water to flush hazardous contaminants from a site.

***In-situ* Isolation/Contamination:** In soil remediation this method prevents the migration of liquid contaminant or leachates containing contaminants.

***In-Situ* Leach Mining (ISL):** The recovery, by chemical leaching, of the valuable components of an ore-body without physical extraction of the ore from the ground. Also referred to as “solution mining.”

***In-situ* Leaching and Chemical Reaction:** Soil remediation process whereby water mixed with a surfactant is used to leach contaminants from the soil into the groundwater. The groundwater is then collected downstream of the leaching site, through a collection system for treatment and/or disposal.

***In-situ* Oxidation:** Technology that oxidizes contaminants dissolved in ground water, converting them into insoluble compounds.

***In-situ* Passive Remediation:** The easiest to implement and least expensive remediation methodology because it involves no action at the site; it lets nature takes its course, but is not readily or normally accepted by regulators.

***In-situ* Stripping:** Treatment system that removes or “strips” volatile organic compounds from contaminated ground or surface water by forcing an airstream through the water and causing the compounds to evaporate.

***In-situ* Technologies:** Remedial technologies performed in place at the site.

***In-situ* Vitrification:** Employs electrical current passed through electrodes driven into the soil that produce extreme heat and converts soil into a durable glassy material. The organic constituents are pyrolized in the melt and migrate to the surface where they combust in the presence of oxygen. Inorganics in the soil are effectively bound in the solidified glass.

***In-situ* Volatilization:** Commonly known as air stripping, this process uses forced air or drawn air currents through in-place soil to remove volatile compounds.

Innovative Cleanup Technology: Any new or developing soil remediation technology.

Inoculum: 1. Bacteria or fungi injected into compost to start biological action. 2. A medium containing organism, usually bacteria or a virus, that is introduced into cultures or living organisms.

Inorganic Chemicals: Chemical substances of mineral origin, not of basically carbon structure.

Inorganic Substance: A substance that is mineral in origin that does not contain carbon compounds, except as carbonates, carbides, etc.

Input Validation Attacks: Intentionally sending unusual input in the hopes of confusing an application.

Insecticide: A pesticide compound specifically used to kill or, prevent the growth of insects.

Insider Attack: An attack originating from inside a protected network.

Insolation: The solar radiation received by the earth and its atmosphere—**in**coming **so**lar radia**tion**.

Insoluble: Not able to be dissolved.

Inspection and Maintenance (I/M): 1. Activities to ensure that vehicles' emission controls work properly. 2. Also applies to wastewater treatment plants and other anti-pollution facilities and processes.

Inspiratory: Of, relating to, or used for the drawing air into the lungs.

Institutional Sources of MSW: Wastes generated in hospitals, schools, jails and prisons, and government centers.

Institutional Waste: Waste generated at institutions such as schools, libraries, hospitals, prisons, etc.

Instream Use: Water use taking place within a stream channel; e.g., hydro-electric power generation, navigation, water quality improvement, fish propagation, recreation.

Insulator (or dielectric substance): Substances that do not have the property to conduct electricity.

Integrated Exposure Assessment: Cumulative summation (over time) of the magnitude of exposure to a toxic chemical in all media.

Integrated Pest Management (IPM): A mixture of chemical and other, non-pesticide, methods to control pests.

Integrated Waste Management: Using a variety of practices to handle municipal solid waste; can include source reduction, recycling, incineration, and landfilling.

Integrity: The need to ensure that information has not been changed accidentally or deliberately, and that it is accurate and complete.

Intensity: Describes the strength of an odor sample.

Intensity of Stress: The stress per unit area, usually expressed in pounds per square inch. Due to a force of **P** pounds producing tension, compression, or shear on an area of **A** square inches, over which it is uniformly distributed. The simple term, stress, is normally used to indicate intensity of stress.

Intercellular Junctions (Animal Cells): The way cells interact with neighbor cells varies, but they all are virtually in contact with each other. Contact is maintained or effected via ***cell junctions***. These junctions function to anchor cells to one another or to provide a passageway for cellular exchange. There are at least three different types of call junctions (contacts): desmosomes, tight junctions, and gap junctions.

- **Desmosomes** are strong protein attachments between adjacent *animal* cells. They are interacting complementary folds of membrane. Desmosomes act like spot welds or interlinking fingers to hold together tissues, such as skin or heart muscle tissues that undergo considerable stress.
- **Tight junctions** are tight bans of proteins that prevent fluids and small molecules from crossing the membrane. The junction completely encircles each cell, preventing the movement of material between the cells. Tight junctions in the stomach lining protect the stomach cells from hydrochloric acid and are characteristic of *animal* cells lining the digestive tract where materials are required to pass through cells to penetrate the bloodstream.
- **Gap junctions** are narrow tunnels (doorways) between *animal* cells that consist of proteins called *connexions*. The proteins prevent the cytoplasms of each cell from mixing, but allow the passage of ions and small molecules. In this manner, they allow the flow of materials and electrical charge.

Interception: In particle collection technology, interception occurs when the particle's center of mass closely misses the object, but, because of its finite size, the particle strikes the object, and is collected.

Interceptor Sewers: Large sewer lines that, in a combined system, control the flow of sewage to the treatment plant. In a storm, they allow some of the sewage to flow directly into a receiving steam, thus keep it from overflowing onto the streets. Also used in separate systems to collect the flows the main and trunk sewers and carry them to treatment points.

Interface: The common boundary between two substances such as a water and a solid, water and a gas, or two liquids such as water and oil.

Interfacial Tension: The strength of the film separating two immiscible fluids (e.g., oil and water) measured in dynes per, or millidynes per centimeter.

Interferometric Synthetic Aperture Radar (InSar): A remote sensing technique that uses radar satellite images to determine movement of the surface of the earth.

Interfinger: A boundary between two rock types in which both form distinctive wedges protruding into each other.

Interflow: Water that enters the soil surface and moves laterally through the soil layers to reappear as surface flow. Flow takes place above groundwater level.

Interim (Permit) Status: Period during which treatment, storage and disposal facilities coming under RCRA in 1980 are temporarily permitted to operate while awaiting a permanent permit. Permits issued under these circumstances are usually called ”Part A” or “Part B” permits.

Interlock: A device that interacts with another device or mechanism to govern succeeding operations. For example: an interlock on an elevator door prevents the car from moving unless the door is properly closed.

Internal Dose: In exposure assessment, the amount of a substance penetrating the absorption barriers, (e.g., skin, lung tissue, gastrointestinal tract) of an organism through either physical or biological processes.

Internal IT Security Measures:

- Conduct a complete security audit of the system before physically connecting it to the network.
- Make sure the system has the latest versions of the software installed and securely configured.
- Consider blocking access to the test system from the Internet during network auditing and testing.
- Verify that the system to connect doesn’t contain any sensitive data yet.
- Install an Intrusion Detection System to see how often the new system is probed for various vulnerabilities.
- Subscribe to appropriate security related newsletters and mailing lists for updates on the latest vulnerabilities.
- Visit the appropriate web sites as an early warning system for potential intrusions from outdated or unpatched software.
- Read the latest security related white papers as an essential step in self education. (Danchev)

Interrupt: A signal that informs the operating system that something has occurred.

Interstate Carrier Water Supply: A source of water for drinking and sanitary use on planes, buses, trains, and ships operating in more than one state. These sources are federally regulated.

Interstate Commerce Clause: The clause in the U.S. Constitution upon which the federal government enacted the Rivers and Harbors Act of 1988, enabling the U.S. Army Corp of Engineers to regulate and in some cases prohibit private and municipal dumping practices.

Interstate Waters: Waters that flow across or from part of state or international boundaries, e.g., the Great Lakes, the Mississippi River, or coastal waters.

Interstitial Monitoring: The continuous surveillance of the space between the walls of an underground storage tank.

Intrastate Product: Pesticide products once registered by states for sale and use only in the State. All intrastate produces have been converted to full federal registration or canceled.

Intubation: Insertion of a tube into a hollow organ or body passage; to intubate.

Invasive species: Non-indigenous species (e.g., plants or animals) that adversely affect the habitats they invade economically, environmentally, or ecologically.

Inventory (TSCA): Inventory of chemicals produced pursuant to section 8 (b) of the Toxic Substances Control Act.

Inversion: A layer of warm air that prevents the rise of cooling air and traps pollutants beneath it; can cause an air pollution episode.

In Vitro: Testing or action outside an organisms (e.g., inside a test tube or culture dish).

In Vivo: Testing or action inside an organism.

Ion: 1. Charged element or compound that has gained or lost electrons so that it is no longer neutral electrically. 2. An atom or radical in solution carrying an integral electrical charge either positive (cation) or negative (anion).

Ion Exchange Treatment: A common water-softening method often found on a large scale at water purification plants that remove some organics and radium by adding calcium oxide or calcium hydroxide to increase the pH to a level where the metals will precipitate out.

Ionic Bonds: A chemical bond in which electrons have been transferred from atoms of low ionization potential to atoms of high electron affinity.

Ionization Chamber: A device that measures the intensity of ionizing radiation.

Ionizing Radiation: Radiation that becomes electrically charged (i.e., changed into ions). *Ionization* is the process by which atoms are made into ions by the removal or addition of one or more electrons; they produce this effect by the high kinetic energies of the quanta (discrete pulses) they emit. Simply, ionizing radiation is any radiation capable of producing ions by interaction with matter. Direct ionizing particles are charged particles (e.g., electrons, protons, alpha particles, etc.) having sufficient kinetic energy to produce ionization by collision. Indirect ionizing particles are uncharged particles (e.g., photons, neutrons, etc.) that can liberate direct ionizing particles. Ionizing radiation sources can be found in a wide range of occupational settings, including health care facilities, research institutions, nuclear reactors and their support facilities, nuclear weapon production facilities, and other various manufacturing settings, just to name a few.

These ionizing radiation sources can pose a considerable health risk to affected workers if not properly controlled. Ionization of cellular components can lead to functional changes in the tissues of the body. Alpha, beta, neutral particles, x-rays, gamma rays, and cosmic rays are ionizing radiations.

IRIS: EPA's Integrated Risk Information System, an electronic data base containing the Agency's latest descriptive and quantitative regulatory information on chemical constituents.

Iritis: Inflammation of the iris of the eye.

Irradiated Food: Food subject to brief radioactivity, usually gamma rays, to kill insects, bacteria, and mold, and to permit storage without refrigeration.

Irradiance: The direct, diffuse, and reflected solar radiation that strikes a surface.

Irradiation: Exposure to radiation of wavelengths short than those of visible light (gamma, x-ray, or ultra-violet), for medical purposes, to sterilized milk or other foodstuffs, or to induce polymerization of monomers or vulcanization of rubber.

Irreversible Effect: Effect characterized by the inability of the body to partially or fully repair injury caused by a toxic agent.

Irrigation: 1. Artificial water supply for dry agricultural areas created by means of dams and channels. 2. Continuous washing.

Irritant: A substance that produces an irritating effect when it contacts skin, eyes, nose, or respiratory system.

Irritant Smoke (Stannic Oxychloride): A chemical used to check for general sealing of a respirator during a fit test.

Isoconcentration: More than one sample point exhibiting the same isolate concentration.

Isolate: A pure strain that has been isolated as from diseased tissue, contaminated water, or the air.

Isolation: A state of separation between persons or groups to prevent the spread of disease. The first published recommendations for isolation precautions in the United States hospitals appeared as early as 1877, when a handbook recommended placing patents with infectious diseases in separate facilities. Isolation measures can be undertaken in hospitals or homes, as well as in alternative facilities.

Isomer: A material with the same chemical composition (i.e.., kind and number of elements) as another material but with a different arrangement of those elements. For example, n-butyl alcohol and t-butyl alcohol are isomers of one another.

Isopach: A line drawn on a map through points of equal true thickness of a designated Stratigraphic unit or group of Stratigraphic units.

Isotope: A variation of an element that has the same atomic umber of protons but a different weight because of the number of neutrons. Various isotopes of the same element may have different radioactive behaviors, some are highly unstable.

Isotropy: The condition in which the hydraulic or other properties of an aquifer are the same in all directions.

J

Jar Test: A laboratory procedure that simulates a water treatment plant's coagulation/flocculation units with differing chemical doses, mix speeds, and settling times to estimate the minim or ideal coagulant dose required to achieve certain water quality goals.

Jaundice: Yellowish pigmentation of the skin and tissues.

Jerome Meter: Portable electronic device that measures hydrogen sulfide concentrations by sampling the air for several seconds and providing a nearly instantaneous reading.

Job Hazard Analysis (also called job safety analysis): The breaking down into its component parts of any method or procedure to determine the hazards connected therewith and the requirements for performing it safely.

Joint and Severe Liability: Under CERCLA, this legal concept relates to the liability for Superfund site cleanup and other costs on the part of more than one potentially responsible party (i.e., if there were several owners or users of a site that became contaminated over the years, they could all be considered potentially liable for cleaning up the site.)

Joule: This is the basic energy unit for the metric system, or in a later more comprehensive formulation, the International System of Units (SI). It is ultimately defined in terms of the meter, kilogram, and second.

K

Kelvin: Temperature scale used by scientists that begins at absolute zero and increases by the same degree intervals as the Celsius scale; that is, 0ºC is the same as 273K and 100ºC is 373K.

Keratitis: The state of constantly undergoing or likely to undergo change; unstable.

Kerogen: Insoluble organic matter in sedimentary rocks.

Kilogram (kg): kilogram, 1,000 grams (about 2.2 pounds)

Kilowatt-Hour (KWH): A power demand of 1,000 watts for one hour. Power company utility rates are typically expressed in cents per kilowatt-hour.

Kinetic Energy: The energy resulting from a moving object.

Kinetic Rate Coefficient: A number that describes the rate at which a water constituent such as a biochemical oxygen demand or dissolved oxygen rise or falls or at which an air pollutant reacts.

Km: kilometer, or 1,000 meters.

Krebs Cycle or **Citric Acid Cycle:** The final part of the chain of biochemical reactions by which organisms break down food using oxygen to release energy (respiration).

L

Lability: The state of constantly undergoing or likely to undergo change; unstable.

Laboratory Animal Studies: Investigations using animals as surrogates for humans.

Laboratory Safety Standard: A specific hazard communication program for laboratories, found in 29 CFR 1910.1450. These regulations are essentially a blend of hazard communication and emergency response for laboratories. The cornerstone of the Lab Safety Standard is the requirement for a written Chemical Hygiene Plan.

Labile: Readily coming into equilibrium.

Lacrimation: Excessive tear production.

Lacrimator: A tear-producing chemical.

Lagoon: Treatment structure for agricultural wastes. Lagoons can be aerobic, anaerobic, or facultative depending on their loading and design, and can be used in series to produce a higher quality effluent.

Laminar: Used to describe flat, sheet-like groundwater flows that migrate laterally along the upper surface of a confining layer of soil or rock.

Laminar Flow (also Streamline Flow): 1. Air flow in which air molecules travel parallel to all other molecules; laminar flow is characterized by the absence of turbulence. 2. In a stream where parallel layers of water shear over one another vertically.

Land Application: Application of manure, sewage sludge, municipal wastewater, and industrial wastes to land for reuse of the nutrients and organic matter for their fertilizer and soil conditioning values.

Land Application Area: CAFO regulation defines land application area as land under the control of an AFO owner or operator, whether it is owned, rented, or leased, to which manure, litter, or process wastewater from the production area is or may be applied (40 CFR 122.23(b)(3)).

Land Ban: Phasing out of land disposal of most untreated hazardous wastes, as mandated by the 1984 RCRA amendments.

Land Disposal Restrictions: Rules that require hazardous wastes to be treated before disposal on land to destroy or immobilize hazardous constituents that might migrate into soil and ground water.

Land Farming (of Waste): Another name for land treatment whereby various contaminants are spread on soil and worked into the surface and subsurface to allow biodegradation to take place.

Landfill Gas: Gas that is generated by decomposition of organic material at landfill disposal sites. Landfill gas is approximately 50 percent methane.

Landfilling: An ultimate disposal technique whereby solid and hazardous wastes are disposed of in excavated sites.

Landfills: Land waste disposal sites located without regard to possible pollution of groundwater and surface water resulting from runoff and leaching; waste is covered intermittently with a layer of earth to reduce scavenger, aesthetic, disease, and air pollution problems.

Landscape: Environment, both natural and built, that surrounds us.

Landscape Character: Measure of an apparent harmony or unity among all landscape elements, built and natural that can be intensified or preserved to make a memorable scene.

Landscape Ecology: The study of the distribution patterns of communities and ecosystem, the ecological processes that affect those patterns, and changes in pattern and process over time.

Landscape Indicator: A measurement of the landscape, calculated from mapped or remotely sensed data, used to describe spatial patterns of land use and land cover across a geographic area. Landscape indicators may be useful as measures of certain kinds of environmental degradation such as forest fragmentation.

Landscape Quality: Composite of those landscape conditions and perceived values that provide diverse and pleasant surroundings for human use and appreciation. Recognized components of landscape quality include visual resource, landscape use, viewscape, and visibility.

Langelier Index (LI): An index reflecting the equilibrium pH of a water with respect to calcium and alkalinity; used in stabilizing water to control both corrosion and scale deposition.

Langley (L): Unit of solar irradiance. On gram calorie per square centimeter. 1 L =85.93 kwh/m^2

Lapse Rate: The rate of temperature change with altitude. In the troposphere the normal lapse rate is -3.5°F per 1000 ft.

Large Quantity Generator: Person or facility generating more than 2,200 pounds of hazardous waste per month. Such generators produce about 90 percent of the nation’s hazardous waste, and are subject to all RCRA requirements.

Large Water System: A water system that services more than 50,000 customers.

Laryngeal: Relating to, affecting, or near the larynx (voice box).

Laser Induced Fluorescence: A method for measuring the relative amount of soil and/or groundwater with an in-situ sensor.

Latency: Time from the first exposure of a chemical until the appearance of a toxic effect.

Latent: Existing in hidden or dormant form; not currently showing signs of activity or existence.

Latent Heat of Fusion: The amount of heat required to change one gram of a substance from the solid to the liquid phase at the same temperature.

Latent Heat of Vaporization: The amount of heat required to change one gram of a substance from the liquid to the gas phase at the same temperature.

Latent Period: Symptom-free period.

Lateral Sewers: Pipes that run under city streets and receive the sewage from homes and businesses, as opposed to domestic feeders and main trunk lines.

Laundering Weir: Sedimentation basin overflow weir.

Lava Cascade: cascade of water is a small waterfall formed as water descends over rocks. In similar fashion, a lava cascade refers to the rush of descent of lava over a cliff. In Hawaii, lava cascades typically occur when lava spills over the edge of a crater, a fault scarp, or a sea cliff into the ocean.

Lava Channels: Narrow, curved or straight open pathways through which lava moves on the surface of a volcano. The volume of lava moving down a channel fluctuates so that the channel may be full or overflowing at times and nearly empty at other times. During overflow, some of the lava congeals and cools along the banks to form natural levees that may eventually enable the lava channel to build a few meters above the surround ground.

Lava Drapery: The cooled, congealed rock on the face of a cliff, crater, or fissure formed by lava pouring or cascading over their edges.

Lava Flow: Lava flows are associated with volcanoes and others are the result of fissure flow. These masses of molten rock pour onto the Earth’s surface during an effusive eruption. Both moving lava and the resulting solidified deposit are referred to as lava flows. Because of the wide range in (1) viscosity of the different lava types (basalt, andesite, dacite, and rhyolite); (2) lava discharge during eruptions; and (3) characteristics of the erupting vent and topography over which lava travels, lava flows come in a great variety of shapes and sizes.

Lava Spillways: Confined lava channels on the sides of a volcanic cone or shield that form when lava overflows the rim of the vent.

Lava Surge: Intermittent surges or accelerations in the forward advance of lava can occur when the supply of lava to a flow from suddenly increases or a flow front gives way. The supply of lava may increase as consequence of a higher discharge of lava from the vent, a sudden change in the vent geometry so that a great volume of lava escapes (e.g., the collapse of a vent wall), or by the escape of ponded lava from along a channel. Lava surges may be accompanied by thin, short-live breakouts of fluid lava from the main channel and flow front.

Lavage: Washing out a hollow organ (such as the stomach) by flushing with water.

Law of Conservation of Mass : In any ordinary physical or chemical change, matter is neither created nor destroyed but merely changed from one form to another.

Laws of Population Ecology: Note: The information in this section is based on and adapted from Haemig's (2006) *Laws of Population Ecology*. ECOLOGY .INFO 23.

According to Haemig (2006), the discovery of laws in ecology has lagged behind many of the other sciences (e.g., chemistry, physics, etc.) because ecology is a much younger science. However, as Colyvan and Ginzburg (2003) point out, misunderstandings and unrealistic expectations of what laws are have also hindered the search, as have mistaken beliefs that ecology is just too complex a science to have laws. Nevertheless, over the years, researchers have been able to identify some of the laws that exist in ecology.

Ginzburg (1986) points out that while much remains to be learned, it now appears that laws of ecology resemble laws of physics. Colyvan & Ginsburg (2003) and Ginzburg and Colyvan (2004) point out that laws of ecology describe idealized situations, have many exceptions, and need not be explanatory or predictive. The laws of population ecology are listed and described below.

- **Malthusian Law**—says that when birth and death rates are constant, a population will grow (or decline) at an exponential rate.
- **Allee's Law**—says that there is a positive relationship between individual fitness and either the numbers or density of conspecifics (conspecifics are other individuals of the same species).
- **Verhulst's Law**—this law deals with one factor: intra-specific competition (i.e., competition between members of the same species). Because the organisms limiting the population are also members of the population, this law is also called "population self-limitation" (Turchin 2001).
- **Lotka-Volterra's Law**—says that "when populations are involved in negative feedback with other species, or even components of their environments," oscillatory (cyclical) dynamics are likely to be seen (Berryman 2002, 2003).
- **Liebig's Law**—says that of all the biotic or abiotic factors that control a given population, one has to be limiting (i.e., active, controlling the dynamics) (Berryman, 1993, 2003). Time delays produce by this limiting factor are usually one or two generations long (Berryman1999). Krebs (2001) defines "a factor as limiting if a change in the factor produces a change in average or equilibrium density."
- **Fenchel's Law**—says that species with larger body sizes generally have lower rates of population growth—the maximum rate of reproduction decrease with body size at a power of approximately ¼ the body mass (Fenchel 1974). Fenchel's law is expressed by the following equation:

$$r = aW^{-1/4}$$

where

r = the intrinsic rate of nature increase of the population
a = constant (has 3 different values)
W = average body weight (mass) of the organism (Fenchel 1974)

- **Calder's Law**—says that species with larger body sizes generally have longer population cycles—the length of the population cycle increases with increasing body size at a power of approximately ¼ the body mass (Calder 1983).

$$t = aW^{1/4}$$

where

t = average time of the population cycle
a = a constant
W = average body weight (mass) of the organism

- **Damuth's Law**—says that species with larger body sizes generally have lower average population densities—the average density of a population decreases with body size at a power of approximately ¾ the body mass (Damuth, 1981, 1987, 1991). Damuth's Law is expressed by the following equation:

$$d = aW^{-3/4}$$

where

d = the average density of the population
a = a constant
W = average body weight (mass) of the organism

- **Generation-Time Law**—says that species with larger body sizes usually have longer generation-times—that the generation-time increases with increasing body size at a power of approximately ¼ the body mass (Bonner 1965). Note: The body mass used in this law is the body mass of the organism at the time of reproduction. The Generation-Time Law is expressed by the following equation:

$$g = aW^{1/4}$$

where
g = average generation-time of the population
a = a constant
W = average body weight (mass) of the organism

- **Ginzburg's Law**—says that the length of a population cycle (oscillation) is the result of the maternal effect and inertial populating growth. According to this law, the period lengths in the cycles of a population must be either two generations long or six of more generations long (Ginzburg & Colyvan 2004).

Laxative Effect: The consumption of hard water combined in the presence of magnesium sulfates sometimes leads to the development of laxative effect on new consumers.

LC 50/Lethal Concentration: Median level concentration, a standard measure of toxicity. It tells how much of a substance is needed to kill half of a group of experimental organism in a given time.

LD 50/Lethal Dose: The dose of a toxicant or microbe that will kill 50 percent of the test organism within a designated period. The lower the LD 50, the more toxic the compound.

Leach Liquors: Refers to liquid leached from a substance via water circulation through or over it.

Leachate: The liquid formed when rainwater percolates downward through landfilled wastes, picking up contaminants that might then enter the surrounding environment.

Leachate Collection System: A system that gathers leachate and pumps it to the surface for treatment.

Leaching: Removal of soluble constituents from soils or other material by water.

Lead (Pb): A heavy metal, the accumulation of which in organic tissue could produce, in animals and humans, behavioral changes, blindness, and ultimately, death.

Lead Exposure: Lead has been poisoning workers for thousands of years. Most over-exposures to lead have been found in the construction trades, such as plumbing, welding and painting. In plumbing, soft solder (banned for many uses in the United States), used chiefly for soldering tinplate and copper pipe joints, is an alloy of lead and tin. Although the use of lead-based paint in residential applications has been banned, since lead-based paint inhibits the rusting and corrosion of iron and steel, it is still used on construction projects. Significant lead exposures can also arise from removing paint from surfaces previously coated with lead-based paint. According to OSHA 93-47 (2003), the operations that generate lead dust and fumes include the following:

- Flame-torch cutting, welding, the use of heat guns, sanding, scraping and grind of lead painted surfaces in repair, reconstruction, dismantling, and demolition work;
- Abrasive blasting of structures containing lead-based paints;
- Use of torches and heat guns, and sanding, scraping, and grinding lead-based paint surfaces during remodeling or abating lead-based paint;
- Maintaining process equipment or exhaust ductwork.

The employer is responsible for the development and implementation of a worker lead protection program. This program is essential in minimizing worker risk of lead exposure. The most effective way to protect workers is to minimize exposure through the use of engineering controls and good work practices.

At the minimum, the following elements should be included in the employer's worker protection program for employees exposed to lead:

- Hazard determination, including exposure assessment
- Engineering and work practice controls
- Respiratory protection
- PPE
- Housekeeping
- Hygiene facilities and practices
- Medical surveillance and provisions for medical removal
- Training
- Signs
- Recordkeeping

Lead-Mine Scale: Generally occurs in geothermal process equipment such as in piping where scale-buildup leads to process equipment failure.

Lead Service Line: A service line made of lead which connects the water to the building inlet and any lead fitting connected to it.

Leaking Underground Storage Tanks (LUST): The 1986 U.S. UST cleanup fund.

Leeward: Away from the direction of the wind. Opposite of windward.

Legionella: A genius of bacteria, some species of which have caused a type of pneumonia called Legionnaire's disease.

Lentic (calm waters; standing waters): Lakes, ponds, and swamps.

LEPC: An acronym for Local Emergency Planning Committee.

Lethal: Capable of causing death.

Lethal Concentration 50: Also referred to as LC50, a concentration of aa pollutant or effluent at which 50 percent of the test organism die; a common measure of acute toxicity.

Lethal Dose 50: Also referred to as LD50, the dose of a toxicant that will kill 50 percent of test organisms with a designated period of time; the lower the LD 50, the more toxic the compound.

Lethargy: Abnormal drowsiness.

Leukocyte: White blood cell.

Levee: A natural or manmade earthen barrier along the edge of a stream, lake, or river. Land alongside rivers can be protected from flooding by levees.

Level of Concern (LOC): The concentration in air of an extremely hazardous substance above which there may be serious immediate health effects to anyone expose to it for short periods.

Lidar: Device similar to radar except that it emits pulsed laser light rather than microwaves.

Life-Cycle Analysis: Analysis focused on the environmental impact of a product during the entirety of its life cycle, from resource extraction to post-consumer waste disposal. It is a comprehensive approach to examining the environmental impacts of a product or package.

Life Cycle of a Product: All stages of a product's development, from extraction of fuel for power to production, marketing, use, and disposal.

Lifetime Average Daily Dose: Figure for estimating excess lifetime cancer risk.

Lifetime Exposure: Total amount of exposure to a substance that a human would receive in a lifetime (usually assumed to be seventy years).

Lift: In a sanitary landfill, a compacted layer of solid waste and the top layer of cover material.

Lift Gas: Inert gas usually natural gas that is used for gas lift.

Light-Emitting Diode (LED): A long-lasting illumination technology used for exit signs which requires very little power.

Light Non-Aqueous Phase Liquid (LNAPL): A non-aqueous phase liquid with a specific gravity less than 1.0. Because the specific gravity of water is 1.0, most LNAPLs float on top of the water table. Most common petroleum hydrocarbon fuels and lubricant oils are LNAPLs.

Light Pollution: Excessive or obtrusive artificial light (photo-pollution or luminous pollution).

Lighting[1]: Lighting is an essential element of any building. Proper lighting improves the aesthetics of indoor spaces and provides illumination for tasks and activities. An efficient lighting strategy, including natural daylighting, can provide proper levels of illumination and reduce energy costs. *Daylighting* is a passive solar design used to illuminate a living space, an industrial or commercial working space. In the Northern Hemisphere, southern exposure receives the greatest amount of sunlight, while the opposite is true in the Southern Hemisphere. In other words, large picture types windows place in the south-facing wall or roof allow natural light to penetrate and save on the use of expensive electrical lighting.

Because the proper use of daylighting requires integration of natural and artificial lighting sources early in building design process, it is important to have an understanding of the fundamentals of lighting and lighting technology. Accordingly, in this section, we first present a discussion of lighting technology before discussing the principles and practices associated with daylighting.

Lighting Technologies: Lighting technologies include:

- Lamps—lighting sources, like fluorescent and incandescent light bulbs, and solid-state lighting.
- Ballasts—used with electric discharge lamps such as fluorescent lamps, ballasts transform and control electrical power to the light.
- Luminaries (Fixtures)—complete lighting units that contain the bulbs and, if necessary, the ballasts.

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[1] Much of the information in this section is from USDOE: EERE (2008) *Energy Efficiency and Renewable Energy*. Accessed 02/13/10 @www1.eere.energy.gov/buildings/commercial/printable_versions/lighting.html.

- Lighting Controls—devices such as timers and sensors that can save energy by turning lights off when not needed.
- Daylighting—the use of natural light in a building.
- Solid-State Lighting—no other technology offers as much potential to save energy and enhance the quality of building environments, contributing to energy and climate change solutions.

Lamps

Commonly called light bulbs, lamps produce light. When comparing lamps, it is important to understand the following performance characteristics:

- Color Rendering Index (CRI)—a measurement of a light source's accuracy in rendering different colors when compared to a reference light source with the same correlated color temperature. The highest attainable CRI is 100. Lamps with CRIs above 70 are typically used in office and living environments.
- Correlated Color Temperature (CCT)—a measurement on the Kelvin (K) scale that indicates the warmth or coolness of a lamp's color appearance. The higher the color temperature, the cooler the color appearance. Typically, a CT rating below 3200 K is considered warm, which a rating above 4000K is considered cool.
- Efficacy—the ratio of the light output to the power, measured in lumens per watt (lm/w). The higher the efficacy, the more efficient the lamp.

Lamp types include:

Incandescent Lamps—a standard incandescent lamp consists of a fairly large, thin, frosted glass envelope. Inside the glass is an inert gas such as argon and/or nitrogen. At the center of the lamp is a tungsten filament. Electricity heats the filament. The heated tungsten emits visible light in a process called incandescence. Most standard light bulbs are incandescent lamps. They have CRI of 100 and CCTs between 2600-3000, making them attractive lighting sources of many applications. However, these bulbs are typically inefficient (10-15 lm/w), converting only about 10 percent of the energy into light while transforming the rest into heat. Another type of incandescent lamp is the halogen lamp. Halogen lamps also have a CRI of 100. But they are slightly more energy efficient, and they maintain their light output over time. A halogen lamp also uses a tungsten filament. However the filament is encased inside a much smaller quartz envelope. And the gas inside the envelope is from the halogen group. If the temperature is high enough, the halogen gas will combine with tungsten atoms as they evaporate and redeposit them on the filament. This recycling process lets the filament last much longer. In addition, it is now possible to run the filament hotter. This means more light per unit of energy is obtained. Because the quartz envelope is so close to the filament, it becomes about four times hotter than a standard incandescent lamp. As a result of this wasted heat energy, halogen lamps—popular in torchieres (i.e., portable electric lamp with a reflector bowl that directs light upward to given indirect illumination)—are not very energy efficient. The exposed heat from halogen torchieres can also pose a serious fire risk, especially near flammable objects. Because of this inefficiency and risk, manufacturers have developed torchieres that can use other lamps, such as compact fluorescent lamps.

Fluorescent Lamps—(70-100 lm/w) consist of a sealed glass tube. The tube contains a small amount of mercury and an inert gas, like argon, kept under very low pressure. In these electric-discharge lamps, a fluorescing coating on the glass, called phosphor powder—transform some of the ultraviolet energy generated into light. Fluorescent lamps also require a ballast to start and maintain their operation. Early fluorescent lamps were sometimes criticized as not producing enough warm colors, making them appear as too white or uncomplimentary to skin tones, and a cool white fluorescent lame had a CRI of 62. But today, there are lamps available with CRIs of 80 and above that simulate natural daylighting and incandescent light. They also are available in a variety of CCTs: 2900 to 7000. The "T" designation for fluorescent lamps stands for tubular—the shape of the lamp. The number after the "T" gives the diameter of the lamp in eighths of an inch. The T8 lamp—available straight or U-shaped—has become the standard for new construction. It is also commonly serves as a retrofit replacement for 40-watt T12 lamps, improving efficacy, CRI, and efficiency. In some cases, T10 lamps offer advantages over both T12 and T8 lamps, including higher efficiency, higher CRI values, a wider selection of CCTs, and compatibility with several ballast types. Another lamp type is the T5FT fluorescent lamp. These lamps produce maximum light output at higher ambient temperatures than those that are linear our U-shaped. Linear fluorescent lamps often are less expensive than compact fluorescent lamps. They can also produce more light, are easier to dim, and last longer.

Compact Fluorescent Lamps (CFLs)—are small-diameter fluorescent lamps folded for compactness, with an efficacy of 50-75 lm/w for 27-40 watts. There are several styles of CFLs: two-, four-, and six-tube lamps, as well as circular lamps. Some CFLS have the tubes and ballast permanently connected. Others have separate tubes and ballasts. Some CFLs feature a round adaptor, allowing them to screw into common electrical sockets and making them ideal replacements for incandescent lamps. They last up to ten times longer than incandescent lamps, and they use about one-fourth the energy, producing 90 percent less heat. However, typical 60-100 watt incandescent lamps are no more than 5.3 inches long, while standard CFLs are longer than 6 inches. Therefore, sub-CFLs have been developed. No more than 4.5 inches long, sub-CFLs fit into most incandescent fixtures.

High-Intensity Discharge Lamps (HID)—compared to fluorescent and incandescent lamps, high-intensity discharge (HID) lamps produce a large quantity of light in a small package. HID lamps produce light by striking an electrical arc across tungsten electrodes housed inside a specially designed inner glass tube. This tube is filled with both gas and metals. The gas aids in the starting of the lamps. Then, the metals produce the light once they are heated to a point of evaporation. Like fluorescent lamps, HID lamps require a ballast to start and maintain their operation. Types of HID lamps include mercury vapor (CRI range 15-55), metal halide (CRI range 65-80), and high-pressure sodium (CRI range 22-75). Mercury vapor lamps (25-45 lm/w), which originally produced a bluish-green light, were the first commercially-available HID lamps. Today, they are also available in a color corrected, whiter light. But they are still often being replaced by the newer, more efficient high-pressure sodium and metal halide lamps. Standard high-pressure sodium lamps have the highest efficacy of all HID lamps, but they produce a yellowish light. High-pressure sodium lamps that produce a whiter light are now available, but efficiency is somewhat sacrificed. Metal halide lamps are less efficient but produce an even whiter, more natural light. Colored metal halide lamps are also available.

Low-Pressure Sodium Lamps—have the highest efficacy of all commercially available lighting sources, producing up to 180 lumens/watt. Even though they emit a yellow light, a low-pressure sodium lamp should not be confused with a standard high-pressure sodium lamp—a high-intensity discharge lamp. Low-pressure sodium lamps operate much like a fluorescent lamp and require a ballast. The lamps are also physically large—about 4-feet long for the 180-watt size—so light distribution from fixtures is less controllable. There is a brief warm-up period for the lamp to reach full brightness. With a CRI of 0, low-pressure sodium lamps are used where color rendition is not important but energy efficiency is. They are commonly used for outdoor, roadway, parking lot, and pathway lighting. Low-pressure sodium lamps are preferred around astronomical observatories because the yellow light can be filtered out of the random light surrounding the telescope.

Solid-State Lighting (SSL)—compared to incandescent and fluorescent lamps, solid-state lighting creates light with less directed heat. A semi-conducting material converts electricity directly into light, which makes the light very energy efficient. Solid-state lighting includes a variety of light producing semiconductor devices including light-emitting diodes (LEDs) and organic light-emitting diodes (OLEDs). Warm white LEDs have an efficacy of 50 lm/w, while cool white LEDs can achieve efficacies up to 100 lm/w. Until recently, LEDs—basically tiny light bulbs that fit easily into an electrical circuit—were used as simple indicator lamps in electronics and toys. But recent research has achieved efficiencies equal to fluorescent lamps. And the cost of semiconductor material, which used to be quite expensive, has lowered, making LEDs a more cost-effective lighting option. On-going research shows that LEDs have great potential as energy-efficient lighting for residential and commercial building use. New uses for LEDs include small area lighting, such as task and under-shelf fixtures, decorative lighting, and pathway and step marking. As while LEDs become more powerful and effective, LEDs will be used in more general illumination applications, perhaps with entire walls and ceilings becoming the lighting system. They are already being used successfully in many general illumination applications including traffic signals and exit signs. OLEDs currently are used in very thin, flat display screens, such as those in portable televisions, some vehicle dashboard readouts, and in postage-stamp-sized data screens built into pilots' helmet visors. Because OLEDs emit their own light and can be incorporated into arrays on very thin, flexible materials, they also could be used to fashion large, extremely thin panels for light sources in buildings.

Ballasts

Ballasts consume, transform, and control electrical power for electric-discharge lamps, providing the necessary circuit conditions for starting and operating them. Electric-discharge lamps include fluorescent, high-intensity discharge, and low-pressure sodium. When comparing ballasts, it is important to understand the following performance characteristics:

- Ballast Factor (BF)—the ratio of the slight output of a lamp or lamps operated by a specific ballast to the light output of the same lamp(s) operated by a reference ballast. It can be used to calculate the actual light output of that specific lamp-ballast combination. BF is typically different for each lamp type. Ballasts with extremely high BFs could reduce lamp life and accelerate lumen deficiency because of high lamp current. Extremely low BFs also could reduce lam life because they reduce lamp current.
- Ballast Efficacy Factor (BEF)—the ratio of ballast factor (as a percentage) to power (in watts). BEF comparisons should be made only among ballasts operating the same type and number of lamps.

- System Efficacy—the ratio of the light output to the power, measured in lumens per watt (lm/w), for a particular lamp ballast system.

There are three basic types of ballasts: magnetic, hybrid and electronic ballasts.

Magnetic Ballasts—contain a magnetic core of several laminated steel plates wrapped with copper windings. These ballasts operate lamps at line frequency (60 hertz in North America). Of all ballasts, magnetic ones are the least expensive and also the least efficient. They have greater power losses that electronic ballasts. But magnetic ballasts manufactured today are 10 percent more efficient than the older high-loss magnetic ballasts, which used aluminum windings. Magnetic ballasts are available with dimming capability. However, they cannot be dimmed below 20 percent and still use more electricity than electronic ballasts.

Hybrid Ballasts (Cathode-Disconnect Ballasts)—use a magnetic core-and-coil transformer and an electronic switch for the electrode heating circuit. Like magnetic ballasts, they operate lamps at the frequency (60 hertz in North America). After they start the lamp, these ballasts discount the electrode-heating circuit. Hybrid ballasts cost more than magnetic ballasts, but they are more energy efficient.

Electronic Ballasts—in the early 1980s, manufacturers began to replace the core-and-coil transformer with solid-state, electronic compounds that could operate lamps at 20-50 kilohertz. These electronic ballasts experience half the power loss of magnetic ballasts. Also lamp efficacy increases by approximately 10 to 15 percent compared to 60-hertz operation. Electronic ballasts are the most expensive, but they are also the most efficient. Operating lamps with electronic ballasts reduces electricity use by 10 to 15 percent over magnetic ballasts of the same light output. They are also quieter, lighter, and they virtually eliminate lamp flicker. Electronic ballasts are also available as dimming ballasts. These ballasts allow the light level to be controlled between 1 and 100 percent. There are a variety of electronic ballasts available for use with fluorescent lamps. Electronic ballasts have been successfully used with lower watt high-intensity discharge (HID) lamps (primarily 35-100 w/MH). These ballasts provide an energy savings over magnetic ballasts of 8 to 20 percent. Their lighter weight also helps in some HID application, such as track lighting.

Luminaires (Lighting Fixtures)

A lamp or lamp-ballast combination may produce light very efficiently, but if it is installed in an inefficient luminaire, the overall system efficiency may still be poor. The best luminaire manufacturers will design their fixtures around specific lamps to optimize the amount of light delivered to the work area. For example, a luminaire designed specifically for a compact fluorescent lamp can deliver almost ten times as much illumination as an incandescent fixture fitted with the same compact fluorescent lamp.

Luminaire components include reflectors, diffusers—which absorb some of the light from a lamp—and polarizing panels. Reflectors can be used to direct more of the light produced by the lamp out of the luminaire onto the work area. Polarizing panels can sometimes increase the contrast of a visual task.

When comparing luminaires, it is important to understand the flowing performance characteristics:

- Illuminance—the amount of light that reaches a surface. It is measured in footcandles (lumens/square foot) or lux (lumens/square meter).
- Luminaire Efficacy/Efficiency Rating (LER)—the light output (lumens) per watt of electricity use (lm/w).

Before selecting luminaires or lighting fixtures for an office building, factory, warehouse, or even a parking lot, it is a good idea to consult a certified lighting designer. A lighting designer will not only help find the most energy-efficient luminaires, but also provide lighting that makes for a comfortable and more productive work environment.

Today, energy-efficient commercial lighting design includes more than just the ambient or general lighting of a workspace, such as the use of ceiling luminaires. When designing or retrofitting the lighting, the general Illuminance can be reduced if task lighting is implemented properly into the overall design. Task lighting can result in significant energy savings and improved visibility for workers.

Lighting Controls

Lighting controls help conserve energy and make a lighting system more flexible. The mos t common light control is the on/off switch. Other types of light control technologies include: manual dimming, photosensors, occupancy sensors, clock switches or timers, and centralized controls.

Manual Dimming—these controls allow occupants of a space to adjust the light output or Illuminance. This can result in energy savings through reductions in input power, as well as reductions in peak power demand, and enhanced lighting flexibility. Slider switches allow the occupant to change the lighting overt the complete output range. They are simplest of the manual controls. Preset scene controls change the dimming setting for various lights all at once with the press of a button. It is possible to have different settings for the morning, afternoon, and evening. Remote control dimming is also available. This type of technology is well suited for retrofit projects, where it is useful to minimize rewiring.

Photosensors—these devices automatically adjust the light output of a lighting system based on detected Illuminance. The technology behind photosensors is the photocell. A photocell is a light-responding silicon chip that converts incident radiant energy into electrical current. While some photosensors just turn lights off and on, others can also dim lights. Automatic dimming can help with lumen maintenance. Lumen maintenance involves dimming luminaires when they are new, which minimizes the wasteful effects of over-design. The power supplied to them is gradually increased to compensate for light loss over the life of the lamp.

Occupancy sensors—turn lights on and off base don't their detection of motion within a space. Some sensors can also be used in conjunction with dimming controls to keep the lights from turning completely off when a space is unoccupied. This control scheme may be appropriate when occupancy sensors control separate zones in a large space, such as in a laboratory or in an open office area. In these situations, the lights can be dimmed to a predetermined level when the space is unoccupied. Sensors can also be used to enhance the efficiency of centralized controls by switching off light sin unoccupied areas during normal working hours as well as after hours. There are three basic types of occupancy sensors, these include:

- Passive infrared (PIR)—sensors react to the movement of a heat-emitting body thrugh their field of view. Wall box-type PIR occupancy sensors are best suited of small, enclosed spaces such as private offices, where the sensor replaces the light switch on the wall and no extra wiring is require. They should not be used where walls, partitions, or other objects might block the sensors' ability to detect motion.
- Ultrasonic—these sensors emit an inaudible sound pattern and re-read the reflection. They react to changes in the reflected sound pattern. These sensors detect very minor motion better than most infrared sensors. Therefore, they are good to use in spaces such as restrooms with stalls, which can block the field of view, because the hard surfaces will reflect the sound pattern.
- Dual-technology (hybrid)—occupancy sensors that use both passive infrared and ultrasonic technologies to minimize the risk of false triggering (lights coming on when the space is unoccupied). They also ten dot be more inexpensive.

Clock Switches or Timers—These control lighting for a preset period of time. They come equipped with an internal mechanical or digital clock, which will automatically adjust for the time of year. The user determines when the light should be turned on and when they should be turned off. Clock switches can be used in conjunction with photosensors.

Centralized Controls—these are building controls or building automation systems that can be used to automatically turn on, turn off, or dim electrical lights around a building. In the morning, the centralized control system can be used to turn on the lights before employees arrive. During the day, a central control system can be used to dim the lights during periods of high power demand. And, at the end of the day, the lights can be turned off automatically. A centralized lighting control system can significantly reduce energy use in buildings where lights are left on when not needed.

Lignin: Structural constituent of wood and (to a lesser extent) other plant tissues, which encrusts the cell walls and cements the cells together.

Limit of Detection (LOD): The minimum concentration of a substance being analyzed test that has a 99 percent probability of being identified.

Limited: Limiting nutrients such as carbon, nitrogen, and phosphorous.

Limited Degradation: An environmental policy permitting some degradation of natural systems but terminating at a level well beneath an established health standard.

Limiting Factor: Factors such as temperature, light, water, or a chemical limit the existence, growth, abundance, or distribution of an organism.

Limiting Nutrient: Nutrient that restricts plant growth.

Limits (dose limits): The permissible upper bounds of radiation doses.

Limnetic: The open water surface layer of a lake through which reaches sufficient sunlight for photosynthesis.

Limnology: The study of lakes and other bodies of open fresh water in terms of their plant and animal biology, and their physical properties.

Lindane: A pesticide that causes adverse health effects in domestic water supplies and is toxic to firewater fish and aquatic life.

Line Shaft Pump: Fluid pump that has the pumping mechanism in the wellbore and that is driven by a shaft connected to a motor on the surface.

Linear Gel: A simple guar-based fracturing fluid usually formulated using guar and water with additives or guar with diesel fuel.

Linear Scale: The relation between a distance on a map and the corresponding distance on the Earth. Scale varies from place to place on every map. The degree of variation depends on the projection used in making the map.

Liner: 1. A relatively impermeable barrier designed to keep leachate inside a landfill. Liner materials include plastic and dense clay. 2.A casing string that does not extend to the top of wellbore, but instead is anchored or suspended from inside the bottom of the previous casing string. 3. An insert or sleeve for sewer pipes to prevent leakage or infiltration.

Lipid Solubility: The maximum concentration of a chemical that will dissolve in fatty substances. Lipid soluble substances are insoluble in water. They will very selectively disperse through the environment via uptake in living tissue.

Lipids: Substances, such as fats that are some to the principal structure constituents of the cells of living organisms.

Liquefaction: Changing a solid into a liquid.

Liquid: A state of matter between a solid and a gas.

Liquid Collector: A medium-temperature solar thermal collector, employed predominately in water heating, which uses pumped liquid as the heat-transfer medium.

Liquid Injection Incinerator: Commonly used system that relies on high pressure to prepare liquid wastes for incineration by breaking them up into tiny droplets to allow easier combustion.

Liquid Manure: Mixture of water and manure that behaves more like a liquid than a solid, generally less than 5 percent solids.

List: Shorthand term for EPA list of violating facilities or firms debarred from obtaining government contracts because they violated certain sections of the Clean Air or Clean Water Acts. The list is maintained by the Office of Enforcement and Compliance Monitoring.

List Based Access Control: Associates a list of users and their privileges with each object.

Listed Waste: Wastes listed as hazardous under RCRA but which have not been subjected to the Toxic Characteristics Listing Process because the dangers they present are considered self-evident.

Liter: A metric unit of volume, equal to one cubic decimeter (1.76 pints).

Lithology: The study and description of rocks, in terms of their color, texture, and mineral composition.

Lithosphere: The earth's crust—the layers of soil and rock which comprise the earth's crust.

Litter: The intact and partially decayed organic matter lying on top of the soil; discards thrown about without regard to the environment.

Live Cull: A classification that includes live cull trees. When associated with volume, it is the net volume in live cull trees that are 5.0 inches in d.b.h. and larger.

Livestock Wastes: Manure with added bedding, rain or other water, soil, etc. It also includes wastes such as milkhouse or washing wastes not particularly associated with manure. It also includes hair, feathers, and other debris.

Livestock Water Use: Water used for livestock watering, feed lots, dairy operations, fish farming, and other on-farm needs.

Living Communities, Relationships: In addition to the pyramid-shaped relationships, there are other important relationships in living communities. Some of these involve food energy and some do not. In this section several of these relationships are described.

Symbiosis is a close (intimate) ecological relationship (organisms live together in close proximity) between the individuals of two (or more) different species. Sometimes a symbiotic relationship benefits both species, sometimes one species benefits at the other's expense, and in other cases neither species benefits. One thing is certain; the relationship is *obligate*, meaning at least one of the species must be involved in the relationship to survive.

Ecologists use a different term for each type of symbiotic relationship:

- Mutualism—both organisms benefit
- Commensalism—one organism benefits, the other is unaffected
- Parasitism—one organism benefits, the other is harmed
- Competition—neither organism benefits
- Neutralism—both organisms are unaffected

LNAPLs: Light Nonaqueous-Phase Liquids, including gasoline, heating oil, and kerosene.

Load: The simultaneous demand of all customers required at any specified point in an electric power system.

Load Balancing: Keeping the amount of electricity produced (the supply) equal to the consumption (the demand). This is one of the challenges of wind energy production, which produces energy on a less predicable schedule than other methods.

LOAEL: Lowest observed adverse effect level.

Loam: The textural-class name for soil with a moderate amount of sand, silt, and clay. Loam soils contain 7–27 percent clay, 28–50 percent silt, and 23–52 percent sand.

Local Education Agency (LEA): In the asbestos program, an educational agency at the local level that exists primarily to operate schools or to contract for educational services, including primary and secondary public and private schools. A single, unaffiliated school can be considered an LEA for AHERA purposes.

Local Emergency Planning Committee (LEPC): A committee appointed by the state emergency response commission, a required by SARA Title III, to formulate a comprehensive emergency plant for its jurisdiction.

Local Exhaust Ventilation: Is the most predominant method of controlling workplace air is used to control air contaminants by trapping and removing them near the source. In contrast to dilution ventilation (which lets the contamination spread throughout the workplace, later to be diluted by exhausting quantities of air from the workspace), local exhaust ventilation surrounds the point of emission with an enclosure, and attempts to capture and remove the emissions before they are released into the worker's breathing zone. The contaminated air is usually drawn through a system of ducting to a collector, where it is cleaned and delivered to the outside through the discharge end of the exhauster. A typical local exhaust system consists of a hood, ducting, an air-cleaning device, fan, and a stack. A local exhaust system is usually the proper method of contaminant control if:

- the contaminant in the workplace atmosphere constitutes a health, fire, or explosion hazard.
- national or local codes require local exhaust ventilation at a particular process.
- maintenance of production machinery would otherwise be difficult.
- housekeeping or employee comfort will be improved.
- emission sources are large, few, fixed, and/or widely dispersed.
- emission rates vary widely by time.
- emission sources are near the worker-breathing zone.

Local Solar Time: A system of astronomical time in which the sun crosses the true north-south meridian at noon, and which differs from local time according to longitude, time zone, and equation of time.

Localized: Restricted to a definite part of the body; not general or systemic.

Lockout: The placement of a lockout device on an energy isolating device, in accordance with an established procedure, ensuring that the energy isolating device and the equipment being controlled cannot be operated until the lockout device is removed.

Lockout Device: A device that uses a positive means (such as a lock, either key or combination type) to hold an energy isolating device in the safe position and prevent the energizing of a machine or equipment. Included are blank flanges and bolted slip blinds.

Lockout/Tagout Procedure: An OSHA procedure found in 29 CFR 1910.147. A tag or lock is used to "tag out" or "log out" a device, so that no one can inadvertently actuate the circuit, system, or equipment that is temporarily out of service.

Log Clipping: The selective removal of log entries from a system log to hide a compromise.

Log Retention: How long audit logs are retained and maintained.

Logging: The process of storing information about events that occurred on the firewall or network.

Logging Residues: The unused portions of growing stock and non-growing stock trees cut or killed by logging and left in the woods.

Loopback Address: Pseudo IP addresses that always refer back to the local host and are never sent out onto a network.

Losing Stream: Typical of arid regions, where streams can recharge groundwater.

Loss: 1. The degradation of a system or component. Loss is best understood when related to dollars lost. Examples include death or injury to a worker, destruction or impairment of facilities or machines, destruction or spoiling of raw materials, and creation of delay. In the insurance business, loss connotes dollar loss, and we have seen underwriters who write it as LO$$ to make that point. 2. In ventilation systems, usually refers to the conversion of static pressure to heat in components of the ventilation system, e.g., "the hood entry loss."

Lot: Any paved or unpaved outdoor animal area—feedlot, handling area, resting areas, etc.

Lotic: Running fresh water systems, for example, rivers or streams.

Low Density Polyethylene (LOPE): Plastic material used for both rigid containers and plastic film applications.

Low Emissivity (Low–E) Windows: New window technology that lowers the amount of energy loss through windows by inhibiting the transmission of radiant heat while still allowing sufficient light to pass through.

Low Head: Head of 66 feet or less.

Low-Level Radioactive Waste (LLRW): Wastes less hazardous than most of those associated with a nuclear recto; generated by hospitals, research laboratories, and certain industrial The Department of Energy, Nuclear Regulatory Commission, and EPA share responsibilities for managing them.

Low NO_x Burners: One of several combustion technologies used to reduce emissions of Nitrogen Oxides (NO_x).

Low-Speed Shaft: Connects the rotor to the gearbox.

Low-Temperature Collectors: Metallic or nonmetallic solar thermal collectors that generally operate at temperatures below 110 degrees Fahrenheit and use pumped liquid or air as the heat transfer medium. They usually contain no glazing and no insulation, and they are often made of plastic or rubber, although some are made of metal.

Lower Detection Limit: The smallest signal above background noise an instrument can reliably detect.

Lower Explosive Limit (LEL): The minimum concentration of a flammable gas in air required for ignition in the presence of an ignition source. Listed as a percent by volume in air.

Lowest Acceptable Daily Dose: The largest quantity of a chemical that will not cause a toxic effect, as determined by animal studies.

Lowest Achievable Emission Rate: Under the Clean Air Act, the rate of emissions that reflects (1) the most stringent emission limitation in the implementation plan of any state for such source unless the owner or operator demonstrates such limitations are not achievable; or (2) the most stringent emissions limitation achieved in practice, whichever is more stringent. A proposed new or modified source many not emit pollutants in excess of existing new source standards.

Lowest Observed Adverse Effect Level (LOAEL): The lowest level of a stressor that causes statistically and biologically significant differences in test samples as compared to other samples subjected to no stressor.

LU: Live unit, 500 kg of body weight.

Luminescent: Glowing.

Lung Damaging Agent: A substance that causes physical injury to the respiratory tract, including the lungs. In extreme cases, membranes swell and lungs become filled with fluid; death results from lack of oxygen.

M

Machine Guarding: The most common sources of mechanical hazards are unguarded shafting, shaft ends, belt drives, gear trains, and projections on rotating parts. Where a moving part passes a stationary part or another moving part, there can be a scissor-like effect on anything caught between the parts. A machine component which moves rapidly with power, or a point of operation where the machine performs its work, are also typical hazard sources.

There are probably over two million metalworking machines and half that many woodworking machines in use that are at least ten years old. Most are poorly guarded, if at all. Even the newer ones may have substandard guards, in spite of OSHA requirements.

Macroinvertebrate (Benthic): The emphasis on aquatic insect studies, which has expanded exponentially in the last three decades, has been largely ecological. This interest in aquatic insects has grown from early limnological roots and sport fishery-related investigations of the ’30s and ’40s, to the use of aquatic insects as indicators of water quality during the ’50s and ’60s. In the ’70s and ’80s, aquatic insects became the dominant forms used in freshwater investigations of basic ecological questions.

Freshwater invertebrates are ubiquitous; even the most polluted or environmentally extreme lotic environments usually contain some representative of this diverse and ecologically important group of organisms.

Benthic macroinvertebrates are aquatic organisms without backbones that spend at least a part of their life cycle on the stream bottom. Examples include aquatic insects—such as stoneflies, mayflies, caddisflies, midges, and beetles—as well as crayfish, worms, clams, and snails. Most hatch from eggs, and mature from larvae to adults. The majority of the insects spend their larval phase on the river bottom and, after a few weeks to several years, emerge as winged adults. The aquatic beetles, true bugs, and other groups remain in the water as adults. Macroinvertebrates typically collected from the stream substrate are either aquatic larvae or adults.

In practice, stream ecologists observe indicator organisms and their responses (biomonitoring) to determine the quality of the stream environment. There are a number of methods for determining water quality based on biologic characteristics. A wide variety of indicator organisms (biotic groups) is used for biomonitoring. The most often used include algae, bacteria, fish, and macroinvertebrates. A search of the database from 1993 to July 1998 carried out by Vesh and Kobzina at the University of California, Berkeley confirmed that macroinvertebrates are the most popular group.

Notwithstanding their popularity, in this text, we use benthic macroinvertebrates for a number of other reasons. Simply, they offer a number of advantages:

1. They are ubiquitous, so they are affected by perturbutations in many different habitats.
2. They are species rich, so the large number of species produces a range of responses.
3. They are sedentary, so they stay put, which allows determination of the spatial extent of a perturbutation.
4. They are long-lived, which allows temporal changes in abundance and age structure to be followed.
5. They integrate conditions temporally, so like any biotic group, they provide evidence of conditions over long periods of time.

In addition, benthic macroinvertebrates are preferred as bioindicators because they are easily collected and handled by samplers; they require no special culture protocols. They are visible to the naked eye and their characteristics are easily distinguished by samplers. They have a variety of fascinating adaptations to stream life. There are a number of excellent references available which are written in plain-English (lay terms). Certain benthic macroinvertebrates have very special tolerances and thus are excellent specific indicators of water quality. Useful benthic macroinvertebrate data are easy to collect without expensive equipment. The data obtained by macroinvertebrate sampling can serve to indicate the need for additional data collection, possibly including water analysis and fish sampling.

Macronutrient: Chemical element required, in relatively large amounts, for proper plant growth.

Macropores: Secondary soil features such as root holes or desiccation cracks that can create significant conduits for movement of NAPT and dissolved contaminants, or vapor-phase contaminants.

Magma: Molten rock within the Earth, from which igneous rock is formed by cooling.

Magnetic Separation: Use of magnets to separate ferrous materials from mixed municipal waste stream.

Magnetic Survey: Measurements of the earth's magnetic field that are then mapped and used to determine subsurface geology.

Major Modification: This term is used to define modifications of major stationary sources of emissions with respect to Prevention of Significant Deterioration and New Source Review Under the Clean Air Act.

Major Stationary Sources: Term used to determine the applicability of Prevention of Significant Deterioration and New Source Regulations. In a nonattainment area, any stationary pollutant source with potential to emit more than 100 tons per year is considered a major stationary source. In PSD areas the cutoff level may be either 100 or 250 tons, depending upon the source.

Malaise: Vague feeling of generalized weakness.

Malicious Code: Software (e.g., Trojan horse) that appears to perform a useful or desirable function, but actually gains unauthorized access to system resources or tricks a user into executing other malicious logic.

Man-Made (Anthropogenic) Beta Particle and Photon Emitters: All radionuclides emitting beta particles and/or photons listed in Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure.

Management Entity: An entity similar to a responsible management entity, but managing a limited set of management activities (e.g., homeowners' association, contracted provider of management services).

Management Factors: The management techniques (fertilization, irrigation, etc.) employed in land and soil management that work to decrease leaching, increase soil surface contaminant concentrations, or maximize soil aeration against volatilization.

Management Oversight and Risk Tree Analysis (MORT): Originally developed for U.S. Department of Energy (USDOE) to help conduct nuclear criticality and hardware analysis, it is defined as a formalized, disciplined logic or decision tree to systematically relate and integrate a wide variety of safety concepts. As an incident analysis technique, it is a graphical checklist that focuses on three main concerns: specific oversights and omissions, assumed risks, and general management system weaknesses (EG&G, 1984).

It is essentially a series of fault trees with three basic subsets or branches:

1. a branch that deals with specific oversights and omissions at the worksite
2. a branch that deals with the management system that establishes policies and makes them work
3. an assumed risk branch that acknowledges that no activity is completely free of risk and that risk management functions must exist in any well managed organization. These assumed risks are those undesirable consequences that have been quantitatively analyzed and formally accepted by appropriate management levels within the organization.

MORT includes about 100 generic causes and thousands of criteria. The MORT diagram terminates in some 1,500 basic safety program elements needed for a successfully functioning safety program—elements that prevent the undesirable consequences indicated at the top of the tree. MORT has three primary goals:

1. to reduce safety-related oversights, errors, and omissions
2. to allow risk quantification and the referral of residual risks to program organizational management levels for appropriate action
3. to optimize the allocation of resources to the safety program and to organizational hazard control efforts.

MORT programs and their associated training courses place emphasis on constructing tree for individual program needs and on a set of readymade MORT trees that can be used for program design, program evaluation, or accident investigation.

Management Plan: Under the Asbestos Hazard Emergency Response Act (AHERA), a document that each Local Education Agency is required to prepare, describing all activities planned and undertaken by a school to comply with AHERA regulations, including building inspections to identify asbestos-containing materials, response actions, and operations and maintenance programs to minimize the risk of exposure.

Management Services: Planning, design, permitting, inspection, construction/installation, operation, maintenance, monitoring, enforcement, and other services required to ensure that the wastewater treatment performance requirements established by the regulatory authority are achieved. Management services should be provided by properly trained personnel and tracked by means of a comprehensive management information system.

Managerial Controls: Methods of nonpoint source pollution control base don decisions about managing agricultural wastes or application times for rates for agrochemicals.

Mandatory Recycling: Programs which by law require consumers to separate trash so that some or all recyclable materials are recovered for recycling rather than going to landfills.

Mandible: The lower jaw.

Manifest: A one-page form used by haulers transported waste that lists EPA identification numbers, type and quantity of waste, the generator it originated from, the transporter that shipped it, and the storage or disposal facility to which it is being shipped. It includes copies for all participants in the shipping process.

Manifest System: Tracking of hazardous waste from “cradle-to-grave” (generation through disposal) with accompanying documents know as manifests.

Manometer: The manometer is often used to measure the static pressure in the ventilation system. The manometer is a simple, U-shaped tube, open at both ends, and usually constructed of clear glass or plastic so that the fluid level within can be observed. To facilitate measurement, a graduated scale is usually present on the surface of the manometer. The manometer is filled with a liquid (water, oil, or mercury). When pressure is exerted on the liquid within the manometer, the pressure causes the level of liquid to change as it relates to the atmospheric pressure external to the ventilation system. The pressure measured, therefore, is relative to atmospheric pressure as the zero point.

When manometer measurements are used to obtain positive pressure readings in a ventilation system, the leg of the manometer that opens to the atmosphere will contain the higher level of fluid. When a negative pressure is being read, the leg of the tube open to the atmosphere will be lower, thus indicating the difference between the atmospheric pressure and the pressure within the system.

Manual Separation: Hand sorting of recyclable or compostable materials in waste.

Manufacturer’s Formulation: A list of substances or component parts as described by the maker of a coating, pesticide, or other product containing chemical or other substances.

Manufacturing Use Product: Any product intended (labeled) for formulation or repackaging into other pesticide products.

Manure: Fecal and urinary defecations of livestock and poultry. Manure does not include spilled feed, bedding, or additional water or runoff.

Map Projection: A systematic representation of a round body such as the earth or a flat (plane) surface. Each map projection has specific properties that make it useful for specific purposes.

Margin of Exposure (MOE): The ratio of the no-observed adverse-effect-level to the estimated exposure dose.

Margin of Safety: Maximum amount of exposure producing no measurable effect in animals (or studied humans) divided by the actual amount of human exposure in a population.

Marine Debris: Human-created waste that has deliberately or accidentally become afloat in a waterway, lake, ocean, or sea.

Marine Pollution: Occurs when harmful effects, or potentially harmful effects, can result from the entry into the ocean of chemicals, particles, industrial, agricultural, and residential waste, or the spread of invasive organisms.

Marine Sanitation Device: Any equipment or process installed on board a vessel to receive, retain, treat, or discharge sewage.

Marsh: A type of wetland that does not accumulate appreciable peat deposits and is dominated by herbaceous vegetation. Marshes may be either fresh or saltwater, tidal or non-tidal.

Mass: The quantity of matter and a measurement of the amount of inertia that a body possesses.

Mass Balance Equations: Used to track pollutants from one place to another.

Material Category: In asbestos program, broad classification of materials into thermal surfacing insulation, surfacing material, and miscellaneous material.

Material Type: Classification of suspect material by its specific use or application; e.g., pipe insulation, fireproofing, and floor tile.

Materials Balance: The law of conservation of mass/matter that says that everything has to go somewhere but is neither created nor destroyed in the process.

Materials Recovery Facility (MRF): A facility that processes residentially collected mixed recyclables into new products available for market.

Matrix Treatments: Treatment performance below the reservoir fracture pressure, and generally are designed to restore the natural permeability of the reservoir following damage to the near-wellbore area. Matrix treatments typically use hydrochloric or hydrofluoric acids, to remove mineral material that reduces flow into the well.

Matter: Anything that exists in time, occupies space, and has mass.

Maximally (or Most) Exposed Individual: The person with the highest exposure in a given population.

Maximum Acceptable Toxic Contamination: For a given ecological effects test, the range (or geometric mean) between the No Observable Adverse Effect Level and the Lowest Observable Adverse Effects Level.

Maximum Available Control Technology (MACT): The emission standard for sources of air pollution requiring the maximum reduction of hazardous emissions, taking cost and feasibility into account. Under the Clean air Act Amendments of 1990, the MACT must not be less than the average emission level achieved by controls on the best performing 12 percent of existing sources, by category of industrial and utility sources.

Maximum Contaminant Levels (MCLs): Primary drinking water standard and maximum contaminant levels allowed based on health-related criteria.

Maximum Contaminant Level Goal (MCLG): Under the Safe Drinking Water Act, a non-enforceable concentration of a drinking water contaminant, set at the level at which no known or anticipated adverse effects on human health occur and which allows an adequate safety margin. The MFLG is usually the starting point for determining the regulated Maximum Contaminant Level.

Maximum Exposure Range: Estimate of exposure or dose level received by an individual in a defined population that is greater than the 98th percentile does for all individuals in that population, but less than the exposure level received by the person receiving the highest exposure level.

Maximum Residue Level: Comparable to a U.S. tolerance level, the Maximum Residue Level the enforceable limit on food pesticide levels in some countries. Levels are set by the Codex Alimentarius Commission, a United Nations agency managed and funded jointly by the World Health Organization and the Food and Agriculture Organization.

Maximum Sustainable Yield: The highest rate at which a renewable resource can be used without impairing or damaging its ability to be fully renewed.

Maximum Tolerated Dose: The maximum dose that an animal species can tolerate for a major portion of its lifetime without significant impairment or toxic effect other than carcinogenicity.

Mcf: Million cubic feet; a unit typically used to define gas production volumes in the coalbed methane industry; 1 Mcf is roughly equivalent to the volume of gas required to heat approximately 12 households for one year (based on the Department of energy’s average household energy consumption statistic, 2001), Mcf can sometimes represent 1,000 cubic feet.

MDA Single-Point Monitor: Units used to monitor ambient air concentrations of individual gases such as hydrogen sulfide over extended periods.

Measure of Effect/Measurement Endpoint: A measurable characteristic of ecological entity that can be related to an assessment endpoint; e.g., a laboratory test of eight species meeting certain requirements may serve as a measure of effect for an assessment endpoint, such as survival of fish, aquatic, invertebrate or algal species under acute exposure.

Measure of Exposure: A measurable characteristic of a stressor e(such as the specific amount of mercury in a body of water) used to help quantify the exposure of an ecological entity of individual organism.

Mechanical Aeration: Use of mechanical energy to inject air into water to cause a waste stream to absorb oxygen.

Mechanical Separation: Using mechanical means to separate waste into various components.

Mechanical Solids Separation: Process of separating suspended solids from a liquid-carrying medium by trapping the particles on a mechanical screen or sieve or by centrifugation.

Mechanical Turbulence: Random irregularities of fluid motion in air caused by buildings or other non-thermal processes.

Mechanical Ventilation: Artificial ventilation of the lungs (as by positive end-respiratory pressure) using means external to the body.

Media: Specific environments—air, water, soil—which are the subject of regulatory concern and activities.

Medical Monitoring: The initial medical exam of a worker, followed by periodic exams. The purpose of medical monitoring is to assess workers' health, determine their fitness to wear personal protective equipment, and maintain records of their health.

Medical Surveillance: A periodic comprehensive review of a worker's health status; acceptable elements of such surveillance program are listed in the Occupational Safety and Health Administration standards for asbestos.

Medical Waste: Any solid waste generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals, excluding hazardous waste identified or listed under 40 CFR Part 261 or any household waste as defined in 40 CFR Sub-section 261.4 (b)(1).

Medium-Size Water System: A water system that serves 3,300 to 50,000 customers.

Medium-Temperature Collectors: Solar thermal collectors designed to operate in the temperature range of 140 degrees to 180 degrees Fahrenheit, but that can also operate at a temperature as low as 110 degrees Fahrenheit. The collector typically consists of a metal frame, metal absorption panel with integral flow channels (attached tubing for liquid collectors or integral ducting for air collectors), and glazing and insulation on the sides and back.

Megawatt (WM): One million watts of electricity.

Melanosis: Abnormal darkening of the skin or tissues.

Melting Point: The temperature at which a substance changes from solid to liquid.

Membrane Filter Technique Colony Counting: Upon completion of the incubation period, the surface of the filter will have growths of both fecal coliform and non-fecal coliform bacterial colonies. The fecal coliform will appear blue in color, while non-fecal coliform colonies will appear gray or cream colored.

When counting the colonies the entire surface of the filter should be scanned using a 10x to 15x binocular, wide-field dissecting microscope.

The desired range of colonies, for the most valid fecal coliform determination is 20 to 60 colonies per filter. If multiple sample dilutions are used for the test, counts for each filter should be recorded on the laboratory data sheet.

1. Too many colonies—Filters that show a growth over the entire surface of the filter with no individually identifiable colonies should be recorded as "confluent growth." Filters that show a very high number of colonies (greater than 200) should be recorded as TNTC (too numerous to count).
2. Not enough colonies—If no single filter meets the desired minimum colony count (20 colonies), the sum of the individual filter counts and the respective sample volumes can be used in the formula to calculate the colonies/100 ml.

Membrane Filtration Technique: *Can be useful for determining the fecal coliform density in wastewater effluents, except for primary treated wastewater that have not been chlorinated or wastewater containing toxic metals or phenols. Chlorinated secondary or tertiary effluents may be tested using this method, but results are subject to verification by MPN technique.*

The membrane filter technique utilizes a specially designed filter pad with uniformly sized pores (openings) that are small enough to prevent bacteria from entering the filter. Another unique characteristic of the filter allows liquids, such as the media, placed under the filter to pass upward through the filter to provide nourishment required for bacterial growth.

Note: In the membrane filter method, the number of colonies grown estimates the number of coliforms.

Meniscus: The curved top of a column of liquid in a small tube.

Mercury (Hg): Heavy metal that can accumulate in the environment and is highly toxic if breathed or swallow.

Mesosphere: An atmospheric layer that extends from the top of the stratosphere to about 56 miles above the earth.

Metabolic Acidosis: Accumulation of acid in the blood and tissues.

Metabolic Heat: Produced within a body as a result of activity that burns energy. All humans produce metabolic heat. A room that is comfortable when occupied by just a few people may become uncomfortable when it is crowded, because of metabolic heat, unless the thermostat is lowered to compensate.

Metabolic Transformation: Refers to the assembly-line like activities that occur in microorganisms during the processing of raw materials into finished products.

Metabolism: Relative to toxicology, the basic function of metabolism is to increase the rate of elimination of foreign chemicals (i.e., xenobiotics). The same factors that allow xenobiotics to be absorbed (e.g., fat-soluble) also greatly reduce their elimination from the body. As a result, we would quickly be overwhelmed by absorbed xenobiotics without a mechanism for modifying their solubility. Metabolism involves a process of biotransformation in which the chemical structure of the xenobiotic is changed. This change increases the water solubility of the chemical, which reduces the ability of the chemical to be stored in the fat, increases its rate of filtration by the kidneys, and thereby greatly increases the rate of elimination for the chemical. This function keeps us from being overwhelmed by exposure to unwanted chemicals.

Metabolism requires the use of enzymes. These enzymes are present in the cells of many organs and tissues. The liver contains the highest concentration of these enzymes, which is consistent with its primary function as the hazardous waste site of the body. In addition, these enzymes occur at the main locations of possible chemical exposure, namely the lungs, GIT, skin, and eyes. Metabolizing enzymes are also present in the kidneys, many endocrine glands (e.g., adrenals), brain, and red blood cells. In addition, bacteria in our GIT also contain metabolizing enzymes that metabolize some chemicals before they are even absorbed. Some of these bacteria are able to metabolize things we otherwise cannot, which stresses the importance of maintaining these bacteria in our GIT.

These enzymes assist in two major types of metabolic reactions of foreign chemicals. The first type, known as Phase I biotransformation, involves only the enzyme and the foreign chemical, and slightly increases the water solubility of that chemical. The second type, known as Phase II biotransformation, requires another chemical known as a cofactor; the increase in the water solubility of the chemical caused by these reactions leads to a much higher rate of elimination.

The need for a cofactor makes a Phase II reaction more likely to be affected by saturation than Phase I reactions. In the saturation process, more chemical reaches a cell than the metabolic processes can control. In this case, the chemical builds up in excess and can cause toxic effects.

Often, the amount of a cofactor present limits the rate at which these reactions can occur. One cofactor is s-adenosylmethionine (SAM), which detoxifies arsenic. This metabolism can be saturated if the amount of arsenic present is greater than the available SAM.

There are several dozen different types of enzymes that metabolize specific types of chemicals. For example, alcohol dehydrogenase is an enzyme that specifically metabolizes alcohol, and acetylcholinesterase is an enzyme that specifically metabolizes one of our neurotransmitters and is affected by organophosphorus insecticides.

One specific kind of Phase I enzyme deserves mention because of its widespread use in research, as well as the valuable information we have obtained regarding metabolism of chemicals through this research. This type of enzyme is known as cytochrome P450, or the mixed function oxidases (MFO). This type of enzyme ranks first in terms of the number and types of chemicals it can metabolize and detoxify. The highest concentration of these enzymes is found in the liver. By experimentation, we have found which chemicals stimulate and which chemicals inhibit specific enzymes within this group. This knowledge has led to increased understanding of how many toxic chemicals exert their effects, and to our growing ability to design chemicals to counteract these effects.

Usually the change to increase water solubility decreases or eliminates the toxicity of a chemical. However, occasionally a Phase I reaction will make a chemical more toxic by exposing a particular part of the chemical to a target. For example, benzo (a) pyrene is a PAH that is a probable human carcinogen. This chemical undergoes a Phase I reaction that leaves an active oxygen radical exposed to DNA. This active radical binds with DNA and causes a mutation. In the absence of this metabolism, this chemical is not toxic.

The metabolism of xenobiotics is extremely complex and occurs in diverse ways.

Metabolites: Ay substances produced by biological processes, such as those from pesticides.

Metals: Elements that tend to lose their valence electrons.

Metamorphic: A type of rock that forms when rocks lying deep below the earth's surface are heated to such a degree that their original crystal structure is lost. As the rock cools, a new crystalline structure is formed.

Meteorology: The study of atmospheric phenomena.

Meter: The standard of length in the metric system, equal to 39.37 inches or 3.28 feet.

Methane ($CH4$): The simplest hydrocarbon of the paraffin series. Colorless, odorless, and lighter than air, it burns with a bluish flame and explodes when mixed with air or oxygen. Methane is a greenhouse gas.

Methane Explosion: Sudden explosions of methane gas occur frequently near the edges of active lava flows. Methane gas is generated when vegetation is covered and heated by molten lava. The explosive gas travels beneath the ground through cracks and fills abandoned lava tubes for long distances around the margins of the flow. Methane gas explosions have occurred at least 100 m from the leading edge of a flow, blasting rocks and debris in all directs.

Methanol: Also know as methyl alcohol or wood alcohol, having the chemical formula CH_3OH. Methanol is usually produced by chemical conversion at high temperature and pressure. Although usually produced from natural gas, methanol can be produced from gasified biomass.

Methemoglobin: An abnormal form of hemoglobin which will not carry oxygen in the blood.

Methemoglobinemia: Excessive accumulation of an inactive form of hemoglobin in the blood.

Method 18: An EPA test method which uses gas chromatographic techniques to measure the concentration of volatile organic compounds in a gas stream.

Method 24: An EPA reference method to determine density, water content and total volatile content (water and VOC) of coatings.

Method 25: An EPA reference method to determine the VOC concentration in a gas stream.

Methoxychlor: Pesticide that causes adverse health effects in domestic water supplies and is toxic to freshwater and marine aquatic life.

Methyl Orange Alkalinity: A measure of the total alkalinity in a water sample in which the color of methyl orange reflects the change in level.

Microbial Community: The community of microbes available to biodegrade contaminants in the soil.

Microbial Degradation: The natural process whereby certain microbes in soil can degrade contaminants into harmless constituents.

Microbial Growth: The amplification or multiplication of microorganism such as bacteria, algae, diatoms, plankton, and fungi.

Microbial Pesticide: A microorganism that is used to kill a pest, but is of minimum toxicity to humans.

Microbiology: The study of organisms that can only be seen under the microscope.

Microclimate: Climate as experienced at the scale of particular site. Include such elements as solar orientation, wind direction, temperature, and precipitation.

Microenvironmental Method: A method of sequentially assessing exposure for a series of microenvironments that can be approximated by constant concentration of a stressor.

Microenvironments: Well-defined surrounds such as the home, office, or kitchen that can be treated as uniform in terms of stressor concentration.

Micronutrient: Chemical element required, in relatively small amounts, for proper plant growth.

Micro-Seismicity: Small movements of the earth causing fracturing and movement of rocks. Such seismic activity does not release sufficient energy for the events to be recognized except with sensitive instrumentation.

Micturition: Urination.

Middens: Primitive dunghills or refuse heaps.

Midnight Dumping: The illegal dumping of solid or hazardous wastes into the environment.

Migration: Moving from one location to another.

Milkhouse Waste: Wastewater from milkhouse operations.

Millidarcy: The customary unit of measurement of fluid permeability; equivalent to 0.001 Darcy.

Milligram (mg): One-thousandth of a gram.

Milligram per Liter (mg/L): A unit of the concentration of a constituent in water or wastewater. It represents 0.001 gram of a constituent in 1 liter of water. It is approximately equal to one part per million (PPM).

Milling of Uranium: The processing of uranium from ore mined by conventional methods, such as underground or open-pit, to separate the uranium from the undesired material in the ore.

Million Gallons per Day (Mgd): A rate of flow of water equal to 133,680.56 cubic feet per day, or 1.5472 cubic feet per second, or 3.0689 acre-feet per day. A flow of one million gallons per day for one year equals 1,120 acre-feet (365 million gallons).

Mined-Through Studies: Mined-through studies are projects in which coalbeds have been actually mined through (i.e., the coal has been removed) so that remaining coal and surrounding rock can be inspected, after the coalbeds have been hydraulically fracture. These studies provide unique subsurface access to investigate coalbeds and surround rock after hydraulic fracturing.

Mineralization: Microbial conversion of an element from an organic to an inorganic state.

Mini-Frac: A small fracturing treatment performed before the main hydraulic fracturing treatment to acquire stress data and to test pre-simulation permeability.

Minimal Risk Level (MRL): An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse health effects.

Minimization: A comprehensive program to minimize or eliminate wastes; usually applied to wastes at their point of origin.

Minimum Transport Velocity (MTV): The minimum velocity that will transport particles in a duct with little settling; MTV varies with air density, particulate loading, and other factors.

Mining of an Aquifer: Withdrawal over a period of time of ground water that exceeds that rate of recharge of the aquifer.

Mining Waste: The earth and rock (including minerals and/or chemicals within) from a mine, discarded because the mineral or fuel content is too low to warrant extraction. This waste is an environmental problem if toxic substances leach from it into a river, stream, groundwater, or the soil.

Mining Water Use: Water use during quarrying rocks and extracting minerals from the land.

Minor Source: New emissions sources or modifications to existing emissions sources that do not exceed NAAQS emission levels.

Miosis: Contracted or pinpoint pupils.

Miscellaneous ACM: Interior asbestos-containing building material or structural components, members or fixtures, such as floor and ceiling tiles; does not include surfacing materials or thermal system insulation.

Miscible Liquids: Two or more liquids that can be mixed and will remain mixed under normal conditions.

Missed Detection: The situation that occurs when a test indicates that a tank is "tight" when, in fact, it is leaking.

Mists: 1. A dispersion of liquid particulates. 2. Minute liquid droplets suspended in air.

Mitigation: Measures taken to reduce adverse impacts on the environment.

Mitochondria: A microscopic body found in the cells of almost all living organisms and containing enzymes responsible for the conversion of food to usable energy.

Mitosis: The process of cell division.

Mixed Funding: Settlements in which potentially responsible parties and EPA share the cost of a response action.

Mixed Glass: Recovered container glass not sorted into categories (e.g., color, grade).

Mixed Liquor: A mixture of activated sludge and water containing organic matter undergoing activated sludge treatment in an aeration tank.

Mixed Metals: Recovered metals not sorted into categories such as aluminum, tin, or steel cans or ferrous or non-ferrous metals.

Mixed Municipal Waste: Solid waste that has not been sorted into specific categories (such as plastic glass, yard trimmings, etc.).

Mixed Paper: Recovered paper not sorted into categories such as old magazines, old newspapers, old corrugated boxes, etc.

Mixed Plastic: Recovered plastic unsorted by category.

Mixed Waste: Radioactive waste that is also a hazardous waste under RCRA. Such wastes are jointly regulated by RCRA and Atomic Energy Act.

Mixture: Two or more elements, compounds, or both, mixed together with no chemical reaction occurring.

Mobile Incinerator Systems: Hazardous waste incinerators that can be transported from one site to another.

Mobile Sources: Non-stationary sources of gaseous pollutants, including locomotives, automobiles, ships, and airplanes.

Mobilization: The mobilizing of metals in soil by the acidity of precipitation.

Model Plant: A hypothetical plant design used for developing economic, environmental, and energy impact analyses as support of regulations or regulatory guidelines, first step in exploring the economic impact of potential NSPS.

Modeling: Refers to the use of mathematical representations of contaminant dispersion and transformation to estimate ambient pollutant concentrations.

Modified Bin Method: Way of calculating the required heating or cooling for a building based on determining how much energy the system would use if outdoor temperatures were within a certain temperature interval and then multiplying the energy use by the time the temperature interval typically occurs.

Modified Source: The enlargement of a major stationary pollution source is often referred to as modification, implying that more emissions will occur.

Moduli: Plural of modulus (often referred to as bulk modulus), the ratio of stress to strain, abbreviated as “k”. The bulk modulus is an elastic constant equal to the applied stress divided by the ratio of the change in volume to the original volume of a body.

Modulus of Elasticity: The ratio of stress to strain, for stresses below the elastic limit. By checking the modulus of elasticity, the comparative stiffness of different materials can readily be ascertained. Rigidity and stiffness is very important for many machine and structural applications.

Moisture Content: 1. The amount of water lost from soil upon drying to a constant weight, expressed as the weight per unit of dry soil or as the volume of water per unit bulk volume of the soil. For a fully saturated medium, moisture content indicates the porosity. 2. Water equivalent of snow on the ground an indicator of snowmelt flood potential.

Molar Concentration (molarity): In chemistry, solution that contains one mole of a substance per liter of solvent.

Mold: The most typical forms of fungus found on the earth, comprising approximately 25 percent of the earth’s biomass (McNeel and Kreutzer 1996).

Mold in the Workplace: The earliest known writings that appear to discuss mold infestation and remediation (removal, cleaning up) are found in Leviticus 14: 33–57 of the Old Testament, a description of the process of removing mildew from houses. Where are molds typically found? Name the spot or place and molds have grown there: molds have been found growing in office buildings, schools, automobiles, in private homes, and other locations where water and organic matter are left unattended. Mold is not a new issue—just one that until recently received little attention by regulators in the United States. No state or federal statutes or regulations are on the books concerning molds and IAQ.

The key to limiting mold exposure is to prevent the germination and growth of mold. Building maintenance personnel, architects, and builders need to know effective means of preventing mold growth that might arise from maintenance and construction practices. Locating and cleaning existing growths are also paramount to decreasing the health effects of mold contamination. Using proper cleaning techniques is important because molds are incredibly resilient and adaptable (Davis 2001).

Molds can elicit a variety of health responses in humans. The extent to which an individual may be affected depends upon his or her state of health, susceptibility to disease, the organisms with which he or she came in contact, and the duration and severity of exposure (Ammann, 2000). Some people experience temporary effects that disappear when they vacate infested areas (Burge 1997). For others, the effects of exposure may be long-term or permanent (Yang 2001).

Note that systemic infections caused by molds are not common. Normal, healthy individuals can resist systemic infection from airborne molds.

Those at risk for system fungal infection are severely immunocompromised individuals such as those with HIV/AIDs, individuals who have had organ or bone marrow transplants, and persons undergoing chemotherapy.

In 1994, an outbreak of Stachybotrys chartarum in Cleveland, Ohio was believed by some to have caused pulmonary hemorrhage in infants. Sixteen of the infants died. The CDC sponsored a review of the cases and concluded that the scientific evidence provided did not warrant the conclusion that inhaled mold was the cause of the illnesses in the infants. However, the panel also stated that further research was warranted, as the study design for the original research appeared to be flawed (CDC 1999).

Below is a list of mold components known to elicit a response in humans.

- Volatile Organic Compounds (VOCs): "Molds produce a large number of volatile organic compounds. These chemicals are responsible for the musty odors produced by growing molds" (McNeel and Kreutzer 1996). VOCs also provide the odor in cheeses, and the "off" taste of mold infested foods. Exposure to high levels of volatile organic compounds affect the CNS, producing such symptoms as headaches, attention deficit, inability to concentrate, and dizziness (Ammann 2000). According to McNeel, at present the specific contribution of mold volatile organic compounds in building-related health problems has not been studied. Mold volatile organic compounds are probably responsible for only a small fraction of total VOCs indoors (Davis 2001).
- Allergens: all molds, because of the presence of allergens on spores, have the potential to cause an allergic reaction in susceptible humans (Rose 1999). Allergic reactions are believed to be the most common exposure reaction to molds. These reactions can range from mild transitory responses, like runny eyes, runny nose, throat irritation, coughing and sneezing; to severe, chronic illnesses such as sinusitis and asthma (Ammann 2000).
- Mycotoxins: natural organic compounds capable of initiating a toxic response in vertebrates (McNeel and Kreutzer 1996). Some molds are capable of producing mycotoxins. Molds known to potentially produce mycotoxins that have been isolated in infestations causing adverse health effects include certain species of acremonium, alternaria, aspergillus, chaetomium, caldosporium, fusarium, paecilomyces, penicillium, stachybotrys, and trichoderma (Yang 2001).

While a certain type of mold or mold strain type may have the genetic potential for producing mycotoxins; researchers believe that specific environmental conditions are needed for the mycotoxins to be produced. In other words, although a given mold might have the potential to produce mycotoxins, it will not produce them if the appropriate environmental conditions are not present (USEPA 2001).

Currently, the specific conditions that cause mycotoxin production are not fully understood. The USEPA recognizes that mycotoxins have a tendency to concentrate in fungal spores and that limited information is currently available regarding the process involved in fungal spore release. As a result, the USEPA is currently conducting research in an effort to determine "the environmental conditions required for sporulation, emission, aerosolization, dissemination and transport of [Stachybotrys] into the air" (USEPA 2001).

Mold Prevention: OSHA's "A Brief Guide to Mold in the Workplace" states that controlling moisture control is the key to preventing mold problems. The bulletin lists the following mold prevention tips:

- Repairing plumbing leaks and leaks in the building structure as soon as possible.
- Looking for condensation and wet spots. Fix source(s) of moisture incursion problem(s) as soon as possible.
- Preventing moisture from condensing by increasing surface temperature or reducing the moisture level in the air (humidity). To increase surface temperature, insulate or increase air circulation. To reduce the moisture level in the air, repair leaks, increase ventilation (if outside air is cold and dry), or dehumidify (if outdoor air is warm and humid).
- Keeping HVAC drip pans clean, flowing properly, and unobstructed.
- Performing regularly scheduled building/ HVAC inspections and maintenance, including filter changes.
- Maintaining indoor relative humidity below 70 percent (25–60 percent, if possible).
- Venting moisture-generating appliances, such as dryers, to the outside where possible.
- Venting kitchens (cooking areas) and bathrooms according to local code requirements.
- Cleaning and drying wet or damp spots as soon as possible, but no more than 48 hours after discovery.
- Providing adequate drainage around buildings and sloping the ground away from building foundations. Follow all local building codes.
- Pinpointing areas where leaks have occurred, identifying the causes, and taking preventive action to ensure that they do not reoccur. (OSHA SHIB 03-10-10)

Mold Remediation: In October of 2003, OSHA's Safety and Health Information Bulletin: A Brief Guide to Mold in the Workplace (OSHA SHIB 03-10-10) provides some succinct information and guidance on mold problem recognition, identification, health hazards, remediation (including methods, guidelines, PPE, sampling, and remediation equipment), and prevention. OSHA's information, however, is still only a short bulletin. At the present time, no full-scale standardized recommendations for mold remediation are available; however, USEPA is working on guidelines. Many practitioners in the field agree upon certain aspects of mold cleanup. Their recommendations include:

- A commonsense approach should be taken when assessing mold growth. For example, generally, small amounts of growth, like those commonly found on shower walls pose no immediate health risk to most individuals.
- Persons with respiratory problems, a compromised immune system, or fragile health should not participate in cleanup operations.

- Cleanup crews should be properly attired. Mold should not be allowed to touch bare skin. Eyes and lungs should be protected from aerosol exposure.
- Adequate ventilation should be provided while, at the same time, containing the infestation in an effort to avoid spreading mold to other areas.
- The source of moisture must be stopped and all areas infested with mold thoroughly cleaned. If thorough cleaning is not possible because of the nature of the material (porous versus semi- and non-porous), all contaminated areas should be removed.

How do you know that your remediation efforts are complete? OSHA gives the following suggestions:

- You must have identified and completely corrected the source of the water or moisture problem.
- Mold removal should be complete. Visible mold, mold-damaged materials, and moldy odors should no longer be present.
- Sampling, if conducted, should show that the level and types of mold and mold spores inside the building are similar to those found outside.
- Revisits to the site(s) after remediation should show no signs of moldy or musty odors, water damage, or mold growth. (OSHA SHIB 03-10-10)

Mole: SI unit (symbol mol) of the amount of a substance. The amount of a substance that contains as many elementary entities as there are atoms in 12 g of the isotope carbon-12.

Molecular Diffusion: Dispersion of a chemical caused by the kinetic activity of the ionic or molecular constituents.

Molecular Weight: The weight of one molecule of a substance relative to ^{12}C, expressed in grams.

Molecule: The fundamental particle that characterizes a compound. It consists of a group of atoms held together by chemical bonds.

Monitor: A self-supporting firefighting nozzle which can function unattended and delivers a large volume of fire-suppressant material.

Monitoring: Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

Monitoring Wells: Installed wells specifically designed to provide a means to monitor a contaminant plume in soil/groundwater.

Monoclonal Antibodies (MABs and MCAs): 1. Man-made (anthropogenic) clones of a molecule, produced in quantity for medical or research purposes. 2. Molecules of living organisms that selectively find and attach to other molecules to which their structure conforms exactly. This could also apply to equivalent activity by chemical molecules.

Monoculture: A large number of users who run the same software, and are thus vulnerable to the same attacks.

Montreal Protocol: Treaty, signed in 1987, governs stratospheric ozone protection and research, and the production and use of ozone-depleting substances. It provides for the end of production of ozone-depleting substance such as CFCS. Under the Protocol, various research groups continue to assess the ozone layer. The Multilateral Fund provides resources to developing nations to promote the transition to ozone-safe technologies. Requires signatory countries to reduce their consumption of CFCs by 20 percent by 1993, and by 50 percent by 1998.

Moratorium: During the negotiation process, a period of sixty to ninety days during which EPA and potentially responsible parties may reach settlement but no site response activities can be conducted.

Morbidity: Rate of disease incidence.

Morphogenesis: Evolutionary development of the structure of an organism or part.

Morphology, Soil: Constitution of the soil including the texture, structure, consistence, color, and other physical, chemical, and biological properties of the various soil horizons that make up the soil profile.

Mortality: Death rate.

Most Probable Number: An estimate of microbial density per unit volume of water sample, based on probability theory.

Motility: An organism's mobility; ability to move.

Motor Controllers and Motor Control Centers: Provides the means for controlling the starting, stopping, reversing, speed, etc., of electric motors.

Motor Dysfunction: Difficulty moving.

Mottling: Spots or blotches of different colors or shades of color interspersed with the dominant soil color caused in part by exposure to alternating unsaturated and saturated conditions.

MS: Mass spectrometer.

MSW (Municipal Solid Waste): Residential solid waste and some nonhazardous commercial, institutional, and industrial wastes.

MTBE: Methyl tertiary butyl ether is a fuel oxygenate produced by reacting methanol with isobutylene.

Mucosa: The lining of certain body passages, such as the gastrointestinal tract or the airways.

Muck Soils: Earth made from decaying plant materials.

Mudballs: Round material that forms in filters and gradually increases in size when not removed by backwashing.

Mulch: A layer of material (wood chips, straw, leaves, etc.) placed around plants to hold moisture, prevent weed growth, and enrich or sterilize the soil.

Multi-Media Approach: Joint approach to several environmental media, such as air, water, and land.

Multiple Chemical Sensitivity: A diagnostic label for people who suffer multi-system illnesses as a result of contact with, or proximity to, a variety of airborne agents and other substances.

Multiple Use: Use of land for more than one purpose: e.g., grazing of livestock, watershed and wildlife protection, recreation, and timber production. Also applies to use of bodes of water for recreational purposes, fishing, and water supply.

Multiplier Effect: The multiplier effect is sometimes called the ripple effect because a single expenditure in an economy can have repercussions throughout the entire economy. The multiplier is a measure of how much additional economic activity is generated from an initial expenditure.

Multistage Remote Sensing: A strategy for landscape characterization that involves gathering and analyzing information at several geographic scales, ranging from generalized levels of detail at the national level through high levels of detail at the local scale.

Municipal Discharge: Discharge of effluent from wastewater treatment plants which receive wastewater from households, commercial establishments, and industries in the coastal drainage basin. Combined sewer/separate storm overflows are included in this category.

Municipal Services Sources of MSW: Wastes generated in restaurants, hotels, stores, motels, service stations, repair shops, markets, office buildings, and print shops.

Municipal Sewage: Wastes (mostly liquid) originating from a community, may be composed of domestic wastewaters and/or industrial discharges.

Municipal Sludge: Semi-liquid residue remaining from the treatment of municipal water and wastewater.

Municipal Solid Wastes (MSW): Municipally derived wastes, including paper, yard wastes, glass and metals, and plastics.

Municipal Water System: A water system that has at least five service connections or which regularly serves twenty-five individuals for sixty days; also called a public water system.

Mutagen/Mutagenicity: An agent that causes a permanent genetic change in a cell other than that which occurs during normal growth. Mutagenicity is the capacity of a chemical or physical agent to cause such permanent changes.

Mutation: Any alteration in a gene from its natural state. This change may be disease causing for a benign, normal variant. Specific mutations and evolution in influenza viruses cannot be predicted, making It difficult if not impossible to know if or when a viruses such as H5N1 might acquire the properties needed to spread easily among humans.

Mycelium: An interwoven mass of threadlike filaments or hyphae forming the main body of most fungi. The reproductive structures, or ‘fruiting bodies’, grown from the mycelium.

Mycology: The branch of botany that deals with fungi.

Mycotoxins: Some molds are able to produce *mycotoxins,* natural organic compounds that are capable of initiating a toxic response in vertebrates (McNeel and Kreutzer 1996).

Myocardial: Pertaining to the muscular tissue of the heart.

Myocardial Failure: Heart failure.

N

NA Identification Number: An acronym for North America. A four-digit number assigned to some chemicals found in transport in North America.

N.O.S.: Not otherwise specified, e.g., where the name of a specific chemical is not listed in the applicable regulations, a generic name such as "Corrosive liquid, n.o.s." is used on shipping papers.

N_2: Dinitrogen molecule.

N: Nitrogen.

Narcotic: A drug (as opium) that in moderate does dulls the senses relieves pain and induces profound sleep, but in excessive does causes stupor, coma, or convulsions.

National Ambient Air Quality Standards (NAAQS): 1. List of maximum concentrations, or pollutant thresholds, above which human exposure may result in adverse health effects. Serves as an administrative benchmark for clean air. 2. Established by the EPA at two levels: Primary and Secondary. Primary standards must be set at levels that will protect public health and include an "adequate margin of safety," regardless of whether the standards are economically or technologically achievable. Primary standards must protect even the most sensitive individuals, including the elderly and those with respiratory ailments. Secondary air quality standard are meant to be even more stringent than primary standards. Secondary standards are established to protect public welfare (for example, structures, crops, animal, fabrics).

National Emissions Standards for Hazardous Air Pollutants (NESHAPS): Emissions standards set by EPA for an air pollutant not covered by NAAQS that may cause an increase in fatalities or in serious, irreversible, or incapacitating illness. Primary standards are designed to protect human health, secondary standards to protect public welfare (e.g., building facades, visibility, crops, and domestic animals).

National Environmental Performance Partnership Agreements: System that allows states to assume grater responsibility for environmental programs based on their relative ability to execute them.

National Estuary Program: A program established under the Clean Water Act Amendments of 1987 to develop and implement conservation and management plans for protecting estuaries and restoring and maintaining their chemical, physical, and biological integrity, as well as controlling point and nonpoint pollution sources.

National Institute of Standards and Technology (NIST): A unit of the US Commerce Department that promotes and maintains measurement standards. It has active programs for encouraging and assisting industry and science to develop and use these standards.

National Municipal Plan: A policy created in 1984 by EPA and the states in 1984 to bring all publicly owned treatment works (POTWs) into compliance with Clean Water Act requirements.

National Oil and Hazardous Substances Contingency Plan (NOHSCP/NCP): The federal regulation that guides determination of the sites to be corrected under both the Superfund program and the program to prevent or control spills into surface waters or elsewhere.

National Pollutant Discharge Elimination System (NPDES): A provision of the Clean Water Act (CWA) which prohibits discharge of pollutants into waters of the United States unless a special permit is issued by the EPA, a state, or, where delegated, a tribal government on an Indian reservation.

National Priorities List (NPL): The NPL identifies the worst waste sites in the nation based on such factors as the quantities and toxicity of wastes involved, the exposure pathways, the number of people potentially exposed, and the importance and vulnerability of the underlying groundwater.

National Response Center: The federal operations center that receives notifications of all releases of oil and hazardous substances into the environment; open twenty-four hours a day, is operated by the U.S. Coast Guard, which evaluates all reports and notifies the appropriate agency.

National Response Team (NRT): Representatives of thirteen federal agencies that, as a team, coordinate federal response to nationally significant incidents of pollution—an oil spill, a major chemical release, or a superfund respond action—and provide advice and technical assistance to the responding agency(ies) before and during a response action.

National Secondary Drinking Water Regulations: Commonly referred to as NSDWRs.

National Toxicology Program (NTP): Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

National Uranium Resource Evaluation (NURE): A program begun by the U.S. Atomic Energy Commission (AEC) in 1974 to make a comprehensive evaluation of U.S. uranium resources and continued through 1983 by the AEC's successor agencies, the Energy Research and Development Administration (ERDA) and the Department of Energy (DOE). The NURE program included aerial radiometric and magnetic surveys, hydrogeochemical and stream boreholes, and geologic studies to identify and evaluate geologic environments favorable for uranium.

Natural Disaster: Any "act of God" (e.g., fire, flood, earthquake, lightning, or wind) that disables a system component.

Natural Gas: A gas composed of a mixture of hydrocarbon molecules that have one, two, three and four carbon atoms.

Natural Pollutants: When the term "pollutant" is mentioned, certain common images often form in people's minds, dependent upon their experiences. For example, to some the image of a pollutant could be a spilled organic chemical (oil, PCBs, many pesticides), an inorganic chemical (salt, nitrate, metals), an acid (sulfuric acid, nitric acid, hydrochloric acid), a physical pollutant (soil and/or trash), radiological pollutants (radon, radium, and uranium), or biological pollutants (pathogenic microorganisms).

Differentiating pollutants from one another on the basis of whether a particular pollutant is *organic* or *inorganic* is somewhat difficult. The term *organic* is commonly used to refer to what is natural by individuals outside scientific circles—"organic" produce, for example, is produce grown without artificial fertilizers or pesticides. When we state that a chemical is organic, however, what we are really saying is that it contains at least one carbon atom (though typically more). The term "natural" comes into play when speaking about organic chemicals simply because organic chemicals are synthesized "naturally" by animals, microorganisms, and plants.

Inorganic chemicals differ from organic simply because inorganic chemicals do not contain carbon. A common example of inorganic pollutants are the synthetic plant nutrients found in fertilizers. The best known acid pollutants are nitric acid and sulfuric acid (acids commonly found in acid rain). *Physical* pollutants consist primarily of solid materials found in inappropriate locations. Trash sitting in a vacant lot is an example of a physical pollutant. Soil carried in stormwater runoff from city streets, tarmac, construction sites, from agricultural fields is another example. Another physical pollutant (one not commonly recognized) comes from thermal sources such as high-temperature water released from industrial plants.

Radioactive chemicals found naturally in rocks, water, and soil are radioactive pollutants. Two of the better known radioactive elements are radon (a radioactive gas) and radium, both of which occur in nature. Man-generated (anthropogenic) sources of radioactive pollutants are certain hazardous waste sites (radioactive waste storage sites, for example).

Biological pollutants consist of pathogenic microorganisms (viruses, protozoa, fungi, worms and infectious bacteria). Soil, water, and air (the focus of this text) usually contain microorganisms, some of which can be pathogenic (disease-causing). Microorganisms do not have to be alive to become biological pollutants. Dead microorganisms and parts of organisms (e.g., insects) can also pollute air, water, and to a lesser extent, soil.

What does all of this have to do with natural pollutants? Organic pollutants and radioactive pollutants, for example, are natural pollutants. Other common natural pollutants may not be obvious (ones we do not often think about) so we should talk about a few of these before we present a proper, balanced explanation or judgment of what pollution is, and more specifically what a pollutant is, and what the sources of pollutants are.

In light of this, consider the following three natural pollutants: natural human waste products and waste products produced by other living organisms; the fallen leaf that pollutes; and a metal-laden rock (part of the earth's crust) that pollutes.

First, humans and other living organisms naturally produce wastes, some of which can be categorized as pollutants. For now, let's focus on human waste products. Humans produce waste products each and every time they breathe. Each breath of air taken into the human respiratory system while it performs its vital function, is chemically changed somewhat and eventually exhaled into the environment. That exhaled air may be considered a non-pollutant type waste product. On almost a continuous basis, human beings slough off dead skin cells and hair follicles which are another type of non-pollutant waste (though if someone else's shed hair touches your clothes or skin, you may have a different view—you may feel that you have been contaminated [polluted]). Human-produced natural pollution has another manifestation, one that we are all familiar with—the production of human feces, a waste product. Human waste is a pollutant in many cases, of course, because of the presence of pathogenic microorganisms such as *Escherichia coli (E. coli)* and others that can contaminate our water supply, our drinking water. As a matter of fact, the major source of pathogenic bacteria is from human feces, which makes up approximately 34 percent of feces.

Next, let's shift our focus to leaf pollution.

Do we mean that pile of leaves covering the lawn in front of the house? That same blanket of dead leaves that is such a pain in the neck to rake up and dispose? Or those leaves that fall on top of the car or boat, or that clutter gutters, or make their way into the internal works of outdoor air conditioning units and eventually cause them to fail? No. Not exactly. Remember, pollution and/or pollutants are a matter of judgment. The situations just described probably qualify more as nuisance items than pollutants to most people.

The type of pollution caused by fallen leaves is water pollution—stream pollution in particular.

Consider a local stream you are familiar with, one that courses through a local forested area. During spring and summer, when you walk along the stream bank surrounded by trees of myriad types with their corresponding plethora of leaves, you probably have no difficulty in recognizing Nature's architectural genius in designing them—but you might have difficulty in comprehending how those leaves—the palmately compound leaf of the buckeye; the pinnately compound leaf of the black walnut; the lobed leaves of a tulip poplar; the simple leaves of the dogwood; the palmately veined leaves of the maple; the globe-shaped succulent leaves of the string-of-pearls; the lobed leaves of oak trees—could possibly pollute the stream. But they can and they do.

Obviously, while the leaves remain on the trees, they present little if any pollution affect on the stream. However, during leaf-fall in autumn, the dead, fallen leaves pollute the stream. Leaves are organic and biodegradable. When they fall from the tree and into the stream and remain in the stream during the degradation process, they remove dissolved oxygen (DO) by increasing biochemical oxygen demand (BOD). BOD is a widely used parameter of organic pollution applied to both wastewater and surface water involving the measurement of the DO used by microorganisms in the biochemical oxidation of organic matter. Simply put, when microorganisms work to degrade the leaves in the stream, they create biochemical oxygen demand which in turn reduces the DO content of the stream water. If the DO level falls from its normal healthy level of approximately 8 ppm (ppm or parts per million is analogous to the amount of water in a full shot glass of water compared to the water in a full swimming pool) to levels as low as 2 ppm or lower (unhealthy level). At a DO level of 2 ppm or lower, the stream is considered polluted: it is unable to provide enough DO to support higher aquatic life forms.

Along with reducing dissolved oxygen content, and in turn making a water body polluted, organic debris such as tree bark, branches and trees can pollute streams and other water bodies in other ways. Consider, for example, an account as told by Charles R. Swindoll about U.S. Senate chaplain Peter Marshall's eloquent account of the "Keeper of the Spring," a quiet forest dweller who lived high above an Austrian village along the eastern slope of the Alps.

Keeper of the Spring

The old gentleman had been hired many years earlier by a young town councilman to clear away the debris from the pools of water up in the mountain crevices that fed the lovely spring flowing through their town. With faithful, silent regularity, he patrolled the hills, removed the leaves and branches, and wiped away the silt that would otherwise have choked and contaminated the fresh flow of water. The village soon became a popular attraction for vacationers. Graceful swans floated along the crystal clear spring, the mill wheels of various businesses located near the water turned day and night, farmlands were naturally irrigated, and the view from restaurants was picturesque beyond description.

Years passed. One evening the town council met for its semiannual meeting. As they reviewed the budget, on man's eye caught the salary figure being paid the obscure keep of the spring. Said the keeper of the purse, "who is the old man? Why do we keep him on year after year? No one ever sees him. For all we know, the strange ranger *of the hills is doing us no good. He isn't necessary any longer." By a unanimous vote, they dispensed with the old man's services.*

For several weeks, nothing changed.

By early autumn, the trees began to shed their leaves. Small branches snapped off and fell into the pools, hindering the rushing flow of sparkling water. One afternoon someone noticed a slight yellowish-brown tint in the spring. A few days later, the water was much darker. Within another week, a slimy film covered sections of the water along the banks, and a foul odor was soon detected. The mill wheels moved more slowly, some finally ground to a halt. Swans left, as did the tourists. Clammy fingers of disease and sickness reached deeply into the village.

Quickly, the embarrassed council called a special meeting. Realizing their gross error in judgment, they rehired the old keeper of the spring, and within a few weeks, the veritable river of life began to clear up. The wheels started to turn, and new life returned to the mallet in the Alps.

It is important to point out that while the presence of organic debris in streams can be detrimental to the health of the stream, the stream's acquisition of organic is a double-edged sword; a Jekyll and Hyde situation. This situation is clearly demonstrated in Case Study 4.2, which points to the good aspects of leaf-fall into streams.

Leaves in the Stream

Autumn leaves entering streams are nutrition-poor because trees absorb most of the sugars and amino acids (nutrients) that were present in the green leaves (Suberkropp et al. 1978). Leaves falling into streams may be transported short distances but usually are caught by structures in the streambed to form leaf packs. These leaf packs are then processed in place by components of the stream communities in a series of well documented steps. Within twenty-four to forty-eight hours of entering a stream many of the remaining nutrients in leaves leach into the water. After leaching, leaves are composed mostly of structural materials like non-digestible cellulose and lignin. Within a few days, fungi (especially Hyphomycetes), protozoa, and bacteria process the leaves by microbial processing (Barlocher and Kendrick 1975). Two weeks later, microbial conditioning leads to structural softening of the leaf and, among some species, fragmentation. Reduction in particle size from whole leaves (coarse particulate organic matter, CPOM) to fine particulate organic matter (FPOM) is accomplished mainly through the feeding activities of a variety of aquatic invertebrates collectively known as "shredders" (Cummins 1974). Shredders (stoneflies, for example) help to produce fragments shredded from leaves but not ingested and fecal pellets, which reduce the particle size of organic matter. The particles then are collected (by mayflies, for example) and serve as a food resource for a variety of micro- and macroconsumers. Collectors eat what they want and send even smaller fragments downstream. These tiny fragments may be filtered out of the water by a true fly larva (i.e., a filterer). Leaves may also be fragmented by a combination of microbial activity and physical factors such as current and abrasion (Benfield et al. 1977).

Leaf-pack processing by all the elements mentioned above (i.e., leaf species, microbial activity, physical and chemical features of the stream) is important. However, the most important point is that these integrated ecosystem processes convert whole leaves into fine particles which are then distributed downstream and used as an energy source by various consumers (Spellman 1996).

Lastly, metal- or mineral-laden soils or rocks (such as soils laden with mercury) are sources of pollution. Mercury-laden soils degas volatile mercury to the atmosphere, and emit that mercury into the atmosphere, where it is eventually washed out into water bodies. While in water, bacteria work to transform a portion to methyl mercury, which is taken up by aquatic plants and certain aquatic animals. These are eaten by successively higher orders of animals on the food chain, where it builds up to progressively higher levels in animal tissues. More than 90 percent of human mercury exposure results from consumption of mercury-contaminated fish. Some might call this type of exposure event poisoning more than a polluting; however, clearly poisoning is a serious form of pollution. Minamata Bay in Tokyo, for example, is contaminated by mercury, which can lead to methyl mercury poisoning in humans.

Necrosis: Death of plant or animal cells or tissues. In plants, necrosis can discolor stems or leaves or kill a plant entirely.

Negotiations (Under Superfund): After potentially responsible parties are identified for a site. EPA coordinates with them to reach a settlement that will result in the PRP paying for or conducting the cleanup under EPA supervision. If negotiations fail, EPA can order the PRP to conduct the cleanup or EPA can pay for the cleanup using Superfund monies and then sue to recover the costs.

Nematocide: A chemical agent which is destructive to nematodes.

Neoplasm: Abnormal growth of tissue, such as cancer.

Neoprene: A synthetic rubber produced by polymerization of chloroprene and used in weather-resistant products adhesives, shoe soles, sportswear, paints, and rocket fuels.

Nephelometric Turbidity Unit (NTU): Unit of measure for the turbidity of water. Essentially, a measure of the cloudiness of water as measured by a nephelometer. Turbidity is based on the amount of light that is reflected off particles in water.

Nerve Agent: 1. An agent that interferes with the function of the central nervous system. Exposure is primarily through contact with the liquid (via skin and eyes) and secondarily through inhalation of the vapor. 2. An agent that causes severe irritation to the skin and mucous membranes, as well as pain; also called urticant.

Net Metering: Arrangement that permits a facility (using a meter that reads inflows and outflows of electricity) to sell any excess power it generates over its load requirement back to the electrical grid to offset consumption.

Net Photovoltaic Module Shipment: The difference between photovoltaic cell shipments and photovoltaic cell purchases.

Net Summer Capacity: The maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load, as demonstrated by a multi-hour test, at the time of summer peak demand. This output reflects a reduction in capacity due to electricity use for station service or auxiliaries.

Netting: A concept in which all emissions sources in the same area that owned or controlled by a single company are treated as one large source, thereby allowing flexibility in controlling individual source sin order to meet a single emission standard.

Network-Level Firewall: A firewall in which traffic is examined at the network protocol packet level.

Network Mapping: To compile an electronic inventory of the systems and the services on a network.

Network Taps: Hardware devices that hook directly onto the network cable and send a copy of the traffic that passes through it to one or more other networked devices.

Network Worm: A program or command file that uses a computer network as a means for adversely affecting a system's integrity, reliability or availability, A network worm may attack from one system to another by establishing a network connection. It is usually a self-contained program that does not need to attach itself to a host file to infiltrate network after network.

Networks and Stand-Alones: Networked computer systems offer so many benefits that most places are heading in that direction, if they aren't there already. These days, servers and a IT staff handle computer operations at many facilities, and while many facilities might have stand-alone computes dedicated to specific purposes, facilities with only stand-alone computers are rapidly becoming a thing of the past. The differences between stand-alone computers and a networked system make some aspects of data protection easier, and others harder.

Server systems allow IT staff to automatically and regularly back up all data, keep track of employee internet and email usage (in part to protect from data theft or loss) and to help diagnose problems. Servers also allow IT staff to monitor many types of employee computer activity. How far management goes in keeping tabs on worker computer use is up to individual facility policy, but networked systems provide the possibility. Setting up the capability for and gathering that information is possible on stand-alone computers, too, but is much more labor-intensive. Duplication of equipment is also an expensive factor for stand-alones.

One real advantage of stand-alones is that they are isolated if a computer virus strikes. Even if a viral infection occurs (from a modem or data transfer device), it is isolated and can be confined. Data exchange and back-up are much more time consuming, however. With a stand-alone system, choosing each workstation's peripherals in light of the other stand-alone workstations keeps data transfer and backup both possible and simple.

Neustons: In a water environment, the organisms living on the surface.

Neutralization: Decreasing the acidity or alkalinity of substance by adding alkaline or acidic materials, respectively.

Neutrally Stable Atmosphere: An intermediate class between stable and unstable conditions. Will cause a smokestack plume to cone in appearance as the edges of the plume spread out in a V-shape.

Neutron: Elementary particles that have approximately the same mass as protons but have no charge. They are one constituent of the atomic nucleus.

New Source: Any stationary source built or modified after publication of final or proposed regulations that prescribe a given standard of performance.

New Source Performance Standards (NSPS): Uniform national EPA air emission and water effluent standards which limit the amount of pollution allowed from new sources or from modified existing sources.

New Source Review (NSR): A Clean Air Act requirement that State Implementation Plans must include a permit review that applies to the construction and operation of new and modified stationary sources in nonattainment area to ensure attainment of national ambient air quality standards.

Newton's Laws of Motion: Isaac Newton in his Three Laws of Motion changed our understanding of the universe. Through careful observation and experimentation, Newton was able to describe the motion of objects by what are now called Newton's Laws of Motion. These laws include the *law of inertia* (Newton's first law of motion), the *law of constant acceleration* (Newton's second law of motion), and the *law of momentum* (Newton's third law of motion).

Newton's First Law
According to Newton's first law:

> An object at rest will remain at rest unless acted on by an unbalanced force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

Basically, this law expresses what we mean when we say that an object has inertia. *Inertia* is that property of matter which causes matter to resist change in motion—it is the natural tendency for objects to keep on doing what they're doing.

Note: Mass is a measure of how much inertia an object possesses.

Newton's Second Law
According to Newton's second law:

> Acceleration is produced when a force acts on a mass. The greater the mass (of the object being accelerated) the greater the amount of force needed (to accelerate the object).

Basically, we all know that heavier objects require more force to move the same distance as lighter objects. The Second Law does give us, however, an exact relationship between force, mass, and acceleration. It can be expressed as a mathematical equation:

$$F = MA$$

or

Force = Mass times Acceleration = Newtons (~1/4 pound)

Example
Problem:
A four-wheeled cart weights 1200 kg, it is at rest. A man tries to push the cart to a storeroom, and he makes the cart go 0.05 m/s/s. How much force is the man applying to the cart?

Solution:

$$\begin{aligned} F &= MA \\ F &= 1200 \times 0.05 \\ &= 60 \text{ newtons} \end{aligned}$$

Newton's Third Law
According to Newton's third law,

> For every action there is an equal and opposite reaction.

Basically, what this means is that whenever an object pushes another object it gets pushed back in the opposite direction equally hard.

NFPA: National Fire Protection Association.

NFPA 704: Standard system for the identification of the hazardous of materials for emergency response. A standard providing a readily recognize, easily understood system for identifying specific hazards and their severity using spatial, visual, and numerical methods to describe in simple terms the relative hazards of a material. It addresses the health, flammability, instability, and related hazards that may be presented as short-term, acute exposures that are most likely to occur as a result of fire, spill, or similar emergency.

NFPA 704 Flammability
The red (upper) quadrant of the NFPA 704 symbol. The values are:

4—Danger. Flammable gas or extremely flammable liquid.
3—Warning. Flammable liquid, flash point below 100ºF (38ºC).
2—Caution. Combustible liquid, flash point of 100º to 200ºF (38º to 93ºC).
1—Combustible if heated.
0—Not combustible.

NFPA 704 Health
The blue (left-hand) quadrant of the NFPA 704 symbol. The values are:

4—Danger. May be fatal on short exposure. Specialized protective equipment required.
3—Warning. Corrosive or toxic. Avoid skin contact or inhalation.
2—Warning. May be harmful if inhaled or absorbed.
1—Caution. May be irritating.
0—No unusual hazard.

NFPA 704 Reactivity

The yellow (right-hand) quadrant of the NFPA 704 symbol. The values are:

4—Danger. Explosive material at room temperature.
3—Danger. May be explosive if shocked, heated under confinement or mixed with water.
2—Warning. Unstable or may react violently if mixed with water.
1—Caution. May react if heated or mixed with water, but not violently.
0—Stable. Not reactive when mixed with water.

NFPA 704 Special

The white (lower) quadrant of the NFPA 704 symbol. The values are:
W—Water Reactive.
OX—Oxidizing Agent.

NH_3: Ammonia.

Niche: The functional role of an organism within its community—the complete ecological description of an individual species (including habitat, feeding requirements, etc.).

NIOSH: National Institute for Occupational Safety and Health.

Nitrates: In fresh water pollution, a plant nutrient, usually from fertilizer, that enters the water system and can be toxic to animals and humans in high enough concentrations. Nitrate is found in septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, sanitary landfills, and garbage dumps.

Nitrate Nitrogen: Nitrogen component of the final decomposition product of the organic nitrogen compounds; expressed in terms of the nitrogen par of the compound.

Nitric Oxide (NO): A gas formed by combustion under high temperature and high pressure in an internal combustion engine; it is converted by sunlight and photochemical processes in ambient air to nitrogen oxide. NO is a precursors of ground-level ozone pollution or smog.

Nitrification: The process whereby ammonia in wastewater is oxidized to nitrite and then to nitrate by bacteria or chemical reactions.

Nitriotracetic Acid (NTA): A compound now replacing phosphates in detergents.

Nitrite: 1. An intermediate in the process of nitrification. 2. Nitrous oxide salts used in food preservation.

Nitrogen: Chemical element, commonly used in fertilizer as a nutrient, which is also a component of animal wastes. As one of the major nutrients required for plant growth, nitrogen can promote algal blooms that cause water body eutrophication if it runs off or leaches out of the surface soil. Nitrogen is immediately usable for plant growth in available forms.

Nitrogen Cycle: Succession of biochemical reactions that nitrogen undergoes as it is converted to organic or available nitrogen from the elemental form. Organic nitrogen in waste is oxidized by bacteria into ammonia. If oxygen is present, ammonia is bacterially oxidized first into nitrite and then into nitrate. If oxygen is not present, nitrite and nitrate are bacterially reduced to nitrogen gas, completing the cycle.

Nitrogen Dioxide (NO_2): The result of nitric oxide combining with oxygen in the atmosphere; major component of photochemical smog.

Nitrogen Fixation: Biological process by which elemental nitrogen is converted to organic or available nitrogen.

Nitrogen Oxides (NO_x): There are six oxides of nitrogen: nitrous oxide (N_2O), nitric oxide (NO), dinitrogen trioxide (N_2O_3), nitrogen dioxide (NO_2), dinitrogen tetroxide (N_2O_4), and dinitrogen pentoxide (N_2O_5). Nitric oxide, nitrogen dioxide, and nitrogen tetroxide are fire gases. One or more of them is generated when certain nitrogenous organic compounds (polyurethane) burn. Nitric oxide is the product of incomplete combustion, whereas a mixture of nitrogen dioxide and nitrogen tetroxide is the product of complete combustion. The nitrogen oxides are usually collectively symbolized by the formula NO_x. USEPA, under the Clean Air Act (CAA), regulates the amount of nitrogen oxides that commercial and industrial facilities may emit to the atmosphere. The primary and secondary standards are the same: The annual concentration of nitrogen dioxide may not exceed 100 $\mu g/m^3$ (0.05 ppm). Nitric oxide and nitrogen dioxide rapidly interconverted in the atmosphere.

Nitrogenous Wastes: Animal or vegetable residues that contain significant amounts of nitrogen.

Nitrophenols: Synthetic organopesticides containing carbon, hydrogen, nitrogen, and oxygen.

Nm: Nanometer; 10^{-9}m.

NO: Nitric oxide.

No Apparent Public Heath Hazard: A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No Further Remedial Action Planned: Determination made by EPA following preliminary assessment that a site does not pose a significant risk and so requires no further activity under CERCLA.

No Observable Adverse Effect Level (NOAEL): An exposure level at which there are no statistically or biologically significant increase in the frequency or severity of adverse effects between the exposed population and its appropriate control; some effects may be produced at this level, but they are not considered as adverse, or as precursors to adverse effects. In an experiment with several NOAELS, the regulatory focus is primarily on the highest one, leading to the common usage of the term NOAEL, as the highest exposure without adverse effects.

No-Observed-Effect-Level (NOEL): Exposure level at which there are no statistically or biological significant differences in the frequency or severity of any effect in the exposed or control populations.

N_2O: Nitrous oxide.

Nocturnal Cooling: The effect of cooling by the radiation of heat from a building to the night sky.

Noise: 1. Product-level or product-volume changes occurring during a test that are not related to a leak but may be mistaken for one. 2. High noise levels in the workplace are a hazard to employees. High noise levels are a physical stress that may produce psychological effects by annoying, startling, or disrupting the worker's concentration, which can lead to accidents. High levels can also result in damage to worker's hearing, resulting in hearing loss. In this chapter, we discuss the basics of noise, including those elements the industrial hygienist needs to know to ensure that his/her organization's hearing conservation program is in compliance with OSHA.

Key Terms

There are many specialized terms used to express concepts in noise, noise control and hearing loss prevention. NIOSH (2005) definitions below were written in as non-technical a fashion as possible.

Acoustic Trauma—A single incident which produces an abrupt hearing loss. Welding sparks (to the eardrum), blows to the head, and blast noise are examples of events capable of providing acoustic trauma.

Action Level—The sound level which when reached or exceeded necessitates implementation of activities to reduce the risk of noise-induce hearing loss. OSHA currently uses an eight-hour time weighted average of 85 dBA as the criterion for implementing an effective hearing conservation program.

Attenuate—To reduce the amplitude of sound pressure (noise).

Attenuation—Real Ear Attenuation at Threshold (REAT)—A standardized procedure for conducting psychoacoustic tests on human subjects designed to measure sound protection features of hearing protective devices. Typically, these measures are obtained in a calibrated sound field, and represent the difference between subjects' hearing thresholds when wearing a hearing protector vs. not wearing the protector.

Attenuation Real-World—Estimated sound protection provided by hearing protective devices as worn in "real-world" environments.

Audible Range—The frequency range over which normal ears hear: approximately 20 Hz through 20,000 Hz.

Audiogram—A chart, graph, or table resulting from an audiometric test showing an individual's hearing threshold levels as a function of frequency.

Audiologist—A professional, specializing in the study and rehabilitation of hearing, who is certified by the American Speech-Language-Hearing Association or licensed by a state board of examiners.

Background Noise—Noise coming from sources other than the particular noise sources being monitored.

Baseline Audiogram—A valid audiogram against which subsequent audiograms are compared to determine if hearing thresholds have changed. The baseline audiogram is preceded by a quiet period so as to obtain the best estimate of the person's hearing at that time.

Continuous Noise—Noise of a constant level as measured over at least one second using the "slow" setting on a sound level meter. Note, that a noise which is intermittent, e.g., on for over a second and then off for a period would be both variable and continuous.

Controls—Administrative—Efforts, usually by management, to limit workers' noise exposure by modifying workers' schedule or location, or by modifying the operating schedule of noisy machinery.

Controls Engineering—Any use of engineering methods to reduce or control the sound level of a noise source by modifying or replacing equipment, making any physical changes at the noise source or along the transmission path (with the exception of hearing protectors).

Criterion Sound Level—A sound level of 90 decibels.

dB (Decibel)—The unit used to express the intensity of sound. The decibel was named after Alexander Graham

Bell. The decibel scale is a logarithmic scale in which 0 dB approximates the threshold of hearing in the mid frequencies for young adults and in which the threshold of discomfort is between 85 and 95 dB SPL and the threshold for pain is between 120 and 140 dB SPL.

Double Hearing Protection—A combination of both ear plug and earmuff type hearing protection devices is required for employees who have demonstrated Temporary Threshold Shift during audiometric examination and for those who have been advised to wear double protection by a medical doctor in work areas that exceed 104 dBA.

Dosimeter—When applied to noise, refers to an instrument that measures sound levels over a specified interval, stores the measures, and calculates the sound as a function of sound level and sound duration and describes the results in terms of, dose, time-weighted average and (perhaps) other parameters such as peak level, equivalent sound level, sound exposure level, etc.

Equal-Energy Rule—The relationship between sound level and sound duration based upon a 3 dB exchange rate, i.e., the sound energy resulting from doubling or halving a noise exposures duration is equivalent to increasing or decreasing the sound level by 3 dB, respectively.

Exchange Rate—The relationship between intensity and dose. OSHA uses a 5-dB exchange rate. Thus, if the intensity of an exposure increases by 5 dB, the dose doubles. Sometimes, this is also referred to as the doubling rate. The U.S. Navy uses a 4-dB exchange rate; the U.S. Army and Air Force uses a 3-dB exchange rate. NIOSH recommends a 3-dB exchange rate. Note that the equal-energy rule is based on a 3 dB exchange rate.

Frequency—Rate in which pressure oscillations are produced. Measured in hertz (Hz).

Hazardous Noise—Any sound for which any combination of frequency, intensity, or duration is capable of causing permanent hearing loss in a specified population.

Hazardous Task Inventory—A concept based on using work tasks as the central organizing principle for collecting descriptive information on a given work hazard. It consists of a list(s) of specific tasks linked to a database containing the prominent characteristics relevant to the hazard(s) of interest which are associated with each task.

Hearing Conservation Record—Employee's audiometric record. Includes name, age, job classification, TWA exposure, date of audiogram, and name of audiometric technician. To be retained for duration of employment for OSHA. Kept indefinitely for Workers' Compensation.

Hearing Damage Risk Criteria—A standard which defines the percentage of a given population expected to incur a specified hearing loss as a function of exposure to a given noise exposure.

Hearing Handicap—A specified amount of permanent hearing loss usually averaged across several frequencies which negatively impacts employment and/or social activities. Handicap is often related to an impaired ability to communicate. The degree of handicap will also be related to whether the hearing loss is in one or both ears, and whether the better ear has normal or impartial hearing.

Hearing Loss—Hearing loss is often characterized by the area of the auditory system responsible for the loss. For example, when injury or a medical condition affects the outer ear or middle ear (i.e., from the pinna, ear canal, and eardrum to the cavity behind the eardrum—which includes the ossicles) the resulting hearing loss is referred to as a *conductive* loss. When an injury or medical condition affects the inner ear or the auditory nerve that connects the inner ear to the brain (i.e., the cochlea and the VIIIth cranial nerve) the resulting hearing loss is referred to as a *sensorineural* loss. Thus, a welder's spark which damaged the ear drum would cause a conductive hearing loss. Because noise can damage the tiny hair cells located in the cochlea, it causes a sensorineural hearing loss.

Hearing Loss Prevention Program Audit—An assessment performed prior to putting a hearing loss prevention program into place or before changing an existing program. The audit should be a top-down analysis of the strengths and weaknesses of each aspect of the program.

HTL (Hearing Threshold Level)—The hearing level, above a reference value, at which a specified sound or tone is heard by an ear in a specified fraction of the trials. Hearing threshold levels have been established so that 0 dB HTL reflects the best hearing of a group of persons.

Hz (HERTZ)—The unit of measurement for audio frequencies. The frequency range for human hearing lies between 20 HA and approximately 20,000 Hz. The sensitivity of the human ear drops off sharply below about 500 Hz and above 4,000 Hz.

Impulsive Noise—Used to generally characterize impact or impulse noise which is typified by a sound which rapidly rises to a sharp peak and then quickly fades. The sound may or may not have a "ringing" quality (such as a striking a hammer on a metal plate or a gunshot in a reverberant room). Impulsive noise may be repetitive, or may be a single event (as with a sonic boom). Note: If impulses occurring in very rapid succession (such as with some jack hammers), the noise would not be described as impulsive.

Loudness—The subjective attribute of a sound by which it would be characterized along a continuum from 'soft' to 'loud'. Although this is a subjective attribute, it depends primarily upon sound pressure level, and to a lesser extent, the frequency characteristics an duration of the sound.

Material Hearing Impairment—As defined by OSHA, a material hearing impairment is an average hearing threshold level of 25 dB HTL as the frequencies of 1000, 2000, and 3000 Hz.

Medical Pathology—A disorder or disease. For purposes of this program, a condition or disease affecting the ear, which a physician specialist should treat.

Noise—Noise is any unwanted sound.

Noise Dose—The noise exposure expressed as a percentage of the allowable daily exposure. For OSHA, a 100 percent dose would equal an 8-hour exposure to a continuous 90 dBA noise; a 50 percent dose would equal an 8-hour exposure to an 85 dBA noise or a 4-hour exposure to a 90 dBA noise. If 85 dBA is the maximum permissible level, then an 8-hour exposure to a continuous 85 dBA noise would equal a 100 percent dose. If a 3 dB exchange rate is used in conjunction with an 85 dBA maximum permissible level, a 50 percent dose would equal a 2-hour exposure to 88 dBA, or an 8-hour exposure to 82 dBA.

Noise Dosimeter—An instrument that integrates a function of sound pressure over a period of time to directly indicate a noise dose.

Noise Hazard Area—Any area where noise levels are equal to or exceed 85 dBA. OSHA requires employers to designate work areas, post warning signs, and warn employees when work practices exceed 90 dBA as a "Noise Hazard Area." Hearing protection must be worn whenever 90 dBA is reached or exceeded.

Noise Hazard Work Practice—Performing or observing work where 90 dBA is equaled or exceeded. Some work practices will be specified, however, as a "Rule of Thumb," whenever attempting to hold normal conversation with someone who is one foot away and shouting must be employed to be heard, one can assume that a 90 dBA noise level or greater exists and hearing protection is required. Typical examples of work practices where hearing protection is required are jack hammering, heavy grinding, heavy equipment operations, and similar activities.

Noise-Induced Hearing Loss—A sensorineural hearing loss that is attributed to noise and for which no other etiology can be determined.

Noise Level Measurement—Total sound level within an area. Includes workplace measurements indicating the combined sound levels of tool noise (from ventilation systems, cooling compressors, circulation pumps, etc.).

NRR (Noise Reduction Rating)—The NRR is a single-number rating method which attempts to describe a hearing protector based on how much the overall noise level is reduced by the hearing protector. When estimating A-weighted noise exposures, it is important to remember to first subtract 7 dB from the NRR and then subtract the remainder from the A-weighted noise level. The NRR theoretically provides an estimate of the protection that should be met or exceeded by 98 percent of the wearers of a given device. In practice, this does not prove to be the case, so a variety of methods for "de-rating" the NRR have been discussed.

Ototoxic—A term typically associated with the sensorineural hearing loss resulting from therapeutic administration of certain prescription drugs.

Ototraumatic—A broader term than ototoxic. As used in hearing loss prevention, refers to any agent (e.g., noise, drugs, or industrial chemicals) which has the potential to cause permanent hearing loss subsequent to acute or prolong exposure.

Presbycusis—The gradual increase in hearing loss that is attributable to the effects of aging, and not related to medical causes or noise exposure.

Sensori-Neural Hearing Loss—A hearing loss resulting from damage to the inner ear (from any source).

Sociacusis—A hearing loss related to non-occupational noise exposure.

Sound Intensity (I)—Sound intensity at a specific location is the average rate at which sound energy is transmitted through a unit area normal to the direction of sound propagation.

Sound Level Meter (SLM)—A device which measures sound and provides a readout of the resulting measurement. Some provide only A-weighted measurements, others provide A- and C-weighted measurements, and some can provide weighted, linear, and octave (or narrower) ban measurements. Some SLMs are also capable of providing time-integrated measurements.

Sound Power—The total sound energy radiated by a source per unit time. Sound power cannot be measured directly.

SPL (Sound Pressure Level)—A measure of the ratio of the pressure of a sound wave relative to a reference sound pressure. Sound pressure level in decibels is typically referenced to 20 mPa. When used alone, (e.g., 90 dB APL) a given decibel level implies an unweighted sound pressure level.

STS—Standard Threshold Shift—OSHA uses the term to describe a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2000, 3000 and 4000 Hz in either ear. Used by OSHA to trigger additional audiometric testing and related follow up.

OR

Significant Threshold Shift—NIOSH uses this term to describe a change of 15 dB or more at any frequency, 5000 through 6000 Hz, from baseline levels that is present on an immediate retest in the same ear and at the same frequency. NIOSH recommends a confirmation audiogram within thirty days with the confirmation audiogram preceded by a quiet period of at least fourteen hours.

Threshold Shift—Audiometric monitoring programs will encounter two types of changes in hearing sensitivity, i.e., threshold shifts: permanent threshold shift (PTS) and temporary threshold shift (TTS). As the names imply, any change in hearing sensitivity which is persistent is considered a PTS. Persistence may be assumed if the change is observed on a thirty-day follow-up exam. Exposure to loud noise may cause a temporary worsening in hearing sensitivity (i.e., a TTS) that may persist for fourteen hours (or even longer in cases where the exposure duration exceeded twelve to sixteen hours). Hearing health professionals need to recognize that not all threshold shifts represent decreased sensitivity, and not all temporary or permanent threshold shifts are due to noise exposure. When a permanent threshold shift can be attributable to noise exposure, it may be referred to as a noise-induced permanent threshold shift (NIPTS).

Velocity (c)—Is the speed at which the regions of sound producing pressure changes move away from the sound source.

Wavelength—This term refers to the distance required for one complete pressure cycle to be completed (1 wavelength) and is measured in feet or meters.

Weighted Measurements—Two weighting curves are commonly applied to measures of sound levels to account for the way the ear perceives the “loudness” of sounds.

A-weighting: A measurement scale that approximates the “loudness” of tones relative to a 40 db SPL 1000 Hz reference tone. A-weighting has the added advantage of being correlated with annoyance measures and is most responsive to the mid frequencies, 500 to 4000 Hz.

C-weighting: A measurement scale that approximates the “loudness” of tones relative to a 90 dB SPL 1000 Hz reference tone. C-weighting has the added advantage of providing a relatively “flat” measurement scale which includes very low frequencies.

OCCUPATIONAL NOISE EXPOSURE

As mentioned above, *noise* is commonly defined as any unwanted sound. Noise literally surrounds us every day, and is with us just about everywhere we go. However, the noise we are concerned with here is that produced by industrial processes. Excessive amounts of noise in the work environment (and outside it) cause many problems for workers, including increased stress levels, interference with communication, disrupted concentration, and most importantly, varying degrees of hearing loss. Exposure to high noise levels also adversely affects job performance and increases accident rates.

One of the major problems with attempting to protect workers’ hearing acuity is the tendency of many workers to ignore the dangers of noise. Because hearing loss, like cancer, is insidious, it’s easy to ignore. It sort of sneaks up slowly and is not apparent (in many cases) until after the damage is done. Alarmingly, hearing loss from occupational noise exposure has been well documented since the eighteenth century, yet since the advent of the industrial revolution, the number of exposed workers has greatly increased (Mansdorf 1993). However, today the picture of hearing loss is not as bleak as it has been in the past, as a direct result of OSHA’s requirements. Now that noise exposure must be controlled in all industrial environments, that well-written and well managed hearing conservation programs must be put in place, and that employee awareness must be raised to the dangers of exposure to excessive levels of noise, job-related hearing loss is coming under control.

DETERMINING WORKPLACE NOISE LEVELS

The unit of measurement for sound is the decibel. **Decibels** are the preferred unit for measuring sound, derived from the bel, a unit of measure in electrical communications engineering. The decibel is a dimensionless unit used to express the logarithm of the ratio of a measured quantity to a reference quantity.

With regard to noise control in the workplace, the industrial hygienist’s primary concern is first to determine if any “noise-makers” in the facility exceed the OSHA limits for worker exposure—exactly which machines or processes produce noise at unacceptable levels. Making this determination is accomplished by conducting a noise level survey of the plant or facility. Sound measuring instruments are used to make this determination. These include noise dosimeters, sound level meters, and octave-band analyzers. The uses and limitations of each kind of instrument are discussed below.

1. **Noise Dosimeter**. The noise dosimeters used by OSHA meet the American National Standards Institute (ANSI) Standard S1.25-1978, “Specifications for Personal Noise Dosimeter,” which set performance and accuracy tolerances. For OSHA use, the dosimeter must have a 5-dB exchange rate, use a 90-dBA criterion level, be set at slow response, and use either an 80-dBA or 90-dBA threshold gate, or a dosimeter that has both capabilities, whichever is appropriate for evaluation.
2. **Sound Level Meter (SLM).** When conducting the noise level survey, the industrial hygienist should use an ANSI-approved Sound-level meter (SLM)—a device used most commonly to measure sound pressure. The SLM measures in decibels. One decibel is one-tenth of a bel and is the minimum difference in loudness that is usually perceptible.

The sound level meter (SLM) consists of a microphone, an amplifier and an indicating meter, which responds to noise in the audible frequency range of about 20 to 20,000 Hz. Sound level meters usually contain "weighting" networks designated "A", "B", or "C". Some meters have only one weighting network; others are equipped with all three. The A-network approximates the equal loudness curves at low sound pressure levels, the B-network is used for medium sound pressure levels, and the C-network is used for high levels.

In conducting a routine workplace sound level survey, using the A-weighted network (referenced dBA) in the assessment of the overall noise hazard has become common practice. The A-weighted network is the preferred choice because it is thought to provide a rating of industrial noises that indicates the injurious effects such noise has on the human ear (gives a frequency response similar to that of the human ear at relatively low sound pressure levels).

With an approved and freshly calibrated (always calibrate test equipment prior to use) sound level meter in hand, the industrial hygiene is ready to begin the sound level survey. In doing so, the industrial hygienist is primarily interested in answering the following questions:

1. What is the noise level in each work area?
2. What equipment or process is generating the noise?
3. Which employees are exposed to the noise?
4. How long are they exposed to the noise?

3. **Octave-Band Noise Analyzers.** Several Type 1 sound level meters (such as the GenRad 1982 and1983 and the Quest 155) used by OSHA have built-in octave band analysis capability. These devices can be used to determine the feasibility of controls for individual noise sources for abatement purposes and to evaluate hearing protectors.

   Octave-band analyzers segment noise into its component parts. The octave-band filter sets provide filters with the following center frequencies: 31.5; 63; 125; 250; 500; 1,000; 2,000; 4,000; 8,000; and 16,000 Hz.

   The special signature of a given noise can be obtained by taking sound level meter readings at each of these settings (assuming that the noise is fairly constant over time). The results may indicate those octave-bands that contain the majority of the total radiated sound power.

   Octave-band noise analyzers can assist industrial hygienists in determining the adequacy of various types of frequency-dependent noise controls. They also can be used to select hearing protectors because they can measure the amount of attenuation offered by the protectors in the octave-bands responsible for most of the sound energy in a given situation.

ENGINEERING CONTROL FOR INDUSTRIAL NOISE

When the industrial hygienist investigates the possibility of using engineering controls to control noise, the first thing he or she recognizes is that reducing and/or eliminating all noise is virtually impossible. And this should not be the focus in the first place, eliminating or reducing the "hazard" is the goal. While the primary hazard may be the possibility of hearing loss, the distractive effect (or its interference with communication) must also be considered. The distractive effect or excessive noise can certainly be classified as hazardous whenever the distraction might affect the attention of the worker. The obvious implication of noise levels that interfere with communications is emergency response. If ambient noise is at such a high level that workers can't hear fire or other emergency alarms, this is obviously an unacceptable situation.

NOISE UNITS, RELATIONSHIPS, AND EQUATIONS

A number of noise units, relationships and equations that are important to the industrial hygienist involved with controlling noise hazards in the workplace are discussed below.

1. **Sound Power (w)**—Sound power of a source is the total sound energy radiated by the source per unit time. It is expressed in terms of the sound power level (L_w) in decibels referenced to 10^{-12} watts (w_0). The relationship to decibels is shown below:

$$L_w = 10 \log w/w_0$$

   where:
   L_w = sound power level (decibels)
   w = sound power (watts)
   w_0 = reference power (10^{-12} watts)
   log = a logarithm to the base 10

2. Units used to describe **sound pressures** are

$$1\ \mu\text{bar} = 1\ \text{dyne/cm}^2 = 0.1\ \text{N/cm}^2 = 0.1\ \text{Pa}$$

3. **Sound pressure level** or SPL = $10 \log p^2/p_0$

   where:
   SPL = sound pressure level (decibels)
   p = measured root-mean-square (rms) sound pressure (N/m^2, μbars). Root-mean-square (rms) value of a changing quantity, such as sound pressure, is the square toot of the mean of the squares of the instantaneous values of the quantity.

p_0 = reference rms sound pressure 20 µPa, N/m^2, µbars)

4. **Speed of sound** (c) = c = fλ
5. **Wavelength** (λ) = c/f
6. Calculation of **frequency of octave bands** can be calculated using the following formulae:

Upper frequency band: $f_2 = 2f_1$

where:
f_2 = upper frequency band
f_1 = lower frequency band

One-half octave band: $f_2 = \sqrt{2}(f_1)$

where:
f_2 = ½ octave band
f_1 = lower frequency band

One-third octave band: $f_2 = \sqrt[3]{2}(f_1)$

where:
f_2 = 1/3 octave band
f_1 = lower frequency band

7. Formula for **adding noise sources**, when sound power is known:

$$L_w = 10 \log (w_1 + w_2)/(w_0 + w_0)$$

where:
L_w = sound power in watts
w_1 = sound power of noise source 1 in watts
w_2 = sound power of noise source 2 in watts
w_0 = reference sound power (reference 10^{-12}) watts

8. Formula for **sound pressure additions**, when sound pressure is known:

$$\text{SPL} = 10 \log p^2/p_0^2$$

where:
$p^2/p_0^2 = 10^{\text{SPL}/10}$

and:
SPL = sound pressure level (decibels)
p = measured root-mean-square (rms) sound pressure (N/m^2, µbars)
p_0 = reference rms sound pressure (20 µPa, N/m^2, µbars)

For three sources, the equation becomes:

$$\text{SPL} = 10 \log (10^{\text{SPL}_1/10}) + (10^{\text{SPL}_2/10}) + (10^{\text{SPL}_3/10})$$

When adding any number of sources, whether the sources are identical or not, the equation becomes:

$$\text{SPL} = 10 \log (10^{\text{SPL}_1/10} \ldots .. + {}^{10\text{SPL}_n/10})$$

Determining the sound pressure level from multiple identical sources:

$$\text{SPL}_f = \text{SPL}_i + 10 \log n$$

where:
SPL_f = total sound pressure level (dB)
SPL_i = individual sound pressure level (dB)
n = number of identical sources

9. The equation for determining **noise levels in a free field** is expressed as:

$$\text{SPL} = L_w - 20 \log r - 0.5$$

where:
SPL = sound pressure (reference 0.00002 N/m^2)
L_w = sound power (reference 10^{-12} watts)
r = distance in feet

10. Calculation for **noise levels with directional characteristics** is expressed as:

$$\text{SPL} = L_w - 20 \log r - 0.5 + \log Q$$

where:
SPL = sound pressure (reference 0.00002 N/m^2)
L_w = sound power (reference 10^{-12} watts)
r = distance in feet
Q = directivity factor
  Q = 2 for one reflecting plane
  Q = 4 for two reflecting planes
  Q = 8 for three reflecting planes

11. Calculating the **noise level at a new distance** from the noise source can be computed as follows:

$$\text{SPL} = \text{SPL}_1 + 20 \log (d_1)/(d_2)$$

where:
SPL = sound pressure level at new distance (d_2)
SPL_1 = sound pressure level at d_1
d_n = distance from source

12. **Calculating Daily Noise Dose** can be accomplished using the following formula, which combines the

effects of different sound pressure levels and allowable exposure times.

$$\text{Daily Noise Dose} = \frac{C_1 + C_2 + C_3 \ldots.. + C_n}{T_1 \quad T_2 \quad T_3 \qquad T_n}$$

where:
C_i= number of hours exposed at given SPL_i
T_i= number of hours exposed at given SPL_i

13. **Calculating OSHA Permissible Noise Levels** using the formula below:

$$T_{SPL} = 8/2^{(SPL - 90)/5}$$

where:
T_{SPL} = time in hours at given SPL
SPL = sound pressure level (dBA)

14. Formula for converting noise dose measurements to the **equivalent eight-hour TWA:**

$$TWA_{eq} = 90 + 16.61 \log (D)/(100)$$

where:
TWA_{eq} = eight-hour equivalent TWA in dBA
D = noise dosimeter reading in percent

Noise Pollution: Any unwanted sound that disrupts the activity or balance of human or animal life.

Non-Analyzable Constituents: Constituents that lack appropriate test methods or chemical standards an therefore cannot be properly measured to determine compliance with LDR concentration–based standards in 268.40 and 268.48.

Non-Aqueous Phase Liquid (NAPL): Contaminants that remain undiluted as the original bulk liquid in the subsurface, e.g., spilled oil.

Non-Attainment Area: Area that does not meet one or more of the National Ambient Air Quality Standards for the criteria pollutants designated in the Clean Air Act.

Non-Binding Allocations of Responsibility (NBAR): A process for EPA t propose a way for potentially responsible parties to allocate coast among themselves.

Non-Community Water System: A public water system that is not a community water system; e.g., the water supply at a campsite or national park.

Non-Compliance Coal: Any coal that emits greater than 3.0 pounds of sulfur dioxide per million BTU when burned. Also known as high-sulfur coal.

Non-Contact Cooling Water: Water used for cooling which does not come into direct contact with any raw material, product, byproduct, or waste.

Non-Conventional Onsite Wastewater Treatment System: System using technologies that are used where conventional onsite treatment system cannot meet established performance or prescriptive requirements because of limiting site conditions. Also referred to as Alternative onsite wastewater treatment systems.

Non-Conventional Pollutant: Any pollutant not statutorily listed or which is poorly understood by the scientific community.

Non-Degradation: An environmental policy which disallows any lowering of naturally occurring quality regardless of pre-established health standards.

Non-Ferrous Metals: Nonmagnetic metals such as aluminum, lead, and copper. Products made all or in part from such metals include containers, packaging, appliances, furniture, electronic equipment and aluminum foil.

Non-Flammable: Not capable of being burned under normal conditions.

Non-*in situ* Technology: Remediation/recycling technology that takes place away from the contamination site.

Non-Ionizing Electromagnetic Radiation: 1. Radiation that does not change the structure of atoms but does heat tissue and may cause harmful biological effects. 2 Microwaves, radio waves, and low-frequency electromagnetic fields from high-voltage transmission lines.

Non-Methane Hydrocarbon (NMHC): The sum of all hydrocarbon air pollutants except methane; significant precursors to zone formation.

Non-Methane Organic Gases (NMOG): The sum of all organic air pollutants. Excluding methane; they account for aldehydes, ketones, alcohols, and other pollutants that are not hydrocarbons but are precursors of zone.

Non-Point Source (NPS) Pollution: Pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land-use activities, which are carried to lakes and streams by surface runoff. Non-point source pollution is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it pucks up soil particles and pollutants, such as nutrients and pesticides.

Non-Polar: Not polar; not having an electric charge.

Non-Potable: Water that is unsafe or unpalatable to drink because it contains pollutants, contaminants, mineral, or infective agents.

Non-Road Emissions: Pollutants emitted by combustion engines on farm and construction equipment, gasoline-powered lawn and garden equipment, and power boats and outboard motors.

No-Till: 1. Planting procedure that requires no tillage except that done by a coulter in the immediate area of the crop row. 2. Planting crops without prior seedbed preparation, into an existing cover crop, sod, or crop residues, and eliminating subsequent tillage operations.

Non-Transient Non-Community Water System: A public water system that regularly serves at least 25 of the same non-resident persons per day for more than six months per year.

Nonattainment Area (NAA): Area found to exceed the National Ambient Air Quality Standards for any one or more regulated pollutant and subsequently required to implement a regional plan to reduce emissions and bring the area into attainment.

Noncombustible: A material that in the form in which it is used and under the conditions anticipated will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat, as defined by fire protection industry standards on the basis of large scale fire tests performed by a nationally recognized independent fire test authority.

Nonconforming Use: Means the use of any land, building, or structure that does not comply with the use regulations of the zoning district in which such use is located, but which complied with the use regulations in effect at the time the use was established.

Nondischarging Treatment Plant: A treatment plant that does not discharge treated wastewater into any stream or river. Most are pond systems that dispose of the total flow they receive by means of evaporation or percolation to groundwater, or facilities that dispose of their effluent by recycling or reuse (e.g., spray irrigation or groundwater recharge).

Noncarbonate Hardness: A property of water where the hardness cannot be removed by boiling and is classified as permanent.

Nonfriable Asbestos-Containing Materials: Any material containing more than one percent asbestos (as determined by Polarized Light Microscopy) that, when dry, cannot be crumbled, pulverized, or reduced to powder by hand pressure.

Nonhazardous Industrial Waste: Industrial process waste in wastewater not considered municipal solid waste or hazardous waste under RCRA.

Nonindustrial Private: An ownership class of private lands where the owner does not operate wood-using processing plants.

Nonionizing Radiation: That radiation on the electromagnet spectrum that has a frequency of 10^{15} or less and a wavelength in meters of $3 \text{ X } 10^{-7}$.

Nonpoint Source: Source of pollution in which wastes are not released at one specific, identifiable point but from a number of points that are spread out and difficult to identify and control.

Nonpoint Source Pollution: Pollution that cannot be traced to a specific source but rather comes from multiple generalized sources.

Nonrenewable Resources: Resources that exist in finite supply or are consumed at a rate faster than the rate at which they can be renewed.

Nonspecific Source Wastes: Generic wastes commonly produced by manufacturing and industrial processes; for example, spent solvents.

Nonutility Generation: Electric generation by nonutility power produces to supply electric power for industrial, commercial, and military operations, or sales to electric utilities.

Nonutility Power Producer: A corporation, person, agency, authority, or other legal entity or instrumentality that owns electric generating capacity and is not an electrical utility. Nonutility power produces include qualifying cogenerators, qualifying small power produces, and other nonutility generators without a designated, franchised service area that do not file forms listed in the Code of Federal regulations, Title 18, Part 141.

Nonvolatile: A substance that does not evaporate at normal temperatures when exposed to the air.

Normal Lapse Rate: The rate of temperature change with height is called the lapse rate. On average, temperature decreases –65ºC/100m or –6.5ºC/km, the normal lapse rate.

Normal Production Operation: Using a machine or equipment to perform its intended production function.

Notice of Deficiency: An EPA request to a facility owner or operator requesting additional information before a preliminary decision on a permit application can be made.

Notice of Intent to Cancel: Notification sent to registrants when EPA decides to cancel registration of a produce containing a pesticide.

Notice of Intent to Deny: Notification by EPA of its preliminary intent to deny a permit application.

Notice of Intent to Suspend: Notification sent to a pesticide registrant when EPA decides to suspend product sale an distribution because of failure to submit requested data in a timely and/or acceptable manner, or because of imminent hazard.

NPDES permit: NPDES permit is an authorization, license, or equivalent control document issued by EPA or an approved state agency to implement the requirements of the NPDES regulations; for example, a permit to operate a CAFO.

NRCS: National Resource Conservation Service.

Nuclear Electric Power (Nuclear Power): Electricity generated by an electric power plant whose turbines are driven by steam produced by the heat from the fission of nuclear fuel in a reactor.

Nuclear Fallout: The residual radiation hazard from a nuclear explosion, so named because it "falls out" of the atmosphere into which it is spread during the explosion.

Nuclear Power Major Health, Safety, and Environmental Legislation

1. **Public Health Service Act (1944) as amended in '57, '58, '60, '76 (42 USC 201 et seq.)** provides EPA with the authority to conduct a range of radiation protection activities:
   - Collect, analyze, and interpret data on environmental radiation levels
   - Research the environmental and human health effects of exposure to radiaton
   - Develop protective action guides
   - Provide training and technical assistance to the sties. It also provides the authority to develop and implement a plan to effective provide personnel, equipment, medical supplies, or aother federal resources in responding to health emergencies.
2. **1946 Atomic Energy Act as amended in 1954 (42 USC 2011 et seq.)** established the Atomic Energy Commission (AEC) to promote the "utilization of atomic energy for peaceful purposes to the maximum extent consistent with the common defense and security and with the health and safety of the public." When EPA was formed, the AEC's authority to issue generally applicable environmental radiaton standards was transferred to EPA. Other federal and state organizations must follow these standards when developing requirements for their areas of radiation protection.

   EPA also received the Federal Radiation Council's authority under the AEA:
   - To develop guidance for federal and state agencies contain recommendations for their use in developing radiation protection requirements.
   - To work with states to establish and execute radiation protection programs.
3. **Energy Policy and Conservation Act of 1975** began the modern energy policy era, which, not coincidentally, was a response to an oil prices spike after an OPEC embargo in 1973–1974. The Act not only created the Strategic Petroleum reserve to counter severe disruptions in the nation's oil supply, but also introduced for the first time Corporate Average Fuel economy (CAFÉ) standards for automobile manufacturers, requiring that average fuel economy of vehicles sold by auto manufactures in the United States achieve double in fuel efficiency.
4. **1963 Clean Air Act (CAA) as amended in 1970, 1977, 1990 (42 USC 7401 et seq.)** was first passed in 1955 as the Air Pollution Control, Research and Technical Assistance Act and amended in 1963 to become the CAA. A more significant statute was passed in 1970 and amended in 1977 and 1990. It provides EPA authority to regulate air pollutants from a wide variety of sources including automobiles, electric power plants, chemical plants, and other industrial sources. Section 112 provides EPA the authority to list hazardous air pollutants, or HAPs, and to develop and enforce emission limits for each of them. Section 112(a) introduced the concept of "ample margin of safety to protect public health" in setting these limits. The limits are referred to as "National Emission standards for Hazardous air Pollutants" or NESHAPs. Section 103 of the CAA provides EPA broad authority to gather information, to provide grants, to conduct or promote research, and to coordinate and accelerate training.

5. **Occupational Safety and Health Act (OSH Act) of 1970** provides the Department of Labor authority to set comprehensive workplace safety and health standards, including permissible exposures to chemicals in the workplace, and authority to conduct inspections and issue citations for violations of safety and health regulations.
6. **Marine Protection, Research, and Sanctuaries Act as amended in 1977 (32 USC 1401 et seq.)** authorizes EPA to issue permits and promulgate regulations for disposing of materials into the territorial waters of the United States when it will not degrade o endanger human health, welfare, ecological systems, the marine environment, or the economy.
7. **Federal Water Pollution Control Act amended by the Clean Water Act (CWA)** of ’77, ’87, (33 USC 1251 et seq.) was first enacted in 1948 as the Federal Water Pollution Control Act. Subsequent extensive amendments defined the statue to be known as the CWA in 1972; it was further amended in 1977 and 987. The CWA provides EPA authority to regulate effluents from sewage treatment works, refineries, chemical plants, and other industry sources into U.S. waterways. EPA has recently undertaken control efforts in on-point source pollution as well. The primary objective of the CWA is to restore and maintain the integrity of the nation’s waters. The CWA sets these provisions:
   - Performance standards for major industries to ensure pollution control
   - Requirement for states and tribes to set specific water quality criteria appropriate for the waters and to develop pollution control programs for meeting them
   - A permitting process to ensure that any development or other activity in valuable wetlands and other aquatic habitats is conducted in an environmentally sound manner
   - Authority for EPA to initiate an emergency response to any accidental release of oil or hazardous substances, including radionuclides, when there is a substantial threat to the public health or welfare. This authority is similar to that assigned by the Comprehensive Environmental Response, Compensation and Liability Act. However, it only applies to discharges or potential discharges of pollutant to navigable waters of the United States.
8. **1974 Safe Drinking Water Act (SWDA) as amended in 1977, 1986, 1996 (43 USC s/s 300f et seq.)** requires EPA to promulgate and enforce primary standards for contaminants in public water systems, including radionuclides. Initially, EPA was to set interim regulations for a limited group of contaminants and later revise those regulations to set standards for the remaining contaminants. The 1986 amendments required EPA to develop maximum contaminant level guidelines (MCLGs) and maximum contaminant levels, or MCLs, concurrently and to finalize the interim regulations. Under this statute EPA may delegate program enforcement authority to the States. The 1996 amendments to the SDWA directed EPA to do the following:
   - Withdraw the Notice of Proposed Drinking Water Rule, including the proposed MCLGs and MCLs and monitoring, reporting, and public notification requirements for radon, due to the controversy over the cost-benefit basis for the proposed standard.
   - Arrange for the National Academy of Sciences (NAS) to conduct a formal study of radon in drinking water; publish a risks reduction and cost analysis for possible radon MCLs by February 1999; promulgate the radon MCLG and National Primary Drinking Water Regulation (NPDWR) for drinking water by the year 2000; develop an alternative MCL for radon, as directed to ensure that any revised drinking water standard will maintain or increase public health protection; and review all drinking water regulations every six years.
9. **Resource Conservation and Recovery Act (RCRA) of 1976 as amended in 1984, 1986 (42 USC 6901 et seq.)** provides EPA with authority to establish standards and regulations for handling and disposing of solid and hazardous wastes (cradle-to-grave provisions). RCRA has four main goals:
   - Protect human health and the environment from hazards posed by waste disposal.
   - Conserve energy and natural resources through waste recycling and recovery.
   - Reduce or eliminate the generation of waste, including hazardous waste.
   - Ensure that wastes are managed in an environmentally safe manner.

   RCRA focuses only on active and planned facilities. It does not address abandoned or historical sites. Although sources, special nuclear, or by-product material as defined by the AEA is specially excluded from RCRA, it generally does apply to naturally occurring radioactive materials.
10. **1978 Uranium Mill Tailings Radiation Control Act (UMTRCA) (4 USC 1022 et seq.)** amended the AEA by directing EPA to set generally applicable health and environmental standards to govern the stabilization, restoration, disposal, and control of effluents and emissions at both active and inactive mill tailings sites.

    Title 1 of the Act covers inactive uranium mill tailing sites, depository sites, and vicinity properties.

It directs EPA, the Department of Energy, and the Nuclear Regulatory Commission to undertake the following:

EPA

Must set standards that provide protection as consistent with the requirements of RCRA as possible. The standards must include ground water protection limits.

DOE

Implements EPA's standards for the tailings piles and the vicinity properties provides perpetual care for some properties.

NRC

Reviews completed site cleanups for compliance with EPA standards. Licenses the site to the state or DOE for perpetual care.

Title II of the Act covers operating uranium processing sites licensed by the NRC. EPA was directed to promulgate disposal standards in compliance with Subtitle C of the Solid Waste Disposal Act, as amended, to be implemented by NRC or the Agreement States. The 1993 Amendments to UMTRCA further directed EPA to promulgate general environmental standards for the processing, possession, transfer, and disposal of uranium mill tailings. NRC was required to implement these standards at Title II sites.

11. **1980 Low-Level Radioactive Waste Policy Act (LLRWPA) as amended in 1985 (42 USC 2021b et. Seq.)** requires each State to be responsible for providing disposal capacity for commercial Low Level Waste (LLW) generated within its borders by January 1, 1986. It encouraged States to form regional compacts to develop new disposal facilities. The LLRWPA was amended in 1985 to provide States more time to develop facilities and to provide incentives for volume reduction of LLW.
12. **Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA) (42 USC 9601 et seq.)** provides the basic legal framework for the Federal "Superfund" program to clean up abandoned hazardous waste sites. It creates a tax on the chemical and petroleum industries and provides broad federal authority to respond directly to releases or threatened releases of hazardous substances pollutants, and contaminants that may endanger public health or the environment. CERCLA also authorizes and directs EPA to carry out a program of training and evaluation of training needs in the procedures for the handling and removal of hazardous substances. CERCLA applies to hazardous substances defined by other environmental laws. For example, since the CAA amendments list radionuclides as hazardous substances, they are covered by CERCLA. CERCLA authorizes two kinds of response actions:
    - *Short-term removal actions*—address actual or threatened releases requiring prompt response to protect human health or the environment at any site.
    - *Long-term remedial actions*—address actual or threats of releases that are serious, but not immediately life threatening. EPA conducts long-term remedial response actions only at sites on the National Priority List, commonly know as superfund sites.

    These response actions are conducted in accordance with the concept of operations contained in the NCP (40 CFR Part 300).

    While the above is a general description of how CERCLA works, response actions are handled somewhat differently at federal and federally licensed sites. This reflects the division of radiation protection responsibilities among various federal agencies. For example:
    - The Department of Defense and the Department of Energy coordinate response actions at their sites.
    - Nuclear Regulatory Commission Regulations—rather than CERCLA regulations—govern response actions at some NRC-licensed facilities. (Nuclear Regulatory Commission-licensed facilities that are covered by the Price Anderson Amendments (Section 170) of the AEA).
13. **1982 Nuclear Waste Policy Act (NWPA) (42 USC 10101 et seq.)** supports the use of deep geologic repositories for the safe storage and/or disposal of radioactive waste. The Act establishes procedures to evaluate and select sites for geologic repositories and for the interaction of state and federal governments. It also provides a timetable of key milestones the federal agencies must meet in carrying out the program.

    The NWPA assigns DOE the responsibility to site, build, and operate a deep geologic repository for the disposal of HLW and spent nuclear fuel (SNF). It directs EPA to develop standards for protection of the general environment from offsite releases of radioactive material in repositories. The Act directs NRC to license DOE to operate a repository only if it meets EPA's standards and all other relevant requirements.
14. **Emergency Planning and Community Right-to-Know Act of 1986**, also known as SARA Title III, mandates state and community development of emergency preparedness plans and also establishes an annual manufacturing-sector emissions reporting program.

15. **Hazardous Materials Transportation Act (HMTA)** provides the Department of Transportation the authority to regulate the packaging and movement of hazardous materials.
16. **1987 Nuclear Waste Policy Amendments Act (NWPAA) (42 USC 10101 et seq.)** directs DOE to consider Yucca Mountain as the primary site for the first geological repository for HLW and SNF, and prohibits DOE from conducting site specific activities at a second site, unless authorized by Congress. It also requires the Secretary of Energy to develop a report on the need for a second repository no later than January 1, 2010. The NNWPAA also established a commission to study the need and feasibility of a monitored retrievable storage facility.
17. **1988 Indoor Radon Abatement Act (IRAA)** establishes a long-term goal that indoor air be as free from radon as the ambient air outside buildings. The law authorized funds for radon-related activities at the state and federal levels:
    - establishing state programs and providing technical assistance.
    - conducting radon surveys of schools and federal buildings.
    - establishing training centers and a proficiency program for firms offering radon services.
    - developing model construction standards.
    - developing a citizen's guide to radon.
18. **Pollution Prevention of Act of 1990** makes it the national policy of the United States to reduce or eliminate the generation of waste at the source whenever feasible and directs the EPA to undertake a multimedia program of information collection, technology transfer, and financial assistance to the states to implement this policy and to promote the use of source reduction techniques.
19. **Energy Policy Act (EnPA) of 1992** introduced one of the key drivers of the renewable energy industry to-date, the Production Tax Credit (PTC), which offers to independent power producers a subsidy per kwh generated from renewable sources for a period of 10 years from the beginning of power generation. The EnPA requires EPA to "promulgate standards to ensure protection of public health from high-level radioactive wastes in a deep geologic repository that might be built under Yucca Mountain in Nevada." It directs EPA to issue these site-specific public health and safety standards, "based upon and consistent with the finings and recommendations of the National Academy of Sciences. . . ."
20. **1992 Waste Isolation Pilot Plant Land Withdrawal Act (WIPP LWA) as amended in 1996 (L 102-579)** sets aside the land for developing and building a transuranic radioactive waste repository and assigns the following specific regularity and enforcement roles to EPA:
    - finalize generally applicable standards for disposal of SNF, HLW, and TRU (transuranic). (These standards limit releases of radioactive materials to the environment and notify future generations of the location and content of the disposal facility.)
    - develop criteria for the disposal of TRU at the WIPP that are consistent with the generally applicable standards.
    - certify that the WIPP complies with the generally applicable stands if DOE satisfies the criteria.
    - ensure that the WIPP complies with other applicable environment and public health and safety regulations.
    - reevaluate the WIPP every five years to determine wither it should be recertified.

    It also prohibits the application of the general standards to sites being considered for the disposal of HLW and SNF under the NWPA (e.g., Yucca Mountain).

    The 1996 WIPP LWA Amendments (PL104-201) dictated:
    - specified November 30, 1997 as a non-binding date for the WIPP site to open, pending certification by EPA that the site meets environmental regulatory requirements.
    - exempted the WIPP from RCRA Land Disposal Requirements withdrew requirements in the original Act that DOE conduct underground tests onsite with transuranic waste to determine whether it could be disposed of safely.
21. **Federal Energy Regulatory Commission (FERC)** is an independent regulatory agency within the Department of Energy and is perhaps the leading regulatory body in determining the impact on the average consumer of energy. FERC has jurisdiction over electricity pricing, licensing for hydroelectric plants and liquid natural gas (LNG) terminals, and oil pipeline transport rates.
22. **Energy Policy Act of 2005** does everything from extending Daylight Savings Time to authorizing $50 million in grants for biomass energy projects to changing the depreciation allowances for gas distribution lines.

Nuclear Reactor: An apparatus in which a nuclear fission chain reaction can be initiated, controlled, and sustained at a specific rate. A reactor includes fuel (fissionable material), moderating material to control the rate of fission, a heavy-walled pressure vessel to house reactor components, shielding to protect personnel, a system to conduct heat away from the reactor, and instrumentation for monitoring and controlling the reactor's systems. In the vast majority of the world's nuclear power plants, the heat energy generated by uranium fuel is transferred to ordinary water and is carried away from the reactor's core either as steam in boiling water reactors (BWRs) or as superheated water in pressurized-water reactors (PWRs).

- *Boiling Water Reactor* (BWR)—In a typical commercial boiling water reactor (1) the reactor core creates heat, (2) a steam-water mixture is produced when very pure water (reactor coolant) movers upward through the core absorbing heat, (3) the steam-water mixture leaves the top of the core and enters the two stages of moisture separation where water droplets are removed before the steam is allowed to enter the steam line, (4) the steam line directs the steam to the main turbine causing it to turn the turbine generator, which produces electricity. The unused steam is exhausted to th condenser where it is condensed into water. The resulting water is pumped out of the condenser with series of pumps, reheated, and pumped back to the reactor vessel. The reactor's core contains fuel assembles which are cooled by water, which is forced-circulated by electrically powered pumps. Emergency cooling water is supplied by other pumps which can be powered by onsite diesel generators. Other safety systems, such as the containment cooling system, also need electric power.
- *Pressurized-Water Reactor* (PWR) *and Reactor Vessel*—In a typical commercial pressurized light-water reactor (1) the reactor core generates heat, (2) pressurized-water in the primary coolant loop carries the heat to steam heat, (3) inside the steam generator heat from the primary coolant loop vaporizes the water in a secondary loop producing steam., (4) the steam line directs the steam to the main turbine causing it to turn the turbine generator, which produces electricity. The unused steam is exhausted to the condenser where it is condensed into water. The resulting water is pumped out of the condenser with a series of pumps, reheated, and pumped back to the steam generator. The reactor core contains fuel assemblies which are cooled by water, which is force-circulated by electrically powered pumps. Emergency cooling water is supplied by other pumps, which can be powered by onsite diesel generators. Other safety systems, such as the containment cooling system, also need power.

Nuclear Winter: Prediction by some scientists that smoke and debris rising from massive fires of a nuclear war could block sunlight for weeks or months, cooling the earth's surface and producing climate changes that could, for example, negatively affect world agricultural and weather patterns.

Nucleoid: The primitive nuclear region of the procaryotic cell.

Nucleophile: A chemical compound or group that is attracted to nuclei and tends to donate or share electrons.

Nuclide: An atom characterized by the number of protons, neutrons, and energy in the nucleus.

Nuisance: Any condition that inhibits the reasonable use or enjoyment of property.

Null Session: Known as Anonymous Logon, it is a way of letting an anonymous user retrieve information such as user names and shares over the network or connect without authentication.

Nutrient: Any substance assimilated by living things that promotes growth. The term is generally applied to nitrogen and phosphorus in wastewater, but is also applied to other essential and trace elements.

Nutrient Assimilation: Conversion or incorporation of plant nutrients into plant cells and tissue.

Nutrient Cycles: See *Biogeochemical Cycles*.

Nutrient Excretion Factor: An estimate of an element, for example nitrogen, excreted by an animal usually reported as kg per day (or year) per animal (animal unit or kg of bodyweight).

Nutrient Pollution: Contamination of water resources by excessive inputs of nutrients. In surface waters excess algal production is a major concern.

Nutrient Transformation: The changing in the form of a plant element that may affect the stability, availability, or mobility of the compound. An example is the changing of ammonium nitrogen to nitrate nitrogen.

Nutrients: Elements required for plant or animal growth, including the macronutrients (nitrogen, phosphorus, and potassium), which are the major nutrients required and micronutrients, which include a number of other elements that are essential but needed in lesser amounts.

Nutrition: The process of nourishing or being nourished.

O

Occupied Space: The space within a building or structure that is normally occupied by people, and that may be conditioned (heated, cooled, and/or ventilated).

Occupational Environmental Limits (OELs): Many processes and procedures generate hazardous air contaminants that can get into the air people breathe. Normally, the body can take in limited amounts of hazardous air contaminants, metabolize them and eliminate them from the body without producing harmful effects. Safe levels of exposure to many hazardous materials have been established by governmental agencies after much research in their short tem (acute) and cumulative (chronic) health effects using available human exposure data (usually from industrial sources) and animal testing. When the average air concentrations repeatedly exceed certain thresholds, called *exposure limits*, adverse health effects are more likely to occur. Exposure limits do change with time as more research is conducted and more occupational data is collected.

A fairly standard terminology has come to be used with regard to Occupational Environmental Limits (OELs).

Let's pause right here and talk about Permissible Exposure Limits (PELs) and threshold Limit Values (TLVs).

A workplace exposure level, such as PEL or TLV, is expressed as the concentration of the air contaminant in a volume of air. It is important to know what they are and what significance they play in the industrial hygienist's daily activities. Let's begin with TLVs.

Threshold Limit Values (TLVs) are published by the American Conference of Governmental Industrial Hygienists (ACGIH) (an organization made up of physicians, toxicologists, chemists, epidemiologists, and industrial hygienists) in its *Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment*. These values are used in assessing the risk of a worker exposed to a hazardous chemical vapor; concentrations in the workplace can often be maintained below these levels with proper controls. The substances listed by ACGIH are evaluated annually, limits are revised as needed, and new substances are added to the list, as information becomes available. The values are established from the experience of many groups in industry, academia and medicine, and from laboratory research.

The chemical substance exposure limits listed under both ACGIH and OSHA are based strictly on airborne concentrations of chemical substances in terms of milligrams per cubic meter (mg/m^3), parts per million (ppm) (the number of "parts" of air contaminant per million parts of air), and fibers per cubic centimeters ($fibers/cm^3$). The smaller the concentration number, the more toxic the substance is by inhalation. The ACGIH has established some "rules of thumb" in regards to exposure limits. Substances with exposure limits below 100 ppm are considered highly toxic by inhalation. Those substances with exposure limits of 100–500 ppm are considered moderately toxic by inhalation. Substances with exposure limits greater than 500 ppm are considered slightly toxic by inhalation. Allowable limits are based on three different time periods of average exposure: (1) 8-hour work shifts known as TWA (time weighted average), (2) short terms of 15 minutes or STEL (short-term exposure limit), and (3) instantaneous exposure of "C" (ceiling). Unlike OSHA's PELs, TLVs are recommended levels only, and do not have the force of regulation to back them up.

OSHA has promulgated limits for personnel exposure in workplace air for approximately 400 chemicals listed in Tables Z1, Z2, and Z3 in Part 1910.1000 of the Federal Occupational Safety and Health Standard. These limits are defined as *permissible exposure limits* (PEL) and like TLVs are based on 8-hour time weighted averages or ceiling limits when preceded by a "C" (Exposure limits expressed in terms other than ppm must be converted to ppm before comparing to the guidelines). Keeping within the limits in the Subpart Z Tables is the only requirement specified by OSHA for these chemicals. The significance of OSHA's PELs is that they have the force of regulatory law behind them to back them up—compliance with OSHA's PELs is the law.

Evaluation of personnel exposure to physical and chemical stresses in the industrial workplace requires the use of the guidelines provided by TLVs and the regulatory guidelines of PELs. For the industrial hygienist to carry out the goals of recognizing, measuring and effecting controls (of any type) for workplace stresses, such limits are a necessity, and have become the ultimate guidelines in the science of industrial hygiene. A word of caution is advised, however. These values are set only as guides for the best practice, and are not to be considered absolute values. What are we saying here? These values provide reasonable assurance that occupational disease will not occur, if exposures are kept below these levels. On the other hand, occupational disease is likely to develop in some people—if the recommended levels are exceeded on a consistent basis.

Time-Weighted Average (TWA) is the fundamental concept of most OELs. It is usually presented as the average concentration over an 8-hour workday for a 40-hour workweek.

Eight-hour *Threshold Limit Values-Time Weighted Averages* (TLV-TWA) exist for some four hundred plus chemical agents commonly found in the workplace. NIOSH list sampling and analytical methods for most of these agents.

Short-Term Exposure Limits (STELs) are recommended when exposures of even short duration to high concentrations of a chemical are known to produce acute toxicity.

The STEL is the concentration to which workers can be exposed continuously for a short period of time without suffering from (1) irritation, (2) chronic or irreversible tissue damage, or (3) narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self rescue, or reduced work efficiency.

The STEL is defined as a 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the overall 8-hour TWA is within limits, and it should not occur more than four times per day. Note: There should be at least 60 minutes between successive exposures in this range. If warranted, an averaging period other than 15 minutes can also be used. STELS are not available for all substances.

Ceiling (C) is the concentration that should not be exceeded during any part of the working exposure, assessed over a 15-minute period.

The *Action Level* is concentration or level of an agent at which it is deemed that some specific action should be taken. Action levels are found only in certain substance specific standards by OSHA. In practice the action level is usually set at one-half of the TLV.

Skin notation denotes the possibility that dermal absorption may be a significant contribution to the overall body burden of the chemical. A "SKIN" notation that follows the exposure limit indicates that a significant exposure can be received if the skin is in contact with the chemical in the gas, vapor, or solid form.

Airborne particulate matter is divided into three classes based on the likely deposition with the respiratory tract. While past practice was to provide TLVs in terms of total particulate mass, the recent approach is to take into account the aerodynamic diameter of the particle and its site of action. The three classes of airborne particulate matter are described below.

1. *Inhalable Particulate Mass (IPM) TLVs* are designated for compounds that are toxic if deposited at any site within the respiratory tract. The typical size for these particles can range from submicron size to approximately 100 microns.
2. *Thoracic Particulate Mass (TPM) TLVs* are designated for compounds that are toxic if deposited either within the airways of the lung or the gas-exchange region. The typical size for these particles can range from approximately 5 to 15 microns.
3. *Respirable Particulate Mass (RPM) TLVs* are designated for those compounds that are toxic if deposited within the gas-exchange region of the lung. The typical size for these particles is approximately 5 microns or less.

Nuisance dust is no longer used since all dusts have biological effects at some dose. The term *particulates* not otherwise classified is now being used in place of nuisance dusts.

Biological Exposure Limits (BEl) covers nearly forty chemicals. A BEl has been defined as a level of a determinant that is likely to be observed in a specimen (such as blood, urine, or air) collected from a worker who was exposed to a chemical and who has similar levels of the determinant as if he or she had been exposed to the chemical at the TLV.

Occupational Safety and Health Act (OSH Act): A federal law passed in 1970 to assure, so far as possible, every working man and woman in the nation safe and healthful working conditions. To achieve this goal, the Act authorizes several functions, such as encouraging safety and health programs in the workplace and encouraging labor-management cooperation in health and safety issues.

Ocean Acidification: The on-going decrease in the pH of the earth's oceans, caused by their uptake of anthropogenic carbon dioxide from the atmosphere (Caldeira & Wickett 2003).

Ocean Discharge Waiver: A variance from Clean Water Act requirements for discharge into marine waters.

Ocean Thermal Energy Conversion: The most plentiful renewable energy source in our planet by far is solar radiation: 170,000 TW (170,000 x 10^{12} W) fall on Earth. Because of its dilute and erratic nature, however, it is difficult to harness. To do so, that is, to capture this energy, we must employ the use of large collecting areas and large storage capacities; these requirements are satisfied on Earth only by the tropical oceans. We are all taught at an early age that oceans (and water in general) cover about 71 percent (or 2/3rds) of Earth's surface. In a fitting reference to the vast oceans covering the majority of Earth, Ambrose Bierce (1842–1914) commented: "A body of water occupying about two-thirds of the world made for man who has no gills." So, true, we have no gills; thus, for those who look out upon those vast bodies of water that cover the surface they might ask: What is their purpose? And, of course, this is a good question with several possible answers. In regard to renewable energy, we can look out upon those vast seas and wonder: How can we use this massive storehouse of energy for our own needs? Because it is so vast and deep it absorbs much of the heat and light that comes from the sun. One thing seems certain: Our origin, past, present, and future, lies within those massive wet confines we call oceans.

Ocular: Of or relating to the eye.

Odor Patch: Single-use piece of cardboard or plastic coated with a chemical that changes color when exposed to the gas being measured.

Odor Plume: A downwind air mass containing odorous gases from an odor source like an animal production building or a manure storage facility.

Odor Threshold: The minimum odor of a water or air sample that can just be detected after successive dilutions with odorless water.

Odor Unit: Volume of diluted air divided by the volume of odorous sample air at either detection or recognition.

OECD Guidelines: Testing guidelines prepared by the Organization of Economic and Cooperative Development of the United Nations. They assist in the preparation of protocols for studies of toxicology, environmental fate, etc.

Off-Gassing: The release of chemicals from non-metallic substances under ambient or greater pressure conditions.

Off-Site Facility: A hazardous waste treatment, storage, or disposal area that is located away from the generating site.

Offsets: A concept whereby emissions from proposed new or modified stationary sources are balanced by reductions from existing sources to stabilize total emissions.

Offstream Use: Water withdrawn from surface or ground water sources for use at another place.

OH: Hydroxyl radical.

Oil and Gas Waste: Gas and oil drilling muds, oil production brines, and other waste associated with exploration for, development and production of crude oil or natural gas.

Oilfield Brine: A very saline water that is produced with oil.

Olfactometer: Device that delivers known concentrations of an odorous air sample to a sniffing port for evaluation by trained human panelists who determine the odor detection or recognition thresholds that are reported in odor units.

Olfactometry: Means of measuring odor by using the highly sensitive human sense of smell.

On-Scene Coordinator (OSC): The predesignated EPA, Coast Guard, or Department of Defense official who coordinates and directs Superfund removal actions or Clean Water Act oil- or hazardous-spill response actions.

On-Site Facility: A hazardous waste treatment, storage or disposal area that is located on the generating site.

Onboard Controls: Devices placed on vehicles to capture gasoline vapor during refueling and route it to the engines when the vehicle is starting so that it can be efficiently burned.

One-Hit Model: A mathematical model based on the biological theory that a single "hit" of some minimum critical amount of a carcinogen at a cellular target such as DNA can start an irreversible series of events leading to a tumor.

Onsite Wastewater Treatment System (OWTS): A system relying on natural processes and/or mechanical components that is used to collect, treat, and dispense/discharge wastewater from single dwellings or buildings.

Opacification: The act of process of becoming opaque; clouding.

Opacity: The amount of light obscured by particulate pollution in the air; clear window glass has zero opacity, a brick wall is 100 percent opaque. Opacity is an indicator of change sin performance of particulate control systems.

Opaque: Impenetrable by light; neither transparent not translucent.

Open Burning: Uncontrolled fires in an open dump.

Open Dump: An uncovered site used for disposal of waste without environmental controls.

Operable Unit: Term for each of a number of separate activities undertaken as part of a Superfund site cleanup. A typical operable unit would be removal of drums and tanks from the surface of a site.

Operating Conditions: Conditions specified in a RCRA permit that dictate how an incinerator must operate as it burns different waste types. A trial burn is used to identify operating conditions needed to meet specified performance standards.

Operating Permit: A renewable and revocable permit to operate and maintain an onsite or cluster treatment system in compliance with specific operation or performance requirements.

Operating System: System software that controls a computer and its peripherals. Modern operating systems such as Windows 95 and NT handle many of a computer's basic functions.

Operation and Maintenance: 1. Activities conducted after a Superfund site action is completed to ensure that the action is effective. 2. Actions taken after construction to ensure that facilities constructed to treat waste water will be properly operated and maintained to achieve normative efficiency levels and prescribed effluent limitations in an optimum manner 3. On-going asbestos management plan in a school or other public building, including regular inspections, various methods of maintaining asbestos in place, and removal when necessary.

Operations Level Trained: First responders at the operational level are those persons who respond to releases or potential releases of hazardous material as part of the initial response to the incident for the purpose of protecting nearby persons, the environment, or property from the effects of the release. They shall be trained to respond in a defensive fashion to control the release from a safe distance and keep it from spreading (ANSI/NFPA-42).

Operator Certification: Certification of operators of community and nontransient noncommunity water systems, asbestos specialists, pesticide applicators, hazardous waste transport, and other such specialists as required by the EPA or a state agency implementing an EPA-approved environmental regulator program.

Opiate: A drug, hormone, or other chemical substance having sedative or narcotic effects similar to those from substance containing opium or its derivatives.

Opioid: A synthetic substance with opiate-like qualities.

Optimal Corrosion Control Treatment: An erosion control treatment that minimizes the lead and copper concentrations at users' taps while also ensuring that the treatment does not cause the water system to violate any national primary drinking water regulations.

Oral Exposure: This route of exposure includes ingesting food, water, and other substances (e.g., dirt) that might contain chemicals.

Ingesting chemicals does not automatically mean that some of the chemical will enter your body. The digestive tract is a long tube that starts at the mouth and ends at the anus. It is not until a chemical is absorbed through the intestines that the chemical enters the body. To use a gross example, if your intestines were unwound and the gastrointestinal tract was made into a long tube, one could look into the mouth and see daylight out the other end. Therefore, unlike the lung, oral exposure does not directly lead to chemicals entering the body. This illustrates the difference between exposure, which is contact with a chemical and dose, which is the amount of a chemical that enters the body.

Using tuna fish as an example, ingesting mercury in tuna is an exposure to mercury. The amount of mercury that is absorbed across the intestines and enters the bloodstream is the dose of mercury. The dose controls whether or not toxic effects will result from exposure.

Although eating food and drinking water are the most common forms of oral exposure, others are also important. One common example used in the environmental field is incidentally ingesting soil contaminated with chemicals. Most of us do not intentionally ingest soil, but we will contact soil through some regular activities (e.g., landscaping, gardening). This soil remains on the skin for some period of time. If someone fails to wash their hands and then puts their hand in their mouth, the soil particles on the hand can enter the mouth and be ingested. Chemicals sticking to these soil particles will also be ingested. This can also result from someone eating a sandwich on a lunch break without washing his or her hands. These particles can be too small to see with the naked eye.

Surprisingly, this is the type of exposure that typically leads to the greatest dose and risk or toxic effects at sites contaminated with chemicals. In part, this is because the intestines are designed to absorb chemicals (e.g., nutrients). Unwanted chemicals will get absorbed along with the nutrients, so absorption can be high for some chemicals. This route of exposure can lead to very high doses because concentrations of chemicals are generally much higher in soil than in other media (e.g., air). Soil used for landscaping by homeowners is regulated to prevent excessive amounts of chemicals from being present.

Oral Toxicity: Ability of a pesticide to cause injury when ingested.

Orange Book: The Department of Defense Trusted Computer System Evaluation Criteria. It provides information to classify computer systems, defining the degree of trust that may be placed in them.

Organelle: A specialized part of a cell that resembles and functions as an organ.

Organic: 1. Referring to or derived from living organisms. 2. In chemistry, any compound containing carbon.

Organic Chemistry: The branch of chemistry concerned with compounds of carbon.

Organic Matter: Chemical substances of animal or vegetable origin containing carbon.

Organic Nitrogen: Nitrogen combined in organic molecule such as proteins and amino acids.

Organic Soil: A soil that contains a high percentage (more than 15to 20 percent) of organic matter throughout the soil column.

Organic Substance: Any substance containing carbon.

Organism: Any form of animal or plant life.

Organophosphates: Pesticides that contain phosphorus; short lived, but some can be toxic when first applied.

Organophosphorus: Of, relating to, or being a phosphorus-containing organic pesticide (as malathion) that acts by inhibiting cholinesterase.

Organophyllic: A substance that easily combines with organic compounds.

Organotins: Chemical compounds used in anti-foulant paints to protect the hulls of boats and ships, buoys, and pilings from marine organism such as barnacles.

Original AHERA Inspection/Original Inspections/Inspection: Examination of school buildings arranged by Local Education agencies to identify asbestos-containing-materials, evaluate their condition, and take samples of materials suspected to contain asbestos; performed by EPA-accredited inspectors.

Original Generation Point: Where regulated, medical or other material first becomes waste.

Orthographic: Relating to the physical geography of mountains and mountain ranges.

OSHA: In 1970, President Richard M. Nixon signed into law The *Occupational Safety and Health Act* (OSH Act). The Act is a federal statute that aims to protect employees in the workplace from occupational illness and injuries caused by exposure to biological and physicals hazards and hazardous chemicals. When Congress passed this act, it empowered the Occupational Safety and Health Administration (OSHA) to regulate certain aspects of the workplace, thereby reducing or eliminating the incidence of chemically induced occupational illnesses and injuries.

In regards to OSHA, it is important to point out the significance of Section 5 duties under 29 USD 654 OSH Act of 1970. The following is commonly called OSHA's General Duty Law.

OSH Act Section-5 Duties

(a) Each employer—
    1. shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees;
    2. shall comply with occupational safety and health standards promulgated under this Act.

(b) Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct.

When hazardous chemicals are present in the workplace, OSHA requires employers to limit employee exposure to certain permissible limits averaged over the eight-hour (Time Weighted Average—TWA) workday. Although these limits are established by OSHA, on occasion, the National Institute for Occupational Safety and Health (NIOSH) recommends a revision of the limits based upon its own research efforts. Again, under the

General Duty Clause of the OSH Act it is the responsibility of OSHA and NIOSH to ensure that employers provide every working individual with a safe and healthful working environment.

Meyer (2005) points out that in 1983, OSHA first enacted a standard that sets minimum requirements to which employers must adhere for communicating information to workers: as mentioned earlier, it is known as the *Hazard Communication Standard* (often referred to as *HazCom* or *right-to-know law*). Briefly, its intent is to assure workers of their right to know about the hazards associated with chemicals to which they are being exposed in their places of employment. This law prohibits employers from directing workers to handle hazardous chemicals without first training the workers on the potential hazards involved; workers must also be trained on how to protect themselves from the chemical hazards. This law applies to all chemical substances know to be present within the workplace, chemicals to which workers could be exposed under normal working conditions, and chemicals to which workers could be exposed in an emergency.

OSHA Standards: Chemical Safety: Chemical safety hazards are addressed in specific standards for the general and constructions industries. In this section highlights OSHA standard and other federal standards related to chemical hazards.

General Industry (29 CFR 1910)

- 1910 Subpart H, Hazardous materials
    - 1910.106, Flammable and combustible liquids
    - 1910.119, Process Safety Management Standard
        - Appendix A, List of highly hazardous chemicals, toxics, and reactives
        - Appendix B, Block flow diagram and simplified process flow diagram
        - Appendix C, Compliance guidelines and recommendations for process safety management
        - Appendix D, sources of further information
    - 1910 Subpart l, Fire protection
        - 1910.156, Fire brigades
    - 1910 Subpart Z, Toxic and hazardous substances
        - 1910.1200, Hazard communication
        - 1910.1450, Occupational exposure to hazardous chemicals in laboratories

Construction Industry (29 CFR 1926)

- 1926 Subpart D, Occupational health and environmental controls
    - 1926.59, Hazard communication
    - 1926.64, Process safety management of highly hazardous chemicals
        - Appendix A, B, and C

Other Federal

Department of Transportation (DOT)

- 49 CFR 100-185, Subtitle B—Other Regulations Relating to Transportation.
    - Research and Special Programs Administration. Includes a Segregation Table for Hazardous Materials under section 177.848.

Environmental Protection Agency (EPA)

- 40 CFR68, Protection of the Environment: Chemical Accident Prevention Provisions. Includes a list of regulated substances and thresholds, the petition process for adding or deleting substances to/from the list of regulated substances, the requirements for owners or operators of stationary sources concerning the prevention of accidental releases, and approved state accidental release prevention programs.

OSHA Standards General Industry (29 CFR 1910): A brief description of general industry standards is provided in the following. Note that the listing provided below is taken from OSHA's elaws-*OSHA Hazard Awareness Advisor* @ [http://www.dol.gov.elasw/osha/hazard/keywords.asp].

1903.2 Posting of notice and availability of the Act: Provides for the posting of notices, which inform employees of their protections and obligations under the OSHA Act. It also provides contact information concerning availability of the Act, regulations and applicable standards.

1904.2—1904.7 Log of occupational injuries and illness: Provides rules for the maintenance of a log (OSHA 300 Log) and summary of occupational injuries and illness, including the period covered and access and retention of records.

1904.8 Reporting of fatality or multiple hospitalization incidents: Provides rules for the reporting of the death of an employee or the in-patient hospitalization of three or more employees resulting from a work-related incident.

1904.16 Statistical reporting of occupational injuries and illness: Obligation to maintain a log of occupational injuries and illness upon being notified in writing by the Bureau of Labor Statistics that the employer has been selected to participate in a statistical survey of occupational injuries and illness.

1910.10 Spray finishing using flammable and combustible materials: Defines requirements for the equipment, processes, and materials used in performing spray finishing using flammable and combustible materials.

1910.22 General requirements for walking-working surfaces: Defines requirements for physical upkeep of the workplace, including those for housekeeping, aisles and passageways, covers and guardrails, and floor loading protection.

1910.23 Guarding floor and wall openings and holes: Identifies the need to protect workers against accidental falls through holes in the floor or roof. It also requires guarding of wall openings or access openings.

1910.24 Fixed industrial stairs: Provides specifications for the safe design and construction of fixed general industrial stairs.

1910.25 Portable wood ladders: Prescribes rules and establishes minimum requirements for the construction, care, and use of the common types of portable wood ladders.

1910.26 Portable metal ladders: Prescribe rules and establishes minimum requirements for the construction, care, and use of the common types of portable metal ladders.

1910.27 Fixed ladders: Prescribes rules and establishes minimum requirements for the construction of fixed ladders.

1910.28 Safety requirements for scaffolding: Prescribes general requirements for the construction, operation, maintenance, and use of scaffolds used in the maintenance of buildings and structures.

1910.29 Manually propelled mobile ladder stands and scaffolds: Prescribes rules and requirements for the design, construction, and use of mobile work platforms and rolling scaffolds.

1910.30 Other working surfaces: Prescribes rules and requirements for the design, construction, and use of other working surfaces.

1910.36 General requirements: Provides general fundamental requirements essential to providing a safe means of egress from fire and like emergencies.

1910.37 Means of egress, general: Provides specifications for the design, construction, and maintenance of exit, automatic sprinkler systems, fire alarm signaling systems, fire retardant paint, and exit markings.

1910.38 Employee emergency plans and fire prevention plans: Prescribes requirements for the designated actions employers and employees must take to ensure employee safety from fire and other emergencies.

1910.66 Powered platforms for building maintenance: Prescribes general requirements for the installation of powered platforms dedicated to interior or exterior building maintenance of a specific structure or group of structures.

1910.67 Vehicle-mounted elevating and rotating work platforms: Provides specifications for the design and operation of vehicle-mounted elevating and rotating work platforms.

1910.68 Manlifts: Provides specifications for the construction, maintenance, inspection, and operation of manlifts in relation to accident hazards.

1910.94 Ventilation: Defines criteria for determining whether or not ventilation equipment and systems are required. Also defines specifications for the design, construction, and use of ventilation equipment and systems.

1910.95 Occupational noise exposure: Defines when protection against occupational noise must be provided by employer. Defines the means of measuring occupational noise levels, and employee hearing levels. Defines requirements for employer-provided hearing protection equipment and training.

1910.97 Nonionizing radiation: Establishes radiation protection guide for exposure to electromagnetic radiation and the requirements for a warning symbol.

1910.101 Compressed gases: Defines requirements for inspection, in-plant handling, storage, and utilization of all compressed gases. Also requires safety relief devices for compressed gas containers. Requirements reference Compressed Gas Association (CGA) Pamphlets.

1910.102 Acetylene: Defines requirements for cylinders, piped systems, and generators and filling cylinders for acetylene. Requirements reference Compressed Gas Association (CGA) Pamphlets.

Did You Know?

Acetylene is so flammable that the National Electric Code (NEC) has a special designation (its most stringent) for using electrical equipment around acetylene. No other substance falls into this classification!

1910.103 Hydrogen: Defines requirements for the design, construction, and testing of gaseous and liquefied hydrogen systems.

1910.104 Oxygen: Defines requirements for the design, construction, and testing of bulk oxygen systems.

1910.105 Nitrous oxide: Refers to Compressed Gas Association (CGA) Pamphlet for requirements for design, installation, maintenance, and operation of piped systems for the plant transfer and distribution of nitrous oxide.

1910.106 Flammable and combustible liquids: Defines classes of flammable and combustible liquids and their safe storage and use.

1910.109 Explosives and blasting agents: Defines requirements for storage, transportation, and use of explosives and blasting agents. Includes provisions for water gel explosives, ammonium nitrate, and small arms ammunition, propellants, and primers.

1910.110 Storage and handling of liquefied petroleum gases: Provides requirements for handing and containing and transporting liquefied petroleum gas.

1910.111 Storage and handling of anhydrous ammonia: This standard is intended to apply to the design, construction, location, installation, and operation of anhydrous ammonia systems including refrigerated ammonia storage systems.

1910.119 Process Safety Management (PSM) of highly hazardous chemicals: Contains requirements for preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals.

1910.120 Hazardous waste operations and emergency response: Describes the required procedures and operations for conducting hazardous waste operations and for creating and implementing emergency response plans.

1910.122-.126 Dipping and Coating Operations: Defines requirements for construction, ventilation, use of dipping and coating operations. Defines requirements for conditions and operations in immediate vicinity of dipping, and coating operations.

1910.132 General requirements: Defines general criteria for using personal protective equipment (PPE), and the requirements for its actual use.

1910.133 Eye and face protection: Explains when appropriate eye or face protection should be used and the requirements for their construction and use.

1910.134 Respiratory protection: Describes conditions under which respiratory protection is required. Also provides specifications for the use of respirators.

1910.135 Head protection: Describes conditions under which head protection is required. Also provides criteria for adequate protective helmets.

1910.136 Foot protection: Describes conditions under which foot protection is required. Also provides criteria for adequate protective footwear.

1910.137 Electrical protective equipment: Provides requirements for design, care, and use for electrical protective equipment.

1910.138 Hand protection: Describes conditions under which hand protection is required. Also provides criteria for selecting hand protection.

1910.141 Sanitation: Provides requirements for general housekeeping and maintenance of the premises, the keeping and use of the water supply, toilet facilities, change rooms, clothes drying facilities, consumption of food and beverages on the premises, and food handling.

1910.142 Temporary labor camps: Regulates the location and facilities of camps that house temporary workers.

1910.144 Safety color code for making physical hazards: Defines the color coding system for identifying different types of physical hazards.

1910.145 Specifications for accident prevention signs and tags: Provides the color coding system for identifying different types of physical hazards.

1910.146 Permit-required confined spaces: Contains requirements for practices and procedures to protect employees from the hazards of entry into permit-required confined spaces.

1910.147 The control of hazardous energy (lockout/tagout; LOTO): Requires employers to establish a program and utilize procedures for affixing appropriate lockout or tagout devices to energy isolating devices. This will prevent unexpected energization, start-up, or release of stored energy to prevent injury to employees.

1910.151 Medical services and first aid: Provides general requirements for medical services and first aid.

1910.156 Fire brigades: Contains requirements for the organization, training, and personal protective equipment of fire brigades whenever they are established by an employer.

1910.157 Portable fire extinguishers: Provides requirements for the placement, use, maintenance, and testing of portable fire extinguishers provided for the use of employees.

1910.158 Standpipe and hose systems: Provides requirements for the placement, use, maintenance, and testing of standpipe and hose systems.

1910.159 Automatic sprinkler systems: Provides requirements of the placement, use, maintenance, and testing of automatic sprinkler systems.

1910.160 Fixed extinguishing systems, general: Provides requirements for the use and maintenance of general fixed extinguishing systems

1910.161 Fixed extinguishing systems, dry chemical: Provides requirements for the use and maintenance of fixed extinguishing systems using dry chemical as the extinguishing agent.

1910.162 Fixed extinguishing systems, gaseous agent: Provides requirements for the use and maintenance of fixed extinguishing systems using a gas as the extinguishing agent.

1910.163 Fixed extinguishing systems, water spray and foam: Provides requirements for the use of fixed extinguishing systems using water or foam solution as the extinguishing agent.

1910.164 Fire detection systems: Provides requirements for the placement, use, maintenance, and testing of fire detection systems.

1910.165 Employee alarm systems: Provides requirements for the use, maintenance, and testing of employee alarm systems.

1910.169 Air receivers: Provides requirements for construction, installation, use, and maintenance of compressed air receivers.

1910.176 Handling materials—general: Provides requirements for use of mechanical handling equipment, and for materials storage.

1910.177 Servicing multi-piece and single piece rim wheels: Provides requirements for the servicing of multi-piece and single piece rim wheels.

1910.178 Powered industrial trucks: Contains requirements relating to training of operators, and the design, maintenance, and use of powered industrial trucks.

1910.179 Overhead and gantry cranes: Provides requirements for the design, maintenance, use, and inspection of overhead and gantry cranes.

1910.181 Derricks: Provides requirements for the use, inspection, testing, and maintenance of derricks.

1910.183 Helicopters: Provides requirements for the preparation, use, equipment, and operation of helicopter cranes.

1910.184 Slings: Provides requirements for the safe use, inspection, and maintenance of slings made from alloy steel chain, wire rope, metal mesh, natural or synthetic fiber rope, and synthetic web.

1910.187 Crawler locomotive and truck cranes: Provides requirements for the use, inspection, testing, and maintenance of crawler locomotive and truck canes.

1910.212 General requirements for all machines: Provides general requirements for machine guarding to protect employees in the machine area from hazards, and for anchoring fixed machinery.

1910.213 Woodworking machinery: Provides requirements for general construction of woodworking machines, and for the machine guards. Also addresses the inspection and maintenance of woodworking machinery.

1910.215 Abrasive wheel machinery: Provides requirements for the use of guards and flanges on abrasive wheel machinery, and for the design of such guards and flanges.

1910.216 Mills and calendars in the rubber and plastics industries: Provides requirements for the installation, design, placement, and use of mills and calendars in the rubber and plastics industries.

1910.217 Mechanical power presses: Provides requirements for the guarding, construction, and operation of mechanical power presses. Also provides requirements for the design, construction, setting, and feeding of dies. There are also requirements for the reporting of injuries to employees.

1910.218 Forging machines: Provides requirements for the use, installation, inspection, and maintenance of different types of forging machines.

1910.219 Mechanical power-transmission apparatus: Provides requirements for the installation, guarding, maintenance, and use of mechanical power-transmission apparatus in general. There are specific provisions for shafting; pulleys; belt, rope, and chain drives; and gears, sprockets, and chains.

1910.242 Hand and portable powered tools and equipment, general: Provides general requirements for the safe condition and cleaning of hand and portable powered tools and equipment.

1910.243 Guarding of portable powered tools: Provides requirements for the guarding of portable powered tools. Also defines requirements for the design, use, inspection, and maintenance of explosive actuated fastening tools, and power lawnmowers.

1910.244 Other portable tools and equipment: Provides requirements for the operation and maintenance of jacks and abrasive blast cleaning nozzles.

1910.252 General requirements: Provides general requirements for fire prevention and protection, protection of personnel, and health protection and ventilation when welding, cutting, or brazing.

1910.253 Oxygen-fuel gas welding and cutting: Provides requirements for the selection, use, and operation of oxygen-fueled welding equipment.

1910.254 Arc welding and cutting: Provides requirements for the selection, use, application, and installation of arc welding equipment.

1910.255 Resistance welding: Provides requirements for the installation, use, design, guarding, and maintenance of resistance welding equipment in general. Additional provisions address spot and seam welding machines (nonportable), portable welding machines, and flash welding equipment.

1910.261 Pulp, paper, and paper-board mills: Provides rules and safety requirements for the safe design and operation of pulp, paper, and paper-board mills.

1910.262 Textiles: Provides general safety requirements, and requirements for the design, guarding, and use of textile equipment, processes, materials, protective equipment, and workroom ventilation.

1910.263 Bakery equipment: Provides requirements governing the design, installation, operation, and maintenance of machinery and equipment used within a bakery.

1910.264 Laundry machinery and operations: Provides requirements for the design and operation of equipment used in laundries.

1910.265 Sawmills: Provides rules and safety requirements for the safe design and operation of sawmills.

1910.266 Logging operations: Establishes safety practices, means, methods, and operations for all types of logging, regardless of the end use of wood.

1910.268 Telecommunications: Sets forth safety and health standards that apply to the work conditions, practices, means, methods, operations, installations, and processes performed at: telecommunications centers, and telecommunications field installations.

1910.269 Electric power generation, transmission, and distribution: Provides rules governing the operation and maintenance of electrical power generation, control, transformation, transmission, and distribution lines and equipment.

1910.272 Grain handling facilities: Provides requirements for the control of grain dust fires and explosions, and certain other safety hazards associated with grain handling facilities.

1910.303 General requirements: Provides requirements for the installation and use of electrical equipment. Sets forth safety standards that apply to working conditions around electrical equipment.

1910.304 Wiring design and protection: Provides requirements for the safe design and protection of electrical wiring.

1910.305 Wiring methods, components, and equipment for general use: Provides requirements for the design and installation of electrical equipment for general use, and for methods of wiring.

1910.306 Specific purpose equipment and installations: Provides requirements for the design and installation of electrical specific purpose equipment.

1910.307 Hazardous (classified) locations: Provides requirements for electrical equipment and wiring in locations which are classified as hazardous depending on the properties of the flammable vapors, liquids, or gases, or combustible dusts or fibers which may be present.

1910.308 Special systems: Provides requirements for the design and installation of equipment of special electrical systems, and for their wiring methods.

1910.332 Training: Provides requirements for training of employees who face a risk of electrical shock that is not reduced by the requirements of sections 1910.303 through 1910.308.

1910.333 Selection and use of work practices: Provides requirements on when and how work practices should be employed to prevent electrical shock or other injuries resulting from electrical contacts when work is performed near or on equipment which may be energized.

1910.334 Use of equipment: Provides requirements for the handling, inspection, and use of electrical equipment.

1910.335 Safeguards for personnel protection: Provides requirements for the use of protective equipment and alerting techniques for the protection of personnel

1910.410 Qualifications of dive teams: Provides requirements for dive team members and for designation person-in-charge.

1910.420 Safe practices manual: Provides requirements for developing and maintaining a safe practices manual.

1910.421 Pre-dive procedures: Establishes all information that must be provided and all procedures that must be followed prior to each diving operation.

1910.422 Procedures during dive: Provides requirements for the procedures and equipment that must be maintained during each diving operation.

1910.423 Post-dive procedures: Provides requirements for the procedures that must be performed after each operation.

1910.424 SCUBA diving: Establishes limits and procedures for engaging in SCUBA diving by an employer.

1910.425 Surface-supplied air diving: Establishes limits and procedures for engaging in surface-supplied air diving by an employer.

1910.426 Mixed-gas diving: Establishes limits and procedures for engaging in mixed-gas diving by an employer.

1910.427 Liveboating: Establishes limits and procedures for engaging in diving operations involving liveboating by an employer.

1910.430 Equipment: Provides requirements for the design, construction, maintenance, and use of diving equipment by an employer.

1910.440 Recordkeeping requirements: Provides requirements for the recording of occurrences, and the availability of diving records.

1910.1000 Air contaminants: The regulation establishes the permissible exposure limits (PEL) for more than three hundred chemicals regulated by OSHA. The PEL is based on an eight-hour period of work. Some substances also have a ceiling limit, or a short-term exposure limit (STEL).

Employers are required to employ engineering controls and substitution to eliminate or reduce the hazard, before placing workers in respiratory protection.

Some chemicals may have a “Skin Notation” which means that dermal protection such as barrier creams and gloves are needed to safely work with the chemical.

1910.1001 Asbestos: Provides requirements governing the regulation of occupational exposure to asbestos, including exposure limits, personal protective equipment, engineering controls to reduce exposure, hazard communication, medical surveillance, and recordkeeping.

1910.1003 13 Carcinogens: Provides requirements for the following chemicals:

- 4-Ntirobiphenyl, Chemical Abstracts Service Register Number (CAS No.) 92933
- alpha-Naphtylamine, CAS No. 134327 (1910.1004)
- methyl chloromethyl ether, CAS No. 91941 (1910.1006)
- 3, 3-Dichlorobenzidine (and its salts) CAS No. 91941 (1910.1007)
- bis-Chloromethyl ether, CAS No. 542881 (1910.1008)
- beta-Napthylamine, CAS No. 91598 (1910.1009)
- Benzidine, CAS No. 92875 (1910.1010)
- 4-Aminodiphenyl, CAS No. 92671 (1910.1011)
- Ethyleneimine, CAS No. 151564 (1910. 1012)
- Beta Propiolactone (1910.1013)
- 2-acetylaminofluorene (1010.1014)
- 4-deimethylaminoazobenzene (1910.1015)
- -nitrosodimethylamine (1910.1016)

1919.1003 Coal tar pitch volatiles: Defines coal tar pitch volatiles as used in 1910.1000 (Table Z-1).

1910.1015 Lead: Provides requirements for the monitoring and control of employee exposure to metallic lead, inorganic lead compounds, and lead soaps.

1910.1017 Vinyl chloride: Provides requirements for the control of employee exposure to vinyl chloride (chloroethene), Chemical Abstracts Service Registry No.

75014. It applies to the manufacture, reaction, packaging, repacking, storage, handling, or use of vinyl chloride or polyvinyl chloride, but does not apply to the handling or use of fabricated products made of polyvinyl chloride.

1910.1018 Inorganic arsenic: This standard applies to all occupational exposures to inorganic arsenic except that this section does not apply to employee exposures in agriculture or resulting from pesticide application, the treatment of wood with preservatives, or the utilization of arsenically preserved wood.

1910.1020 Exposure and medical records access: Provides employees, their representatives, and the assistant secretary access to employee exposure and medical records.

1910.1027 Cadmium: This standard applies to all occupational exposures to cadmium and cadmium compounds, in all forms, and in all industries covered by the Occupational Safety and Health Act, except the construction-related industries, which are covered under 29 CFR 1926.63.

1910.1028 Benzene: This section applies to all occupational exposures to benzene, Chemical Abstracts Service Registry No. 71-43-2. This section does not apply to: the storage, transportation, distribution, dispensing, sale, or use of gasoline, motor fuels, or other fuels containing benzene subsequent to its final discharge from bulk wholesale storage facilities.

1910.1029 Coke oven emissions: This section applies to the control of employee exposure to coke oven emissions, except that this section shall not apply to working conditions with regard to which other federal agencies exercise statutory authority to prescribe or enforce standards affecting occupational safety and health.

1910.1030 Blood-borne pathogens: Provides requirements for the control of employee exposure to human blood or other potentially infectious materials.

1910.1043 Cotton dust: This section applies to the control of employee exposure to cotton dust in all workplaces where employees engage in yarn manufacturing, engage in slashing and weaving operations, or work in waste houses for textile operations.

1910.1044 1, 2-dibromo-3-chloropropane: This section applies to occupational exposure to 1, 2-dibromo-3-chloropropane (DBCP).

1910.1045 Acrylonitrile: This section applies to occupational exposures to Acrylonitrile (AN), Chemical Abstracts Service Registry No. 000107131.

1910.1047 Ethylene oxide: This section applies to occupational exposures to ethylene oxide (EtO), Chemical Abstracts Service Registry No. 75-21-8.

1910.1048 Formaldehyde: This standard applies to all occupational exposures to formaldehyde, i.e., from formaldehyde gas, its solutions, and materials that release formaldehyde.

1910.1050 Methylenedianiline: This section applies to occupational exposure to MDA, Chemical Abstracts Service Registry No. 1010-77-9.

1910.1052 Methylene chloride: This applies to occupational exposures to methylene chloride (MC) or dichloromethane (DCM).

1910.1096 Ionizing radiation: This applies to occupational exposure to radiation which includes alpha rays, beta rays, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other atomic particles; but such term does not include sound or radio waves, or visible light, or infrared or ultraviolet light.

Note: This standard was recently renumbered form 1910.96.

1910.1200 Hazard communication: Provides requirements ensuring that the hazards of all chemicals produced or imported are evaluated, and that information concerning their hazards is transmitted to employers and employees by various means, including container labeling and other forms of warning, material safety data sheets, and employee training.

1910.1450 Hazardous Chemicals in laboratories: Provides requirements for the control of occupational exposure to hazardous chemicals in laboratories.

Osmosis: The movement of water molecules through a thin membrane. The osmosis process occurs in our bodies and is also one method of desalinating saline water.

Osteosclerosis: Abnormal hardening of the bone or bone marrow.

Other Biomass: This category of biomass energy includes: agricultural byproducts/crops (agricultural by-products, straw); other biomass gas (digester waste alcohol); other biomass liquids (fish oil liquid acetonitrite, waste, tall oil, waste alcohol); other biomass solids (medical waste, solid by-products); sludge waste; and tires.

Other Glass: Recyclable glass from furniture, appliances, and consumer electronics. Does not include glass from transportation products (care trucks or shipping containers) and construction or demolition debris.

Other Nonferrous Metals: Recyclable nonferrous metals such as lead, copper, and zinc from appliances, consumer electronics, and nonpackaging aluminum products. Does not include nonferrous metals from industrial applications and construction and demolition debris.

Other Paper: For recyclable paper from books, third-class mail, commercial printing, paper towels, plates, and cups; and other nonpackaging paper such as posters, photographic papers, cards and games, milk cartons, folding boxes, bags, wrapping paper, and paperboard. Does not include wrapping paper or shipping cartons.

Other Plastics: Recyclable plastic from appliances, eating utensils, plates, containers, toys, and various kinds of equipment,. Does not include heavy-duty plastics such as yielding materials.

Other Removals: Unutilized wood volume from cut or otherwise killed growing stock, from cultural operations such as precommercial thinnings, or from timberland clearing. Does not include volume removed from inventory through reclassification of timber land to productive reserved forest land.

Other Solid Wastes: Recyclable nonhazardous solid wastes, other than municipal solid waste, covered under Subtitle D of RCRA.

Other Sources: Sources of Roundwood products that are not growing stock. These include available dead, rough, and rotten trees, trees of noncommercial species, trees less the 5.0 inches d.b.h., tops, and Roundwood harvested Roundwood non-forest land (for example, fence rows).

Outdoor Air (OA): Outdoor air is the "fresh" air mixed with return air (RA) to dilute contaminants in the supply air.

Outfall: The place where a sewer, drain, or stream discharges; the outlet or structure through which reclaimed water or treated effluent is finally discharge to a receiving water body.

Overburden: Rock and soil cleared away before mining.

Overcurrent Devices: Overcurrent devices that limit the current that can flow through a circuit or electrical device should be included in any electrical system design. Such a device cuts off power if current exceeds a given limit. The two most common overcurrent devices in use at present are fuses and circuit breakers.

Fuses are composed of materials (usually lead or a lead alloy) that are designed to limit the current flow in the circuit. When current in the circuit exceeds some limiting value, the lead or lead alloy material heats above its melting point and separates, opening the circuit, thereby stopping the flow of current. Safety engineers must understand that fuses are rated at certain design levels. In other words, not every fuse is suited for every electrical circuit. In fact, the danger with fused circuits is when the fuses are replaced with fuses that are too large for the circuit they are designed to protect. When this occurs, so does the danger that too much current will be allowed to flow in a circuit not designed to handle the high level of current flow, which could lead to electrical fires and other problems.

Circuit breakers are actually a form of switch designed to open when current passing through them exceeds a designed limit. Circuit breakers are designed to limit current flow in two different ways. One type is designed to open when the breaker temperature reaches a predetermined level. A common problem with this type of breaker is that the temperature of the environment around it can affect its operation. The second type is magnetic, and opens when a predetermined current level is reached. The advantage of this type of breaker is that environmental conditions have little impact on its operation.

Overdraft: The pumping of water from a ground water basin or aquifer in excess of the supply flowing into the basin; results in a depletion or "mining" of the groundwater in the basin.

Overfire Air: Air forced into the top of an incinerator or boiler to fan the flames.

Overflow Rate: One of the guidelines for design of the settling tanks and clarifiers in a treatment plant; used by plant operators to determine if tanks and clarifiers are over- or under-used.

Overgrazing: Consumption of vegetation on rangeland by grazing animals to the point that the vegetation cannot be renewed or is renewed at a rate slower than consumption.

Overhead Power Lines (Sample Safe Work Practice): Follow this safe work practice when work is performed near overhead lines.

1. Determine the voltage of the overhead lines. If necessary contact the owner of the overhead line.
2. Do not perform work on overhead lines unless the overhead lines are:
   a. De-energized and grounded
      1. Arrangements can be made with the individual or organization that operates or controls the

    lines to de-energize and visibly ground them at the point of work.
  b. Suitably guarded
    1. Arrangements can be made to use protective measures, such as guarding, isolating, or insulation. These precautions shall prevent employees from directly contacting overhead lines with any part of their body or indirectly through conductive materials, tools, or equipment.

3. Ensure all employees working with equipment on the ground or in an elevated position near unguarded overhead lines remain beyond the approach boundary as follows:

Nominal System Voltage Range	*Exposed Movable Conductor*
Less than 50	Not Specified
Greater than 50 v	10 feet

4. Ensure the longest conductive object employees might contact or use can not come closer to any unguarded, energized overhead power line than the approach boundaries specified.

Note: Any objects not insulated for the voltage involved are considered to be conductive.

5. Ensure vehicles and other mechanical equipment, capable of having an elevated structure near energized overhead lines; remain outside the approach boundary as specified.
6. Ensure vehicles and equipment in transport remain farther than foor feet from live overhead lines. Meet all transportation regulatory safe guards. If this distance cannot be maintained then the owner of the overhead lines will need to be contacted to remove the line.
7. Do not attempt to exit a vehicle or piece of equipment with rubber tires that has made contact with live overhead line(s) until the owner of the line(s) has determined it is safe.
8. Do not stand at the ground location of a vehicle or mechanical equipment when there is any possibility of overhead line contact.
9. Never touch a vehicle or mechanical equipment with an elevated structure near an overhead line.

Note: It may not be apparent but the potential for electric shock may be present if the energized line is touching the equipment.

Overland Flow: A land application technique that cleanses waste water by allowing it to flow over a sloped surface. As the water flows over the surface, contaminants are absorbed and the water is collected at the bottom of the slope for reuse.

Overload: Hindrance of system operation by placing excess burden on the performance capabilities of a system component.

Oversized Regulated Medical Waste: Medical waste that is too large for plastic bags or standard containers.

Overthrust: A low-angle thrust fault of large scale, with total displacement (lateral or vertical) generally measured in kilometers.

Overturn: One complete cycle of top to bottom mixing of previously stratified water masses. This phenomenon may occur in spring or fall, or after storms, and results in uniformity of chemical and physical properties of water at all depths.

Oxidant: A collective term for some of the primary constituents of photochemical smog.

Oxidation: When a substance either gains oxygen, or loses hydrogen or electrons in a chemical reaction. One of the chemical treatment methods.

Oxidation Pond: A man-made (anthropogenic) body of water in which waste is consumed by bacteria, used most frequently with other waste-treatment processes; a sewage lagoon.

Oxidation-Reduction: The (redox) process where electrons are lost and gained.

Oxidize: To combine with oxygen.

Oxidizer: Also know as an oxidizing agent, a substance that oxidizes another substance. Oxidizers are a category of hazardous materials that may assist in the production of fire by readily yielding oxygen.

Oxidizing Agent: A substance that oxidizes another substance. Oxidizing agents can cause other materials to combust more rapidly (or upon contact) or make fires burn more strongly.

Oxygen: An element that readily unites with materials.

Oxygen Deficient Atmospheres: The legal definition of an atmosphere where the oxygen concentration is less than 19.5 percent by volume of air. That is, any level below the PEL of 19.5 percent.

Oxygen Demand: The need for molecular oxygen to meet the needs of biological and chemical processes in water. Even though very little oxygen will dissolve in water, it is extremely important in biological and chemical processes.

Oxygen Sag Curve: The oxygen content in a stream or river system after organic pollution is introduced into the water body; organic pollution causes a profusion in growth of organisms that tends to decrease the amount (sag) of oxygen available.

Oxygenated Fuels: Gasoline which has been blended with alcohols or others that contain oxygen in order to reduce carbon monoxide and other emissions.

Oxygenated Solvent: An organic solvent containing oxygen as part f the molecular structure. Alcohols and ketones are oxygenated compounds often used as paint solvents.

Ozonation: Water and odor control technology using ozone (O_3) either in the air or dissolved in water to oxidize pathogens and odorous compounds.

Ozone: Just Another Form of Oxygen: The compound O_3. It is found naturally in the atmosphere in the ozonosphere and is also a constituent of photochemical smog. Ozone (O_3) is a highly reactive pale-blue gas with a penetrating odor. Ozone is an allotropic modification of oxygen. An allotrope is a variation of an element that possesses a set of physical and chemical properties significantly different from the “normal” form of the element. Only a few elements have allotropic forms; oxygen, phosphorous, and sulfur are some of them. Ozone is just another form of oxygen. It is formed when the molecule of the stable form of oxygen (O_2) is split by ultraviolet (UV) radiation or electrical discharge; it has three instead of two atoms of oxygen per molecule. Thus, its chemical formula is represented by O_3.

Ozone forms a thin layer in the upper atmosphere, which protects life on Earth from ultraviolet rays, a cause of skin cancer. At lower atmospheric levels it is an air pollutant and contributes to the greenhouse effect. At ground level, ozone, when inhaled, can cause asthma attacks, stunted growth in plants, and corrosion of certain materials. It is produced by the action of sunlight on air pollutants, including car exhaust fumes, and is a major air pollutant in hot summers. More will be said about ozone and greenhouse effect later in the text.

Ozone Depletion: While ozone concentrations vary naturally with sunspots, the seasons, and latitude, these processes are well understood and predictable. Scientists have established records spanning several decades that detail normal ozone levels during these natural cycles. Each natural reduction in ozone levels has been followed by a recovery. Recently, however, convincing scientific evidence has shown that the ozone shield is being depleted well beyond changes due to natural processes (USEPA 2009).

Ozone Holes: Holes created in the ozone layer because of chemicals, especially CFCs. Designation of amount of such depletion as an “ozone hole” is made when the detected amount of depletion exceeds 50 percent.

Ozone Layer: The protective layer in the atmosphere, about fifteen miles above the ground that absorbs some of the sun’s ultraviolet rays thereby reducing the amount of potentially harmful radiation that reaches the earth’s surface.

P

Package Plant: Term commonly used to describe an aerobic treatment unit serving multiple dwellings or an educational, health care, or other large facility.

Packaging: The assembly of one or more containers and any other components necessary to ensure minimum compliance with a program's storage and shipment packaging requirements. Also, the containers, etc., involved.

Packed Bed Scrubber: An air pollution control device in which emissions pass through alkaline water to neutralize hydrogen chloride gas.

Packed Tower: A remediation method (scrubber) employed to clean a contaminated gaseous waste stream by exposing the wastestream to biological media or chemical scrubbing agents.

Packer: Device that can be placed in the wellbore to block vertical fluid flow so as to isolate zones.

Pad: An initial volume of fluid that is used to initiate and propagate a fracture before a proppant is placed.

Palatable Water: Water, at a desirable temperature, that is free from objectionable tastes, odors, colors, and turbidity.

Paleochannels: Old or ancient river channels preserved in the subsurface as lenticular sandstones.

Pallor: Deficiency of color especially of the face; paleness.

Palpitation: Irregular, rapid beating or pulsation of the heart.

PAN: Peroxyacetyl nitrate.

Pancreatitis: Inflammation of the pancreas.

Pancytopenia: An abnormal reduction in the number of red blood cells, white blood cells, and blood platelets.

Pandemic: The worldwide outbreak of a disease in humans in numbers clearly in excess of normal.

Panzootic: The worldwide outbreak of a disease in animals in numbers clearly in excess of normal.

Paper: In the recycling business, refers to products and materials, including newspapers, magazines, office papers, corrugated containers, bags, and some paperboard packaging that can be recycled into new paper products.

Paper Pellets: Paper compressed and bound into uniform diameter pellets to be burned in a heating stove.

Paper Processor/Plastics Processor: Intermediate facility where recovered paper or plastic products and materials are sorted, decontaminated, and prepared for final recycling.

Parabolic Dish: A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator, generally bow-shaped, with two-axis tracking.

Paraffin: A member of the hydrocarbon series of molecules. They are straight chains with single bonds. All hydrocarbon molecules in natural gas and some in crude oil are paraffins.

Paralysis: Loss or impairment of the ability to move a body part, usually as a result of damage to its nerve supply.

Parameter: A variable, measurable property whose value is a determinant of the characteristics of a system; e.g., temperature, pressure, and density are parameters of the atmosphere.

Paraquat: A standard herbicide used to kill various types of crops, including marijuana. Causes lung damage if smoke from the crop is inhaled.

Parasite: Primary, secondary, or higher consumer that feeds on a plant or animal, known as a host, over an extended period of time.

Parent Material: The unconsolidated and more or less chemically weathered mineral or organic matter from which pedogonic processes develop the solum of soils.

Parenteral: Introduced otherwise than by way of the intestines, e.g., parenteral drug administration can be by intravenous, intramuscular, or subcutaneous injection.

Paresthesia: Sensation of prickling, tingling, or creeping on the skin, with no apparent physical cause.

Parkisonism: A condition causing tremor and weakness of the resting muscles and shuffling gait.

Paroxysmal: Suddenly recurring or intensifying (e.g., pain or symptoms).

Parshall Flume: Device used to measure the flow of water in an open channel.

Participation Rate: Portion of the population participating in a recycling program.

Particle Count: Results of a microscopic examination of treated water with a special "particle counter" that classifies suspended particles by number and size.

Particle Size: The diameter, in millimeters, of suspended sediment or bed material.

Particle-size classifications are:

- Clay—0.00024-0.004 millimeters (mm)
- Silt—0.004-0.062 mm
- Sand—0.063-2.0 mm
- Gravel—2.0-64.0 mm

Particle-Size Distribution: The amounts of the various soil size fractions in a soil sample, usually expressed as weight percentage.

Particulate Loading: The mass of particulates per unit volume of air or water.

Particulate Matter: Substances (such as diesel soot and combustion products resulting from the burning of wood) released directly into the air; any minute, separate particle of liquid or solid material. Dusts, mists, and fumes.

Particulates: 1. Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions. 2. Very small solids suspended in water; they can vary in size, shape, density, and electrical charge and can be gathered together by coagulation and flocculation.

Partition Coefficient: Measure of the sorption phenomenon, whereby a pesticide is divided between the soil and water phase; also referred to as adsorption partition coefficient.

Partitions: Major divisions of the total physical hard disk space.

Parts per Billion (ppb): The number of "parts" by weight of a substance per billion parts of water. Used to measure extremely small concentrations. Analogous to one drop of substance from an eye-dropper dropped into an standard-sized swimming pool.

Parts per Million (ppm): The number of "parts" by weight of a substance per million parts of water. This unit is commonly used to represent pollutant concentrations. Analogous to a whiskey shot glass full of water filled by dropping into a standard-sized swimming pool.

Pascal (Pa): A unit of pressure equal to one newton per square meter.

Passive Smoking/Secondhand Smoke: Inhalation of others' tobacco smoke.

Passive Solar: A system in which solar energy alone is used for the transfer of thermal energy. Pumps, blowers, or thither heat transfer devices that use energy other than solar.

Passive Treatment Walls: Technology in which a chemical reaction takes place when contaminated ground water comes in contact with a barrier such as limestone or a wall containing iron filings.

Password: A secret code assigned to a user and known by the computer system. Knowledge of the password associated with the user ID is considered proof of authorization.

Password Authentication Protocol (PAP): A simple, weak authentication mechanism where a user enters the password and it is then sent across the network, usually in the clear.

Password Cracking: The process of attempting to guess passwords, given the password file information.

Password Sniffing: Passive wiretapping, usually on a local area network, to gain knowledge of passwords.

Patch: A small update released by a software manufacturer to fix bugs in existing programs.

Pathogenic: Causing disease or capable of doing so.

Pathogens: Disease-causing micro-organisms; generally associated with viruses or bacteria.

Pathway: The physical course a chemical or pollutant takes from its source to the exposed organism.

Pay-As-You-Throw/Unit-Based Pricing: Systems under which residents pay for municipal waste management and disposal services by weight or volume collected, not a fixed fee.

PCPs: PCBs (polychlorinated biphenyls), commonly used in electrical transformers and capacitors, are a class of organic compounds production of which are banned in the United States because of toxicity and persistence as an organic pollutant. PCB-containing materials are classified in the regulations according to the concentration of PCBs present. There are three classifications of PCB-containing materials:

- PCB > = 500 ppm
- PCB-contaminated 5-500 ppm
- TSCA-regulated 50-500 ppm
- California-regulated (liquid or waste extract only) 5-50 ppm
- Non-PCB <5 ppm.

Mixtures of PCB-containing material are subject to all requirement of the highest PCB concentration classification within the mixture. The deliberate dilution of PCB materials to reduce the concentration of PCBs in a resulting mixture is prohibited (EHSO 2010).

Peak Flow: The maximum instantaneous discharge of as stream or river at a given location. It usually occurs at or near the time of maximum stage.

Peak Levels: Levels of airborne pollutant contaminants much higher than average or occurring for short periods of time in response to sudden releases.

Peak Watt: A manufacturer's unit indicating the amount of power a photovoltaic cell or module will produce at standard test conditions (normally 1,000 watts per square meter and 25 degrees Celsius).

Peaking Plants: Electricity-generating plants that are operated to meet the pak or maximum load on the system. The cost of energy from such plants is usually higher than from baseload plants.

Peat: Peat consists of partially decomposed plant debris. It is considered an early stage in the development of coal. Peat is distinguished from lignite by the present of free cellulose and a high moisture content (exceeding 70 percent). The heat content of air-dried peat (about 50 percent moisture) is about nine million Btu per ton. Most U.S. peat is used as a soil conditioner.

Pedologist: A person who studies soils.

Peds: A unit of soil structure such as an aggregate, crumb, prism, block, or granule, formed by natural processes.

PEL: OSHA Permissible Exposure Limit.

Pellet: A small, solid, or densely packed ball or mass.

Pellicle: A *Euglena* structure that allows for turning and flexing of the cell.

Penetration: Gaining unauthorized logical access to sensitive data by circumventing a system's protections.

Penetration Testing: Used to test the external perimeter security of a network or facility.

Penstock: A closed conduit or pipe for conduction water to the powerhouse.

Per Capita Use: The average amount of water used per person during a standard time period, generally per day.

Percent Saturation: The amount of a substance that is dissolved in a solution compared to the amount that could be dissolved in it.

Perched Water: Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone (generally an aquaclude).

Percolating Water: Water that passes through rocks or soil under the force of gravity.

Percolation: 1. Downward movement of water through soil. 2. The entrance of a portion of the streamflow into the channel materials to contribute to groundwater replenishment.

Perennial Stream: Type of stream in which flow continues during periods of no rainfall.

Performance-Based Management Program: A program designed to preserve and protect human health and environmental resources by focusing on the achievement of specific, measurable performance requirements based on site assessments.

Performance Boundaries: The point at which a wastewater treatment performance requirement corresponding to the desired level of treatment at that point in treatment sequence is applied. Performance boundaries can be designated at the discharge point of the pretreatment system (e.g., septic tank, package plant discharge to surface waters), at physical boundaries in the receiving environment (impermeable state, ground water table), at a point of use (ground water well), or at a property boundary.

Performance Bond: Cash or securities deposited before a landfill operating permit is issued, which are held to ensure that all requirements for operating and subsequently closing the landfill are faithfully performed. The money is returned to the owner after proper closure of the landfill is completed. If contamination or other problems appear at any time during operation, or upon closure, and are not addressed, the owner must forfeit all or part of the bond which is then used to cover clean-up costs.

Performance Date (for Incinerators): Information collected, during a trail burn, on concentrations of designated organic compounds an pollutants found in incinerator emissions. Data analysis must show that the incinerator meets performance standards under operating conditions specified in the RCRA permit.

Performance Requirement: Any requirement established by the regulatory authority to ensure future compliance with the public health and environmental goals of the community. Performance requirements can be expressed as numeric limits (e.g., pollutant concentrations, mass loads, wet weather flows, structural strength) or narrative descriptions of desired performance, such as no visible leaks or no odors.

Performance Standards: A form of OSHA regulation standards that lists the ultimate goal of compliance, but does not explain exactly how compliance is to be accomplished. Compliance is usually based on accomplishing the act or process in the safest manner possible, based on experience (past performance).

Perimeter-Based Security: The technique of securing a network by controlling access to all entry and exit points of the network.

Period: An interval of geologic time that is a subdivision of an era and made up of epochs; a horizontal row of the periodic table that contains elements with approximately the same energy.

Periodic Law: The properties of elements are periodic functions of the atomic number.

Periodic Table: A list of all elements arranged in order of increasing atomic numbers and grouped by similar physical and chemical characteristics into "periods"; based on the chemical law that physical or chemical properties of the elements are periodic functions of their atomic weights.

Peripheral: Related to, located in, or constituting an outer boundary, surface, or periphery.

Peripheral Nervous System: The part of the nervous system that is outside the central nervous system and comprises the cranial nerves (except the optic nerve), the spinal nerves, and the autonomic nervous system.

Peripheral Neuropathy: Degeneration of certain nerves.

Periphyton: Microscopic underwater plants and animals that are firmly attached to solid surfaces such as rocks, logs, and pilings.

Permanent Pond: Actually a misnomer, as no pond is permanent. A pond shallow enough to permit aquatic plants to penetrate the surface anywhere over its entire mass; its mass is not so great as to allow formation of large waves that could erode the shoreline; permanent ponds have no temperature layering, rather a gradient of temperatures extending from the surface to bottom.

Permanent Wilting Point: Moisture content of soil, on an oven-dry basis, at which a plant (specifically a sunflower) wilts so much that it does not recover when placed in a humid, dark chamber.

Permeability: Quality of the soil that enables water to move downward through the profile. Permeability is measured as the number of inches per hour that water moves downward through the saturated soil. Terms describing permeability are:

Very slow	less than 0.06 inches/hr
Slow	0.06 to 0.2 inches/hr
Moderately slow	0.2 to 0.6 inches/hr
Moderate	0.6 to2.0 inches/hr
Moderately rapid	2.0 to 6.0 inches/hr
Rapid	6.0 to 20 inches//hr
Very rapid	more than 20 inches/hr

Permeability, Intrinsic k [L^2]: Intrinsic permeability is a measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient. It is a property of the medium alone and is independent of the nature of the liquid and of the force field causing movement. It is a property of the medium that is dependent upon the shape and size of the pores.

Permissible Dose: The dose of a chemical that may be received by an individual without the expectation of a significantly harmful result.

Permissible Exposure Limit (PEL): The time-weighted average concentration of an airborne contaminant that a healthy worker may be exposed to eight hours per day or forty hours per week without suffering any adverse health effects. Established by legal means and enforceable by OSHA.

For example,

PEL/IDLH Chart

	Chemical Name	*PEL (8 hr. average)*	*IDLH*
1.	Ammonia	50 ppm	300 ppm
2.	Carbon Dioxide	5,000 ppm	50,000 ppm
3.	Carbon Monoxide	50 ppm	1,200 ppm
4.	Sodium Hydroxide	Must use SCBA to enter	
5.	Sulfur Dioxide	5 ppm	100 ppm
6.	Chlorine	1 ppm	10 ppm
7.	Hydrogen Chloride	5 ppm	100 ppm
8.	Hydrogen Sulfide	10 ppm	100 ppm
9.	Propane	1,000 ppm	2,100 ppm
10.	Oxygen	19.5% (Min)	——
11.	Flammable	10% LEL	

PEL—Permissible Exposure Limit
IDLH —Immediately Dangerous to Life and Health Limit

Permit: An authorization, license, or equivalent control document issued by EPA or an approved state agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.

Permitted Worker: A laboratory worker who does not work with radioactive materials but works in a radiation laboratory.

Permitting Authority: Permitting authority is a state agency (or governmental entity such as a tribal government) that has received authority from EPA to administer the NPDES program. For states that have not received authority from EPA to administer the NPDES program, the EPA regional administrator is the permitting authority.

Permitting System: A key element of RCRA is a permitting system that works to ensure safe operation of facilities that treat, store, or dispose of hazardous wastes.

Peroxide: Chemicals which contain two oxygen atoms bound together. Often explosive.

Perpetual Resource: A resource such as solar energy that comes from an essentially inexhaustible source and thus will always be available on a human time scale regardless of whether or how it is used.

Perseveration: Continual, involuntary repetition of behaviors.

Persistence: Calculated value that relates to the time required for a gas to degrade into a harmless compound.

Persistent Pesticides: Pesticides that do not break down chemically or break down very slowly and remain in the environment after a growing season.

Persistent Substance: A chemical product with a tendency to persist in the environment for quite some time; plastics, for example.

Personal Air Samples: Air samples taken with a pump that is directly attached to the worker with the collecting filter and cassette placed in the worker's breathing zone (required under OSHA asbestos standards and EPA worker protection rule).

Personal Firewalls: Firewalls installed and run on individual PCs.

Personal Measurement: A measurement collected from an individual's immediate environment.

Personal Monitoring: The process of measuring the concentration of a hazardous chemical in the breathing zone of an individual, using a method such as a personal air pump to gather a sample for analysis, a direct-reading instruments, or a monitor worn by the worker in the breathing zone. For physical or biological agents, it is the process of measuring the quantity that potentially contacts or affects any part of an exposed individual. Area monitoring is not considered personal monitoring.

Personal Protective Equipment (PPE): Mansdorf makes a number of important statements concerning personal protective equipment (PPE), ones worth taking some time to look at carefully.

1. "It is best for management to try to eliminate these hazardous exposures through changes in workplace design or engineering controls."

Sound familiar? We consistently make this same point throughout this text. A hazard, any hazard, if possible, should be "engineered out" of the system or process. Determining when and how to engineer out a hazard is one of the safety engineer's primary functions. However, the safety engineer or professional can much more effectively accomplish this if he or she is included in the earliest stages of design. Remember, it does little good (and is often very expensive) to attempt to engineer out any hazard once the hazard is in place.

2. "When hazardous workplace exposures cannot be controlled by these measures, personal protective equipment (PPE) becomes necessary."

   While the goal of the safety engineer is certainly to engineer out all workplace hazards, we realize that this goal is virtually impossible to achieve. Even in this day of robotics, computers, and other automated equipment and processes, the man-machine-process interface still exists. When people are included in the work equation, the opportunity for their exposure to hazards is very real—as injury statistics make clear, it happens.

3. ". . . consider PPE the last alternative in worker protection because it does not eliminate the hazards."

   This is extremely important for two reasons: First, the safety engineer's primary goal is (as we have said before) to engineer out the problem. If this is not possible, the second alternative is to implement administrative controls. When neither is possible, PPE becomes the final choice. The key words here are "the final choice." Secondly, PPE is sometimes incorrectly perceived—by both the supervisor and/or the worker—as their first line of defense against all hazards. This, of course, is incorrect and dangerous. The worker must be made to understand (by means of enforced company rules, policies and training) that PPE affords only minimal protection against most hazards—IT DOES NOT ELIMINATE THE HAZARD.

4. "PPE only provides a barrier between the worker and the hazard."

   When some workers put on their PPE, they also don a "Superperson" mentality. What does this mean? Often, when workers use eye, hand, foot, head, hearing, or respiratory protection, they also adopt a "I can't be touched" attitude. They feel safe, as if the PPE somehow magically protects them from the hazard, so they act as if they are protected, are invincible, are beyond injury. . . . They feel, however illogically, that they are well out of harm's way. Nothing could be further from the truth. Let's look at an example.

OSHA's PPE Standard

In the past, many OSHA standards have included PPE requirements, ranging from very general to very specific. It may surprise you to know, however, that not until 1993–1994 did OSHA incorporate a stand-alone PPE Standard into its 29 CFR 1910/1926 Guidelines. This Personal Protective Equipment standard is covered (General Industry) under 1910.132-138, but you can also find specific PPE requirements elsewhere in the General Industry Standards. For example, 29 CFR 1910.156, OSHA's Fire Brigades Standard has requirements for firefighting gear. In addition, 29 CFR 1926.95-106 covers the construction industry. The PPE standard focuses on head, feet, eye, hand, respiratory, and hearing protection.

Pest: An insect, rodent, nematode, fungus, weed, or other form of terrestrial or aquatic plant or animal life that is injurious to health or the environment.

Pest Control Operator: Person or company that applies pesticides as a business (e.g., exterminator); usually describes household services, not agricultural applications.

Pesticide: A substance or mixture of substances used to kill pests.

Pesticide Regulation Notice: Formal notice to pesticide registrants about important changes in regulatory policy, procedures, regulations.

Pesticide Tolerance: The amount of pesticide residue allowed by law to remain in or on a harvested crop. EPA sets these levels well below the point where the compounds might be harmful to consumers.

PETE (Polyethylene Terepthalate): Thermoplastic material used in plastic soft drinking and rigid containers.

pH: 1. Measure of the hydrogen-ion concentration. 2. A means of expressing hydrogen ion concentration in terms of the powers of 10; measurement of how acidic or basic a substance is. The pH scale runs from 0 (most acidic) to 14 (most basic). The center of the range (7) indicates the substance is neutral.

Pharmacokinetics: The study of the way that drugs move through the body after they are swallowed or injected.

Pharyngitis: Inflammation of the throat (pharynx).

Phenolphthalein Alkalinity: The alkalinity in a water sample measured by the amount of standard acid needed to lower the pH to a level of 8.3 as indicated by the change of color of the phenolphthalein for pink to clear.

Phenols: Organic compounds that are byproducts of petroleum refining, tanning, and textile, dye, and resin manufacturing. Low concentration cause taste and odor problems in water; higher concentrations can kill aquatic life and humans.

Phenytoin: An anticonvulsant drug used most commonly in the treatment of epilepsy.

Phosphate: Phosphate ion exists in water as H^2PO^{4-}. Otherwise phosphate is an ester or salt of phosphoric acid, such as calcium phosphate rock.

Phosphogypsum Piles (Stacks): Principal by-product generated in production of phosphoric acid from phosphate rock. These piles may generate radioactive radon gas.

Phosphorus: One of the primary nutrients required for the growth of plants. Phosphorus is often the limiting nutrient for the growth of aquatic plants and algae.

Phosphorous Cycle: A biogeochemical cycle in which phosphorous is converted into various chemical forms and transported through the biosphere.

Phosphorus Plant: Facilities using electric furnaces to produce elemental phosphorus for commercial use, such as high grade phosphoric acid, phosphate-based detergent, and organic chemicals use.

Photochemical Oxidants: Air pollutants formed by the action of sunlight on oxides of nitrogen and hydrocarbons.

Photochemical Reaction: A reaction induced by the presence of light.

Photochemical Smog: An atmospheric haze that occurs above industrial sites and urban areas resulting from reactions, which take place in the presence of sunlight, between pollutants produced in high temperature and pressurized combustion process (such as the combustion of fuel in a motor vehicle). The primary component of smog is ozone.

Photon: Type of radiation in the form of an electromagnetic wave.

Photophobia: A painful sensitivity to light.

Photosynthesis: The process of using the sun's light energy by chlorophyll-containing plants to convert carbon dioxide (CO_2) and water (H_2O) into complex chemical bonds forming simple carbohydrates such as glucose and fructose.

Photovoltaic (PV) Cell: An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts ad being capable of converting incident light directly into electricity (direct current).

Photovoltaic (PV) Module: An integrated assembly of interconnected photovoltaic cells designed to deliver a selected level of working voltage and current at its output terminals, packaged for protection against environmental degradation, and suited for incorporation in photovoltaic power systems.

Photovoltaics (PV): Hinrichs and Kleinbach (2006) point out that Photovoltaic (PV) has been and will continue to be one of the more glamorous technologies in the energy field. Photovoltaic (Gr. *photo* light, and *volt*, electricity pioneer Alessandro Volta) technology makes use of the abundant energy in the sun, and it has little impact on our environment. *Photovoltaics* is the direct conversion of light (photons) into electricity (voltage) at the atomic level. Some materials exhibit a property known as the *photoelectric effect* (discovered and described by Becquerel in 1839) that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results (i.e., electricity is the flow of free electrons) that can be used as electricity. The first photovoltaic module (billed as a solar battery) was built by Bell laboratories in 1954. In the 1960s, the space program began to make the first serious use of the technology to provide power aboard spacecraft. Space program use helped this technology make giant advancements in reliability and helped to lower cost. However, it was the oil embargo of the 1970s (the so-called energy crisis) that propelled photovoltaic technology to the forefront of recognition for use other than space applications only. Photovoltaics can be used in a wide range of products, from small consumer items to large commercial solar electric systems.

Solar cells are made of silicon and other semiconductor materials such as germanium, gallium arsenide, and silicon carbide are used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are jarred loose from the atoms in the semi-conductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electrical current—that is, again, recall that electron flow is electricity. This electricity can then be used to power a load, such as a light, tool, toaster, and other electrical appliance and/or apparatus.

A number of solar cells electrically connected to each other and mounted on a support panel or frame is called a photovoltaic module. Solar panels used to power homes and businesses are typically made from solar cells combined into modules that hold about forty cells. Modules are designed to supply electricity at a certain voltage, such as a common 12-volts system. The current produced is directly dependent on how much light strikes the module.

Multiple modules can be wired together to form an array. In general, the larger the area of a module or array, the more electricity that will be produced. Photovoltaic modules and arrays produce direct-current (dc) electricity. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination.

Physical and Chemical Treatment: Processes generally used in large-scale wastewater treatment facilities. Physical processes may include air-stripping or filtration. Chemical treatment includes coagulation, chlorination or ozonation. The term can also refer to treatment of toxic materials in surface and ground waters, oil spills, and same methods of dealing with hazardous materials on or in the ground.

Physical Boundaries: Points in the flow of wastewater through the treatment system where treatment processes change. A physical boundary can be at the intersection of it processes or between saturated and unsaturated soil zones. A physical boundary may also be a performance boundary if so designated by the regulatory authority.

Physical Change: The process that alters one or more physical properties of an element or compound without altering its chemical composition. Examples include changing the size and shape of a sample of matter and changing a sample of matter from one physical state to another.

Physical Weathering: The physical changes produced in rocks by atmospheric agents (wind, precipitation, heat, cold, etc.).

Physiologically Based Pharmacokinetic Model: A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is charged by the body, and how it leaves the body.

Phytase-Enzyme: That when added to rations of non-ruminant animals makes the phosphorus in grains and other feed ingredients more available during digestion.

Phytoplankton: That portion of the plankton community comprised of tiny plants; e.g., algae, diatoms.

Phytoremediation: Low-cost remediation option for sites with widely dispersed contamination at low concentrations.

Phytotoxic: Harmful to plants.

Phytotreatment: The cultivation of specialized plants that absorb specific contaminants for the soil through their roots or foliage. This reduces the concentration of contaminants in the soil, but incorporates them into biomasses that may be released back into the environment when the plant dies or is harvested.

Picocuries Per Liter pCi/L: A unit of measure for levels of radon gas; becquerels per cubic meter is metric equivalent.

Piezometer: A nonpumping well, generally of small diameter, for measuring the elevation of a water table.

Pilot Tests: Testing a cleanup technology under actual site conditions to identify potential problems prior to full-scale implementation.

Pioneer Community: The first successfully integrated set of plants, animals, and decomposers found in an area undergoing primary ecological succession.

PIN: In computer security, a personal identification number used during the authentication process. Known only to the user.

Pitot Tube: Is another device used to measure static pressure in ventilation systems. The Pitot tube is constructed of two concentric tubes. The inner tube forms the impact portion, while the outer tube is closed at the end and has static pressure holes normal to the surface of the tube. When the inner and outer tubes are connected to opposite legs of a single manometer, the velocity pressure is obtained directly. If the engineer wishes to measure static pressure separately, two manometers can be used. Positive and negative pressure measurements are indicated on the manometer as above.

Placard: A sign or symbol designed to be hung on a wall, container, or vehicle containing warning information to convey the level of hazard.

Plaintext: Ordinary readable text before being encrypted into ciphertext or after being decrypted.

Plankton: Microscopic floating plant and animal organisms of lakes, rivers, and oceans.

Plasma Arc Reactors: Devices that use an electric arc to thermally decompose organic and inorganic materials at ultra-high temperatures into gases and a vitrified slag residue. A plasma arc reactor can operate as any of the following:

- integral component of chemical, fuel, or electricity production systems, processing high or medium value organic compounds into a synthetic gas used as a fuel
- materials recovery device, processing scrap to recover metal from the slag
- destruction or incineration system, processing waste material into slag and gases ignited inside of a secondary combustion chamber that follows the reactor

Plasma Membrane: See *cytoplasmic membrane*.

Plasmid: A circular piece of DNA that exists apart from the chromosome and replicates independently of it. Bacterial plasmids carry information that renders the bacteria resistant to antibiotics. Plasmids are often used in genetic engineering to carry desired genes into organism.

Plastic Soil: A soil capable of being molded or deformed continuously and permanently by relatively moderate pressure.

Plastics: Non-metallic chemoreactive compounds molded into rigid or pliable construction materials, fabrics, etc.

Plate Tectonics: A theory of global-scale dynamics involving the movement of many rigid plates of the Earth's crust. Tectonic activity is evident along the margins of the plates where buckling, grinding, faulting, and vulcanism occur as the plates are propelled by the forces of deep-seated mantle convection current. Geothermal resources are often associated with tectonic activity, since it allows ground water to come in contact with deep subsurface heat sources.

Plate Tower Scrubber: In absorption scrubbing, plate towers contain perforated horizontal plates or trays designed to provide large liquid-gas interfacial area. The polluted air stream rises up through the perforations in each plate; the rising gas prevents liquid from draining through the openings rather than through a downpipe. During continuous operation, contact is maintained between air and liquid, allowing gaseous contaminants to be removed, with clean air emerging from the top of the tower.

Platelet: A minute body found in the blood of animals that functions to promote blood clotting.

Platy Structure: Laminated or flaky soil aggregate developed predominately along the horizontal axes.

Play: A productive coal-bed methane formation, or a productive oil or gas deposit; a combination of trap, reservoir rock, and seal that has been shown by previously discovered fields to contain natural gas and oil.

Plenum: Duct that transports ventilation air to or from a building. A low-velocity chamber used to distribute static pressure throughout its interior.

Plug Flow: Type of flow that occurs in tanks, basins, or reactors when a slug of water moves through without ever dispersing or missing with the rest of the water flowing through.

Plugging: Act or process of stopping the flow of water, oil, or gas into or out of a formation through a borehole or well penetrating that formation.

Plume: (1) The column of non-combustible products emitted from a fire or smokestack. (2) A vapor cloud formation having shape and buoyancy. (3) A contaminant formation dispersing through the subsurface.

Plutonic: A loosely defined term with a number of current usages. We use it to describe igneous rock bodies that crystallized at great depth or, more generally, any intrusive igneous rock.

Plutonium: A radioactive metallic element chemically similar to uranium.

Plutonium in the Environment: Article (part) of the actinides series in the environment.

PM: Particulate matter.

PM-2.5: Particulate matter having an aerodynamic diameter of 2.5 micrometer or less.

PM-10: Particulate matter having an aerodynamic diameter of 10 micrometer or less.

Pneumoconiosis: Health conditions characterized by permanent deposition of substantial amounts of particulate matter in the lungs and by the tissue reaction to its presence; can range from relatively harmless forms of sclerosis to the destructive fibrotic effect of silicosis.

Pneumonia: An inflammatory lung disease.

Pocket Resuscitation Mask: A device that protects a rescuer from being contaminated by a victim when giving emergency mouth-to-mouth resuscitation. It consist of a curved plastic cup that rests over a victim's mouth and has a short tube attached for the rescuer to blow into.

Point-of-Contract Measurement of Exposure: Estimating exposure by measuring concentrations over time (while the exposure is taking place) at or near the place where it is occurring.

Point-of-Disinfectant Application: The point where disinfectant is applied and water downstream of that point is not subject to recontamination by surface water runoff.

Point-of-Exposure: The place where someone can come into contact with a substance present in the environment.

Point-of-Generation (POG) of a Hazardous Waste: The point at which a waste is first determined to be hazardous. For listed wastes this is the point at which the waste first meets the listing description, and for characteristic wastes it is the point the waste first exhibits the characteristic.

Point-of-Use Treatment Device: Treatment device applied to a single tap to reduce contaminants in the drinking water at the one faucet.

Point Source: "Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, . . . concentrated animal feeding operation . . . from which pollutants are or may be discharged. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture" (33 US § 1362(14)).

Point Source Pollution: Pollution that can be traced to an identifiable source.

Poison or Poisonous: The words "poison" or "poisonous" are synonymous with the word "toxic."

Poisson's ratio: The ratio of the relative change of diameter of a bar to its unit change of length under an axial load that does not stress it beyond the elastic limit.

Polar: Exhibiting polarity, i.e., having electric charges.

Policy: Organizational-level rules governing acceptable use of computing resources, security practices, and operational procedures.

Pollen: The fertilizing element of flowering plants; background air pollutant.

Pollutant: 1. A resource out of place; a resource is anything useful. 2.A contaminant at a concentration high enough to endanger the environment.

Pollutant Delivery Ratio (PDR): The fraction of a pollutant leaving an area that actually enters a body of water.

Pollutant Pathways: Avenues for distribution of pollutants. In most buildings, for example, HVAC systems are the primary pathways although all building components can interact to affect how air movement distributes pollutants.

Pollutant Standard Index (PSI): Indicator of one of more pollutants that my be used to inform the public about the potential for adverse health effects from air pollution in major cites.

Pollutant Threshold: Maximum value that relates to the time required for a gas to degrade into a harmless compound.

Pollute: To impair the quality of some portion of the environment by the addition of harmful impurities.

Pollution: Generally, the presence of a substance in the environment that because of its chemical composition or quantity prevent the functioning of natural processes and produces undesirable environmental and health effects. Under the Clean Water Act, for example, the term has been defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water and other media.

Pollution Prevention: A source reduction as defined in the Pollution Prevention Act, and other practices that reduce or eliminate the creation of pollutants through 1) increased efficiency in the use of raw materials, energy, water, or other natural resources; or 2) protection of natural resource by conservation.

Polonium: A radioactive element that occurs in pitchblende and other uranium-containing ores.

Polychlorinated Biphenyls (PCBs): A group of synthetic, toxic industrial chemical compounds once used in making paint and electrical transformers, which are chemically inert and not biodegradable. PCBs were frequently found in industrial wastes, and subsequently found there way into surface and ground waters. As a result of their persistence, they tend to accumulate in the environment. In terms of streams and rivers, PCBs are drawn to sediment, to which they attach and can remain virtually indefinitely. Although virtually banned in 1979 with the passage of the Toxic Substances Control Act, they continue to appear in the flesh of fish and other animals.

Polycrystalline Diamond Compact Drilling Bit (PDC): A drilling bit that uses polycrystalline diamond compact inserts on the drill bit to drill by means of rotational shear of the rock face.

Polydipsia: Excessive thirst.

Polyelectrolytes: Synthetic chemicals that help solids to clump during sewage treatment.

Polymer: A natural or synthetic chemical structure where two or more like molecules are joined to form a more complex molecular structure (e.g., polyethylene in plastic).

Polymerized: Having undergone polymerization, a process in which two or more smaller molecules are joined to form larger molecules that contain repeating structural units.

Polymorphism: The process by which malicious software changes its underlying code to avoid detection.

Polyneuropathy: A degenerative disease of the nerves.

Polyvinyl Chloride (PVC): A tough, environmentally indestructible plastic that releases hydrochloric acid when burned.

Ponding: Standing water on soils in closed depressions. Unless the soils are artificially drained, the water can be removed only by percolation or evapotranspiration.

Population

Population—defined by the word masters:

Webster's Third New International Dictionary defines population:

- "The total number or amount of things especially within a given area."
- "The organisms inhabiting a particular area or biotype."
- "A group of interbreeding biotypes that represents the level of organization at which speciation begins."

Population—defined by an Ecologist (Abedon 2007):

- A population in an ecological sense is a group of organisms, of the same species, which roughly occupy the same geographical area at the same time.
- Individual members of the same population can either interact directly, or may interact with the dispersing progeny of the other members of the same population (e.g., pollen).
- Population members interact with a similar environment and experience similar environmental limitations.

Population at Risk: A population subgroup that is more likely to be exposed to a chemical, or is more sensitive to the chemical, than is the general population.

Population Density: The number of a particular species in an area. This affected by natality (birth and reproduction), immigration (moving into), mortality (death), and emigration (moving out of).

Population Ecology: 1. Population ecology owes its beginning to the contributions of Thomas Malthus, an English clergyman, who in 1798 published his *Essay on the Principle of Population*. Malthus introduced the concept that at some point in time an expanding population must exceed supply of prerequisite natural resources—the "Struggle for Existence Concept." Malthus's theories profoundly influenced Charles Darwin 1859, *On the Origin of Species*—for example, the "Survival of the Fittest Concept." 2. **Population Ecology (Sharov 1996)**:

Population ecology is the branch of ecology that studies the structure and dynamics of populations.

The term "population" is interpreted differently in various sciences. For example, in human demography a population is a set of humans in a given area. In genetics a population is a group of interbreeding individuals of the same species, which is isolated from other groups. In population ecology a population is a group of individuals of the same species inhabiting the same area.

✔ **Important Point**: Main axiom of population ecology—organisms in a population are ecologically equivalent. Ecological equivalency means:

1. Organisms undergo the same life-cycle
2. Organisms in a particular stage of the life-cycle are involved in the same set of ecological processes
3. The rates of these processes (or the probabilities of ecological events) are basically the same if organisms are put into the same environment (however some individual variation may be allowed) (Sharov 1996).

Population Growth: The size of animal populations is constantly changing due to natality, mortality, emigration, and immigration. As mentioned, the population size will increase if the natality and immigration rates are high. On the other hand, it will decrease if the mortality and emigration rates are high. Each population has an upper limit on size, often called the carrying capacity. Carrying capacity can be defined as being the "optimum number of species' individuals that can survive in a specific area over time" (Enger et al. 1989). Stated differently, the carrying capacity is the maximum number of species that can be supported in a bioregion. A pond may be able to support only a dozen frogs depending on the food resources for the frogs in the pond. If there were thirty frogs in the same pond, at least half of them would probably die because the pond environment wouldn't have enough food for them to live. Carrying capacity, symbolized as *K*, is based on the quantity of food supplies, the physical space available, the degree of predation, and several other environmental factors.

The carrying capacity is of two types: ultimate and environmental. Ultimate carrying capacity is the theoretical maximum density; that is, it is the maximum number of individuals of a species in a place that can support itself without rendering the place uninhabitable. The environmental carrying capacity is the actual maximum population density that a species maintains in an area. Ultimate carrying capacity is always higher than environmental.

The population growth for a certain species may exhibit several types of growth. Smith (1974) points out that "the rate at which the population grows can be expressed as a graph of the numbers in the population against time."

The exponential growth rate is usually exhibited by organisms which are introduced into a new habitat, by organisms with a short life span such as insects, and by annual plants. A classic example of exponential growth by an introduced species is the reindeer transported to Saint Paul Island in the Pribolofs off Alaska in 1911. A total of twenty-five reindeer were released on the island and by 1938 there were over two thousand animals on the small island. As time went by, however, the reindeer overgrazed their food supply and the population decreased rapidly. By 1950 only eight reindeer could be found (Pianka 1988).

Another example of exponential growth is demonstrated by the Lilly Pond Parable. The "parable" (not really a parable) is an excellent example providing insight into long term carrying capacity and population growth.

Lily Pond Parable

1. If a pond lily doubles everyday and it takes 30 days to completely cover a pond, on what day will the pond be ¼ covered?
2. ½ covered?
3. Does the size of the pond make a difference?
4. What kind of environmental, social, and economic developments can be expected as the 30th day approaches?
5. What will begin to happen at one minute past the 30th day?
6. At what point (what day) would preventative action become necessary to prevent unpleasant events?

Answers

1. Day 28. growth will be barely visible until the final few days. (On the 25th day, the lilies cover 1/32nd of the pond, on the 21st day, the lilies cover 1/512th of the pond).
2. 29th day.
3. No. The doubling time is still the same. Even if you could magically double the size of the pond on day 30, it would still hold only one day's worth of growth!
4. The pond will become visibly more crowded each day, and this crowding will begin to exhaust the resources of the pond.
5. The pond will be completely covered. Even through the lilies will be reproducing, there will be no more room for additional lilies, and the excess population will die off. In fact, since the resources of the pond have been exhausted, a significant proportion of the original population may die off as well.
6. It depends on how long it takes to implement the action and how full you want the lily pond to be. If it takes two days to complete a project to reduce lily reproductive rates, that action must be started on day 28, when the pond is only 25 percent full—and that will still produce a completely full pond. Of course, if the action is started earlier, the results will be much more dramatic.

Doubling Time and the Rule of 70

Population growing at a constant rate will have a constant doubling time . . . the time it takes for the population to double in size.

Population growing at a constant rate can be modeled with exponential growth equation:

$$dN/dt = rN$$

The integral of equation is

$$N_t = N_0 e^{rt}$$

How long will it take for the population to double growing at a constant rate "r"?

$$.69/r = T$$

The Rule of 70

The Rule of 70 is useful for financial as well as demographic analysis. It states that to find the doubling time of a quantity growing at a given annual percentage rate, divide the percent at number into 70 to obtain the approximate number of years required to double. For example, at a 10 percent annual growth rate, doubling time is 70/10 = 7 years.

Similarly, to get the annual growth rate, divide 70 by the doubling time. For example, 70/14 years doubling time = 5, or a 5 percent annual growth rate.

The following table shows some common doubling times:

Population: Properties Of (Abedon 2007)**:**

1. Population size (size)—depends on how the population is defined

Growth Rate(% per Year)	*Doubling Time in Years*
0.1	700
0.5	140
1	70
2	35
3	23
4	18
5	14
6	12
7	10
10	7

2. Population density (density)—the number of individual organisms per unit area
3. Patterns of dispersion (dispersion)—individual members of populations may be distributed over a geographical area in a number of different ways including: clumped, uniform, and random distribution.
4. Demographics (demographics)—a population's vital statistics, including:

   - Education
   - Parental Status
   - Work Environment
   - Geographic Location
   - Religious Beliefs
   - Marital Status
   - Income

   Additionally

   - Sex
   - Race
   - Gender
   - Ethnicity
   - Age
   - Sexual Orientation
   - Physical Ability

5. Population growth (growth)—simply, population growth occurs when there are no limitations on growth within the environment. When this occurs two situations occur: (1) the population displays its intrinsic rate of increase (i.e., the rate of growth of a population when that population is growing under ideal conditions and without limits); and (2) the population experiences exponential growth (i.e., exponential growth means that a population's size at a given time is equal to the population's size at an earlier time, times some greater-than-one number) (Abedon 2007).
6. Limits on population growth (limits)—exponential growth cannot go on forever; sooner or later any population will run into limits in their environment.

✔ **Important Point**: Note that all of these properties are not those of individual organisms but instead are properties which exist only if one considers more than one organism at any given time, or over a period of time.

Population Response to Stress: As mentioned earlier, population growth is influenced by multiple factors. When a population reaches its apex of growth (its carrying capacity), certain forces work to maintain population at a certain level. On the other hand, populations are exposed to small or moderate environmental stresses. These stresses work to affect the stability or persistence of the population. Ecologists have concluded that a major factor that affects population stability or persistence is species diversity.

Species diversity is a measure of the number of species and their relative abundance. There are several ways to measure species diversity. One way is to use the straight ratio, D = S/N. In this ratio, D = species diversity, N = number of individuals, and S = number of species. As an example, a community of 1000 individuals is counted; these individuals are found to belong to fifty different species. The species diversity would be 50/1000 or 0.050. This calculation does not take into account the distribution of individuals of each species. For this reason, the more common calculation of species diversity is called the Shannon-Weiner Index. The Shannon-Weiner Index measures diversity by

$$H = -\sum_{i=1}^{s} (\mathrm{pi})\,(\log pi)$$

where

H= the diversity index
s = the number of species
i = the species number
pi = proportion of individuals of the total sample belonging to the ith species.

The Shannon-Weiner Index is not universally accepted by ecologists as being the best way to measure species diversity, but it is an example of a method that is available.

Species diversity is related to several important ecological principles. For example, under normal conditions, high species diversity, with a large variety of different species, tends to spread risk. This is to say that in ecosystems which are in a fairly constant or stable environment, such as a tropical rain forest, usually have higher species diversity. However, as Odum (1983) points out, "diversity tends to be reduced in stressed biotic communities."

If the stress on an ecosystem is small, the ecosystem can usually adapt quite easily. Moreover, even when severe stress occurs, ecosystems have a way of adapting. Severe environmental change to an ecosystem can result from such natural occurrences as fires, earthquakes, floods and from people-induced changes such as land clearing, surface mining, and pollution.

One of the most important applications of species diversity is in the evaluation of pollution. As stated previously, it has been determined that stress of any kind will reduce the species diversity of an ecosystem to a significant degree. In the case of domestic sewage, for example, the stress is caused by a lack of dissolved oxygen (DO) for aquatic organisms.

Population System: Population system or life-system (population system is definitely better, however) is a population with its effective environment (Clark et al. 1967; Berryman 1981; Sharov 1992).

Major Components of a Population System:

1. Population itself. Organisms in the population can be subdivided into groups according to their age, stage, sex, and other characteristics.
2. Resources: food, shelters, nesting places, space, etc.
3. Enemies: predators, parasites, pathogens, etc.
4. Environment: air (water, soil) temperature, composition, variability of these characteristics in time and space (Sharov, 1997).

Porosity: 1. The ratio of the aggregate volume of pore spaces in rock or soil to its total volume, usually stated as a percent. 2. A measure of the water-bearing capacity of subsurface rock. With respect to water movement, it is not just the total magnitude of porosity that is important, but the size of the voids and the extent to which they are interconnected, as the pores in a formation may be open, or interconnected, or closed and isolated. For example, clay may have a very high porosity with respect to potential water content, but it constitutes a poor medium as an aquifer because the pores are usually so small.

Porosity, *n* [dimensionless]: The porosity of a rock or soil is its property of containing interstices or voids and may be expressed quantitatively as the ratio of the volume of its interstices to its total volume (Meinzer 1923, p. 19). It may be expressed as a decimal fraction or as a percentage. With respect to the movement of water only the system of interconnected interstices is significant.

Porosity, effective, n_e [dimensionless]: Effective porosity refers to the amount of interconnected pore space available for fluid transmission. It is expressed as a percentage of the total volume occupied by the interconnecting interstices. Although effective porosity has been used to mean about the same thing as specific yield, such use is discouraged. It may be noted that the present definition of effective porosity differs from that of Meinzer (1923, p. 28).

Position: Position and time are two fundamental quantities that can be used to describe where an object is, where it is headed, and how long it will take to get there.

Positive Crankcase Ventilation (PCV): Technology used to control crankcase emissions.

Positive Pressure Self-Contained Breathing Apparatus (SCBA): An apparatus providing a constant, positive pressure flow of air within the face piece, even if one inhales deeply while doing heavy work. Use apparatus certified by NIOSH and the Department of Labor/Mine Safety and Health Administration in accordance with 42 CFR Part 84. Use it in accordance with the requirements of respiratory protection specified in OSHA 29 CFR 1910.134 (Respiratory Protection) and/or 29 CFR 1910.156 (f) (Fire Brigades Standard).

Post-Chlorination: Addition of chlorine to plant effluent for disinfectant purposes after the effluent has been treated.

Post-Closure: The time period following the shutdown of a waste management or manufacturing facility; for monitoring purposes, often considered to be thirty years.

Post-Consumer Materials/Waste: Recovered materials that are diverted from municipal solid waste for the purpose of collection, recycling, and disposition.

Post Consumer Recycling: Use of materials generated from residential and consumer waste for new or similar purposes; e.g., converting wastepaper from offices into corrugated boxes or newsprint.

Potable Water: Water of a quality suitable for drinking.

Potassium: One of the primary nutrients required for the growth of plants.

Potential Dose: The amount of a compound contained in material swallowed, breathed, or applied to the skin.

Potential to Emit: Amount of emitted pollutant that would be expected from a facility operating year-round at full capacity.

Potentially Responsible Party (PRP): Any individual or company—including owners, operators, transporters or generators—potentially responsible for, or contributing to a spill or other contamination at a Superfund site. Whenever possible, through administrative and legal actions, EPA requires PRPs to clean up hazardous sites they have contaminated.

Potentiation: The ability on one chemical to increase the effect of another chemical.

Potentiometric Surface: The surface to which water in an aquifer can rise by hydrostatic pressure; a surface that represents the total head in an aquifer; that is, it represents the height above a datum plane at which the water level stands in tightly cased wells that penetrated the aquifer.

Powered Air-Purifying Respirator (PAPR): A motorized respirator system that uses a filter to clean surrounding air before delivering to the wearer to breathe. It typically includes a blower/battery box worn on the belt, headpiece, and breathing tube.

ppb: Parts per billion by volume.

ppm: Parts per million by volume.

Precautionary Principle: When information about potential risks is incomplete, basing decisions about the best ways to manage or reduce risks on a preference for avoiding unnecessary health risks instead of on unnecessary economic expenditures.

Pre-Consumer Materials/Waste: Materials generated in manufacturing and converging processes such as manufacturing scarp and trimmings and cuttings. Includes print overruns, over-issue publications, and obsolete inventories.

Pre-Harvest Interval: The time between the last pesticide application and harvest of the treated crops.

Prechlorination: The addition chlorine at the headworks of a treatment plant prior to other treatment processes. Done mainly for disinfection and control of tastes, odors, and aquatic growths, and to aid in coagulation and settling.

Precipitate: A substance separated from a solution or suspension by chemical or physical change.

Precipitation: Precipitation is found in a variety of forms. Which form actually reaches the ground depends upon many factors: for example, atmospheric moisture content, surface temperature, intensity of updrafts, and method and rate of cooling.

Water vapor in the air will vary in amount depending on sources, quantities, processes involved, and air temperature. Heat, mainly as solar irradiation but with some contributed by the earth and human activity and some from change of state processes, will cause some water molecules either in water bodies (oceans, lakes, rivers) or in soils to be excited thermally and escape from their sources. This is called evaporation; if water is released from trees and other vegetation the process is known as evapotranspiration. The evaporated water, or moisture, that enters the air is responsible for a state called humidity. Absolute humidity is the weight of water vapor contained in a given volume of air. The Mixing Ratio refers to the mass of the water vapor within a given mass of dry air. At any particular temperature, the maximum amount of water vapor that can be contained is limited to some amount; when that amount is reached the air is said to be saturated for that temperature. If less than the maximum amount is present, then the property of air that indicates this is its Relative Humidity (RH), defined as the actual water vapor amount compared to the saturation amount at the given temperature; this is usually expressed as a percentage. RH also indicates how much moisture the air can hold above its stated level which, after attaining, could lead to rain.

When a parcel of air attains or exceeds RH = 100 percent condensation will occur and water in some state will begin to organize as some type of precipitation. One familiar form is dew, which occurs when the saturation temperature or some quantity of moisture reaches a temperature at the surface at which condensation sets in, leaving the moisture to coat the ground (especially obvious on lawns).

The term *dew point* has a more general use, being that temperature at which an air parcel must be cooled to become saturated. Dew frequently forms when the current air mass contains excessive moisture after a period of rain but the air is now clear; the dew precipitates out to coat the surface (noticeable on vegetation). Ground fog is a variant in which lower temperatures bring on condensation within the near surface air as well as the ground.

The other types of precipitation are listed in the Table along with descriptive characteristics related to each type.

Evaporation and transpiration are complex processes which return moisture to the atmosphere. The rate of evapotranspiration depends largely on two factors: (1) how saturated (moist) the ground is and (2) the capacity of the atmosphere to absorb the moisture. In this chapter we discuss the factors responsible for both precipitation and evapotranspiration.

Precipitator: Pollution control device that collects particles from an air stream.

Precision: Agreement among individual measurements of the same property, under prescribed similar conditions.

Precursor: In photochemistry, a compound antecedent to a pollutant. Fro example, volatile organic compounds (VOCs) and nitric oxides of nitrogen react in sunlight to form ozone or other photochemical oxidants. As such, VOCs and oxides of nitrogen are precursors.

Types of Precipitation

Type	*Approximate Size*	*State of Water*	*Description*
Mist	0.005 to 0.05 mm	Liquid	Droplets Large enough to be felt on face when air is moving 1 meter/second. Associated with stratus clouds.
Drizzle	Less than 0.5 mm Stratus clouds, generally for several hours.	Liquid	Small uniform drops that fall from stratus clouds, generally for several hours.
Rain	0.5 to 5 mm	Liquid	Generally produced by nimbostratus or cumulonimbus clouds. When heavy, size can be highly variable from one place to another.
Sleet	0.5 to 5 mm	Solid	Small, spherical to lumpy ice particles that form when raindrops freeze while falling through a layer of sub-freezing air. Because the ice particles are small, any damage is generally minor. Sleet can make travel hazardous.
Glaze	Layers 1 mm to 2 cm thick	Solid	Produced when supercooled raindrops freeze on contact with solid objects. Glaze can form a thick covering of ice having sufficient weight to seriously damage trees and power lines.
Rime	Variable accumulation	Solid	Deposits usually consisting of ice feathers that point into the wind. These delicate frostlike accumulations form as supercooled cloud or fog droplets encounter objects and freeze on contact.
Snow	1 mm to 2 cm	Solid	The crystalline nature of snow allows it to assume many shapes, including six-sided crystals, plates, and needles. Produced in supercooled clouds where water vapor is deposited as crystals that remain frozen during their descent.
Hail	5 mm to cm or larger	Solid	Precipitation in the form of hard, rounded pellets or irregular lumps of ice. Produced in large convective, cumulonimbus clouds, where frozen ice particles and supercooled water coexist.
Graupel	2 mm to 5 mm	Solid	Sometimes called "soft hail," graupel. Forms on rime collects on snow. Crystals to produce irregular masses. Of "soft" ice. Because these particles. Are softer than hailstones, they. Normally flatten out upon impact.

Source: NASA 2008.

Preliminary Assessment: A quick analysis to determine how serious the situation is, and to identify all potentially responsible parties. The preliminary assessment uses readily available information; for instance, forms, records, aerial photographs, and personnel interviews.

Preliminary Treatment: (1) In wastewater, involves treatment prior to primary treatment. (2) In industrial applications, pretreatment of wastestream before it becomes plant effluent and then influent into wastewater treatment plant for further treatment.

Prescriptive: Water rights which are acquired by diverting water and putting it to use in accordance with specified procedures; e.g., filing a request with a state agency to use unused water in a stream, river, or lake.

Prescriptive-Based Management Program: Program that applies predetermined requirements such as site characteristics, design standards, and separation distances to permit or otherwise allow the operation of onsite wastewater treatment systems. This type of program requires that proposed sites meet preset specifications that are perceived to protect public health and the environment.

Prescriptive Requirements: Standards or specifications for design, siting, and other procedures and practices for onsite or cluster system applications. Propose deviations from the specified criteria, procedures, or practices require formal approval by the regulatory authority.

Pressure: 1. The force exerted against an opposing fluid or thrust, distributed over a surface; the force pushing on a unit area. Normally, in air applications, measured in atmospheres, Pascal (Pa) or pounds per square inch (psi). 2. In ventilation systems, air moves under the influence of differential pressures. A fan is commonly used to create a difference of pressure in duct systems. 3. Pressure, in mechanics, is defined as the force per unit of area or

$$\text{Pressure} = \frac{\text{total force}}{\text{area}}$$

Pressure is usually expressed in terms of force per unit of area, as in pounds per square inch when dealing with gases, or in pounds per square foot when dealing with weight on a given floor area. The pressure exerted on a surface is the perpendicular force per unit area that acts upon it. Gauge pressure is the difference between total pressure and atmospheric pressure.

Pressure Drop: The loss of static pressure across a point; for example, "the pressure drop across an orifice is 2.0 in. w.g."

Pressure Gradient Force: A variation of pressure with position.

Pressure Sewers: A system of pipes in which water, wastewater, or other liquid is pumped to a higher elevation.

Pressure, Static: In flowing air, that total pressure minus velocity pressure, pushing equally in all directions.

Pressure, Total: In flowing air, the sum of the static and velocity pressures.

Pressure, Velocity: In flowing air, the pressure due to velocity and density of air.

Pressure Vessels: When reports of catastrophic events involving the rupture or explosion of pressurized vessels come to our attention, often people commonly and mistakenly believe that such events are the result of some type of malfunction to a high-pressure system. Currently no one specific standard exists for pressure vessels. However, some OSHA standards require a pressure vessel to be built in accordance with the industry codes and standards (e.g., 29 CFR 1910.106(b)(1)(v)(b)). Flammable and Combustible Liquids requires that pressure vessels be built in accordance with the Code for Unfired Pressure Vessels, Section VIII of the ASME Boiler and Pressure Vessel Code 1968). Standards with requirements for pressure vessels or other related requirements include:

OSHA Standards: General

- 1910.101, Compressed gases (general requirements)
- 1910. 102, Acetylene
- 1910.103, Hydrogen
- 1910.104, Oxygen
- 1910.105, Nitrous oxide
- 1910.106, Flammable and combustible liquids
- 1910.107, Spray finishing using flammable and combustible materials
- 1910.110, Storage and handling of liquefied petroleum gases
- 1910.111, Storage and handling of anhydrous gases
- 1910.169, Air receivers
- 1910.217, Mechanical power presses
- 1910.261, Pulp, paper, and paperboard mills
- 1910.262, Textiles
- 1910.263, Bakery equipment

OSHA Standards: Construction

- 1926.29, Acceptable certifications (pressure vessels and boilers)
- 1926.152, Flammable and combustible liquids
- 1926.153, Liquefied petroleum gas
- 1926.306, Air receivers
- 1926.603, Pile driving equipment

Pressure relief or overpressure devices are an integral and necessary part of any well-designed pressurized system. A number of different overpressure devices are available, each with particular applications. For example, some devices are suitable for gas, vapor, or steam; others are suitable for liquids; others are useful for gases, vapors or liquids. The safety engineer must have more than a basic knowledge of pressure relief devices, because they are so critical to maintaining a safe work environment. Safety engineers must also understand that such devices usually require maintenance and testing—some more than others. The main source of information available to the safety engineer on overpressure safety devices is the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*, which gives specifications for installation and certification testing of overpressure devices. Remember, the actual certificates of testing must be posted in proximity to the equipment; an OSHA inspector or another regulatory official will want to see them any time they audit your facility.

Various types of protective systems are listed and described according to specifications of the American Petroleum Institute (API) and recommendations by Slote (1987).

1. Shut-off Valves—usually installed on all bottom connections so that the vessel contents can be controlled where piping has holed-through from corrosion or accidental damage. A shut-off valve should seriously be considered when the vessel contents of flammable or combustible liquid exceed fifty barrels. The value is usually operated manually, but in the case of large diameter piping, a remote-operated valve should be installed.
2. Safety valve—actuated when the upstream pressure exceeds some predetermined value. The valve rapidly opens fully or pops open to relieve the pressure. Safety valves are used for gas, steam, and vapor.
3. Depressurizing valves—often used to reduce pressure inside an uninsulated vessel when it is exposed to fire. The vessel relief valve, set to open at the vessel maximum allowable working pressure, will not protect the vessel during a fire of long duration. If the vessel metal becomes overheated (above 1000°F) the shell may rupture at normal operating pressure. The valve is usually remotely operated and discharges to the flare header. When the valve is located close to the vessel, the valve operator may require fireproofing to assure that it functions properly when exposed to fire.

4. Relief valves—when the upstream pressure exceeds some predetermined level, a relief valve opens in proportion to the amount of overpressure. Relief valves are used primarily for liquids. These valves are generally spring-loaded devices that open when the pressure of the system reaches the maximum allowable working pressure. Relief valves should be located as specified in the ASME *Boiler and Pressure Vessel Code*. Section VII, Division I, American Petroleum Institute (API) *Recommended Practice 521* Section 2, and API *Recommended Practice 520,* Part 1, Section 4, 5, and Appendix B.
5. Frangible discs (rupture discs)—relatively flat metal pieces, each disc is designed to burst at a particular pressure. Mounted between two flanges along a vent pipe, they range in size from less than .5 in. in diameter to about 4 ft. Rupture pressures range from a few ounces to very high pressures. Other design considerations include pressure cycles, potential corrosion, operating temperature and other factors. Rupture discs generally release large quantities of process material, whereas valves release small quantities. Failure of a disc may produce significant downtime for replacement of the disc, replacement of lost materials, and restart of a process.
6. Water draws—water accumulates in the bottom of some pressure vessels and periodically must be drawn off to a drain line. This operation may be performed by manually operating a valve or by a control valve set to open automatically on high water level and close on low level. Both methods can be hazardous. The manual system requires that an operator remain at the valve whenever water is being drawn, to prevent the escape of flammable liquids or gases when the water level falls too low. A combustible vapor cloud can form when the vessel contains a light vapor pressure material, which could expose both the operator and equipment if the operator is not alert to the inherent dangers in the process. This hazard can be reduced by keeping the water draw line small (preferably one inch); installing a low-level alarm to warn the operator; and keeping the water draw valve as far as practical from the point of emergency. When water is drawn automatically from vessels to a drain, the control valve may fail in the open position, permitting combustible vapors to escape. When automatic water draws are used, the vessel usually should have a low water gauge to alarm in both the field and in the control room.

Note: Whenever a vessel contains a toxic liquid material, the water draw should discharge to a closed system, but never to the flare header, which is generally designed for vapor releases only. Even with other less hazardous material, discharging to a closed system is preferable when feasible.

7. Discharge—lines or channels approaching or leaving a pressure relief device must be sized to provide adequate flow of materials. Discharged materials must flow to some location that presents no danger to people, because high temperatures and high flow rates may cause injury. High volumes must be discharge to adequately sized holding areas or containers.
8. Temperature limit devices—pressure increases and decreases in closed containers are related to temperature changes in accordance with gas laws. Temperature limit sensors and control systems are often used in connection with processes and containers whenever pressure limits create dangers.

Pretreatment: Processes used to reduce, eliminate, or alter the nature of wastewater pollutants from non-domestic sources before they are discharge into publicly owned treatment works (POTWs).

Pretreatment System: Any technology or combination of technologies that precedes discharge to a subsurface wastewater infiltration system or other final treatment unit or process before final dissemination into the receiving environment.

Prevalence: The number of existing disease cases in a defined population during a specific time period.

Prevalence Survey: The measure of the current level of disease(s) or symptoms and exposure through a questionnaire that collects self-sorted information from a defined population.

Prevalent Level Samples: Air samples taken under normal conditions (also known as ambient background samples).

Prevalent Levels: Levels of airborne contaminant occurring under normal conditions.

Prevention: Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Preventive Maintenance: All those systematically planned and scheduled actions performed for the purpose of preventing equipment, system, or factory failure.

Prevention of Significant Deterioration (PSD): EPA program in which state and/or federal permits are required in order to restrict emissions from new or modified sources in places where air quality already meets or exceeds primary and secondary ambient air quality standards.

Primacy: Having the primary responsibility for administering and enforcing regulations.

Primary Consumers: In the food chain, organisms that consume producers (autotrophs).

Primary Drinking Water Regulation: Applies to public water systems and specifies a contaminant level, which, in the judgment of the EPA administrator, will not adversely affect human health.

Primary Effect: An effect where the stressor reacts directly on the ecological component of interest, not on other parts of the ecosystem.

Primary Exposure Pathways: In site remediation, the exposure pathways that directly affect site operations and personnel, or directly affect the cleanup levels that must be achieved by the remedial technology.

Primary Pollutants: Pollutants that are emitted directly into the atmosphere where they exert an adverse influence on human health of the environment. The six primary pollutants are carbon dioxide, carbon monoxide, sulfur oxides, nitrogen oxides, hydrocarbons, and particulates. All but carbon dioxide are regulated in the United States.

Primary Standards: The Clean Air Act (NAAQS) air quality standard covering criteria pollutants.

Primary Treatment: First stage of wastewater treatment process in which mechanical treatment is employed to screen out large solids, and settle out suspended solids.

Primary Waste Treatment: First steps in wastewater treatment; screens and sedimentation tanks are used to remove most materials that float or will settle. Primary treatment removes about 30 percent of carbonaceous biochemical oxygen demand from domestic sewage.

Principal Organic Hazardous Constituents (POHCs): Hazardous compounds monitored during an incinerator's trail burn, selected for high concentration in the waste feed and difficulty of combustion.

Prior Appropriation Doctrine: The system for allocating water to private individuals used in most Western states. The doctrine of Prior Appropriation was in common use throughout the arid West as early settlers and miners began to develop the land. The prior appropriation doctrine is based on the concept of "First in Time, First in Right." The first person to take a quantity of water and put it to beneficial use has a higher priority of right than a subsequent user. The rights can be lost through nonuse; they can also be sold or transferred apart from the land. Contrasts with riparian water rights.

Privacy Issue: The quick growth of the Internet and email use has made employees' privacy rights vs. corporate security/responsibility a pertinent and controversial issue. As email and Internet monitoring grow, more and more disciplinary actions ensue, leaving individuals unsure about their rights to workplace privacy. The struggle to balance individual right to privacy and security with organizational responsibility to protect their own intellectual assets has become increasingly intense.

As a middle ground between absolute freedom for employees to email and surf at will and the "Big Brother Sees All" effect of high levels of employee monitoring, a sensible and reasonable company policy offers compromise. Written company policy, effectively established, regularly discussed with employees and consistently enforced through the appropriate technology is critical to maintaining consistency and predictability in the process of monitoring the workplace, and helps address the privacy issue.

Probabilistic Method: A technique which uses distributions of parameters to perform an analysis. Results are expressed in terms of probabilistic distributions, which quantify uncertainty.

Probability of Detection: The likelihood, expressed as a percentage, that a test method will correctly identify a leaking tank.

Procaryotic: A type of primitive cell lacking a membrane-delimited nucleus.

Processing Uranium: Uranium-recovery operations at a mill, in-situ leach plant, byproduct plant, or other type of recovery operation.

Process Safety Management (PSM): The impetus for OSHA's introduction of the Process Safety Management (PSM) Standard 29 CFR 1910.119 was the pressing need to address the ongoing occurrence of serious accidents at chemical processing plants. Currently, the reality is that Process Safety Management (PSM) is addressed in several specific standards for the general and construction industries. OSHA's standard emphasizes the management of hazards associated with highly hazardous chemicals and establishes a comprehensive management program that integrates technologies, procedures, and management practices.

The following OSHA Standards are applicable to Process Safety Management (PSM)

General Industry (29 CFR 1910)

- 1910 Subpart H, Hazardous materials
    - Appendix A, List of highly hazardous chemicals, toxics, and reactives

  - Appendix B, Block flow diagram and simplified process flow diagram
  - Appendix C, Compliance guidelines and recommendations for process safety management
  - Appendix D, Sources of further information
- 1926 Subpart D, Occupational health and environmental controls
- 1926.64, Process Safety management of highly hazardous chemicals
  - Appendix A, List of highly hazardous chemicals, toxics, and reactives
  - Appendix B, Block flow diagram and simplified process flow diagram
  - Appendix C, Compliance guidelines and recommendations for process safety management

Process Variable: A physical or chemical quantity which is usually measured and controlled in the operation of a water treatment plant or industrial plant.

Process Verification: Verifying that process raw materials, water usage, waste treatment processes, production rate, and other facts relative to quantity and quality of pollutants contained in discharges are substantially described in the permit application and the issued permit.

Process Wastewater: The CAFO regulation defines process wastewater as water directly or indirectly used in the operation of the AFO for any or all of the following: spillage or overflow from animal or poultry watering systems; washing, cleaning, or flushing pens, barns, manure pits, or other AFO facilities; direct contact swimming, washing, or spray cooling of animals; or dust control. Process wastewater also includes any water which comes into contact with any raw materials, products, or by-products, including manure, litter, feed, milk, eggs, or bedding [40 CFR 122.23(b)(7)].

Process Weight: Total weight of all materials, including fuel, used in a manufacturing process; used to calculate the allowable particulate emission rate.

Producers: Organisms that use solar energy (green plant) or chemical energy (some bacteria) to manufacture its own organic substances (food) from inorganic nutrients.

Product Level: The level of a product in a storage tank.

Products of Incomplete Combustion (PICs): Organic compounds formed by combustion. Usually generated in small amounts and sometimes toxic, PICs are heat-altered versions of the original material fed into the incinerator (e.g., charcoal is a P.I.C. from burning wood).

Product Water: Water that has passed through a water treatment plant and is ready to be delivered to consumers.

Production Area: Concentrated Animal Feeding Operations (CAFO) regulation defines production area as the part of an AFO that includes the animal confinement area, the manure storage area, the raw materials storage area, and the waste containment areas. The animal confinement area includes but is not limited to open lots, housed lots, feedlots, confinement houses, stall barns, free stall barns, milkrooms, milking centers, cowyards, barnyards, medication pens, walkers, animal walkways, and stables. The manure storage area includes but is not limited to lagoons, runoff ponds, storage sheds, stockpiles, under house or pit storages, liquid impoundments, static piles, and composting piles. The raw materials storage area includes but is not limited to feed silos, silage burners, and bedding materials. The waste containment area includes but is not limited to settling basins, and areas within berms and diversions which separate uncontaminated stormwater. Also included in the definition of production areas is any egg washing or egg process facility, and any area used in the storage, handling, treatment, or disposal of mortalities [40 CFR 122.23(b)(8)].

Productivity: In ecology, the flow of energy through an ecosystem starts with the fixation of sunlight by plants through photosynthesis. In evaluating an ecosystem, the measurement of photosynthesis is important. Ecosystems may be classified into highly productive or less productive. Therefore, the study of ecosystems must involve some measure of the productivity of that ecosystem.

Program Policy: A high-level policy that sets the overall tone of an organization's security approach.

Prohibited Wastes: Wastes that have to meet their treatment standards before land disposal.

Project XL: An EPA initiative to give states and the regulated community the flexibility to develop comprehensive strategies as alternatives to multiple current regulatory requirements in order to exceed compliance and increase overall environmental benefits.

Prokaryotic cell: Simple cell type, characterized by the lack of a nuclear membrane and the absence of mitochondria.

Proof Testing Rigging Equipment: One of the safety professional's primary duties involving rigging operations is to ensure that the equipment used is safe to use. Ropes, slings, and chains, and other lifting devices must be certified via proof testing verifying their soundness and safety for use.

Proof testing is a nondestructive tension test performed by the sling manufacturer or an equivalent entity to verify construction and workmanship of a sling or other lifting device. During proof testing, a proof load is applied to test the lifting device.

The safety professional in responsible charge for lifting is responsible for ensuring that before each use, each new, repaired, or reconditioned lifting device (rope, chain, or sling)—including all welded components in the sling assembly—is proof tested by the sling manufacturer or equivalent entity, in accordance with American Society of Testing and Materials Specification A391-65 (ANSI G61.1-1968). The safety engineer should ensure that a written certification of the proof test is provided, and that such records are available for review by regulatory auditors. Typically, sling proof test or load test results are stamped, marked or labeled right onto the sling itself. The safety engineer should ensure (along with the satisfactory condition of each sling or other rigging component) that such certification labels and identification tags are attached, visible, and that test data (load rating) is current.

Each day before being used, the sling and all rigging fastenings and attachments must be inspected for damage or defects by a competent person designated by the employer. Some of the items that should be inspected to ensure slings are safe to use include:

1. Alloy steel chain slings must have permanently affixed durable identification stating size, grade, rated capacity, and reach.
2. A thorough periodic inspection of alloy steel chain slings in use must be made on a regular basis (at least once every 12 months).
3. A record must be maintained of the most recent month in which each alloy steel chain sling was thoroughly inspected.
4. Alloy steel chains slings must be permanently removed from service if they are heated above 1000ºF.
5. Worn or damaged alloy steel chain slings and attachments must be taken out of service until repaired.
6. Wire rope slings must be used only with loads that do not exceed the rated capacities.
7. Fiber core wire rope slings of all grades must be permanently removed from service if they are exposed to temperatures in excess of 200°F.
8. Welding of end attachments, except covers to thimbles, must be performed prior to the assembly of the sling.
9. Welded end attachments must be proof tested by the manufacturer or equivalent entity at twice their rated capacity prior to initial use.
10. All synthetic web slings must be marked or coded to show the rated capacities for each type of hitch and type of synthetic web material.

Additional inspection must also be performed during sling use where service conditions warrant. Damaged or defective slings must be immediately removed from service. Make them unusable by burning or cutting them before they are discarded—otherwise they may mysteriously reappear, and be used again.

Propellant: Liquid in a self-pressurized pesticide product that expels the active ingredient from its container.

Properties of Materials: Properties of materials is best explained by referring to the following example: A safety engineer, working with design engineers in a preliminary design conference, might typically be exposed to (should be exposed to) data, parameters and specifications related to the properties of a particular construction material to be used in the fabrication of, for example, a large mezzanine in a warehouse. In constructing this particular mezzanine, consideration was given to the fact that it would be used to store large, heavy equipment components. The demands placed on the finished mezzanine create the need for the mezzanine to be built using materials that can support a heavy load.

For illustration, let's say that the design engineers plan to use an aluminum alloy, type structural—No 17ST. Before they decide to include No 17ST and determine the required quantity needed to build the mezzanine, they are concerned with determining its mechanical properties, to ensure that it will be able to handle the intended load (they will also factor in, many times over, for safety—selecting a type of material that will handle a load much greater than expected).

Using a table on the Mechanical Properties of Engineering Materials in *Urquhart's Civil Engineering Handbook*, 4th ed., (1959) they check the following for No 17ST:

Properties of Engineering Materials No. 17ST

Ultimate strength, psi (defined as the ultimate strength in compression for ductile materials, which is usually taken as the yield point)	tension: 58,000 psi
	compression: 35,000 psi, shear: 35,000 psi
Yield point tension psi	@ 35,000 psi.
Modulus of elasticity, tension or compression, psi:	10,000,000
Modulus of elasticity, shear, and psi	@ 3,750,000
Weight per cu in., lb.:	0.10

Prophylatic: A medical procedure or practice that prevents or protects against a disease or condition (e.g., vaccines, antibiotics, drugs).

Proportionate Mortality Ratio (PMR): The number of deaths from a specific cause in a specific period of time per 100 deaths from all causes in the same time period.

Proposed Plan: A plan for a site cleanup that is available to the public for comment.

Proppant: granules of sand, ceramic, or other minerals that are wedged within the fracture and act to "prop" it open after the fluid pressure from fracture injection has dissipated.

Proprietary Information: Information unique to a company and its ability to compete, such as customer lists, technical data, product costs, and trade secrets.

Prostration: Complete physical or mental exhaustion.

Protective Relays: Consists of an operating element and a set of movable contacts. The operating element receives power from a control power source within the switchgear, and obtains input from a sensing element in the circuit. When the relay detects that some present limit has been exceeded, it initiates some action, such as sounding an alarm or tripping a circuit breaker.

Proteins: Complex nitrogenous organic compounds of high molecular weight made of amino acids; essential for growth and repair of animal tissue. Many, but not all, proteins are enzymes.

Protocol: A formal specification for communicating. Protocols exist at several levels in a telecommunication connection.

Proton: A component of a nucleus, 2000 times more massive than an electron; differs from a neutron by its positive (+1) electrical charge. The atomic number of an atom is equal to the number of protons in its nucleus.

Protozoa: Single-celled microorganisms, includes the most primitive forms of animal life.

Pruritus: Severe itching.

PSIA: A unit or pressure, pounds per square inch absolute.

PSIG: A unit of pressure, pound per square inch gauge.

Psychosis: A serious mental disorder.

Public Availability Session: An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public Comment Period: The time allowed for the public to express its views and concerns regarding an action by EPA (e.g., a Federal Register Notice of proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).

Public Health Action: A list of steps to protect public health.

Public Health Advisory: A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances pose an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public Health Approach: Regulatory and voluntary focus on effective and feasible risk management actions at the national and community level to reduce human exposures and risk, with priority given to reducing exposures with the biggest impacts in terms of the number affected and severity of effect.

Public Health Assessment (PHA): An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health.

Public Health Context: The incidence, prevalence, and severity of disease in communities or populations and the factors that account for them, including infections exposure to pollutants, and other exposures or activities.

Public Health Hazard: A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than one year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public Health Hazard Categories: Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are not public health hazard, on apparent public health hazard, indeterminate public health hazard, public heath hazard, and urgent public health hazard.

Public Health Statement: The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public Health Surveillance: The ongoing, systematic collection, analysis, and interpretation of heath data. This activity also involves timely dissemination of the data and use for public health programs.

Public Hearing: A formal meeting wherein EPA officials hear the public's views and concerns about an EPA action or proposal. EPA is required to consider such comments when evaluating its actions. Public hearings must be held upon request during the public comment period.

Public Notice: 1. Notification by EPA informing the public of Agency actions such as the issuances of a draft permit or scheduling of a hearing. EPA is required to ensure proper public notice, including publication in newspapers and broadcast over radio and television stations. 2. In the safe drinking water program, water suppliers are required to publish and broadcast notices when pollution problems are discovered.

Public Supply: Water withdrawn by public governments and agencies, such as a county water department, and by private companies that is then delivered to users. Public suppliers provide water for domestic, commercial, thermoelectric power, industrial, and public water users. Most people's household water is delivered by a public water supplier. The systems have at least fifteen service connections (such as households, businesses, or schools) or regularly service at least fifteen individuals daily for at least sixty days out of the year.

Public Utility Regulatory Policies Act of 1978 (PURPA): National Energy Act, PURPA contains measures designed to encourage the conservation of energy, more efficient use of resources, and equitable rates. Principal among these were suggested retail rate reforms and new incentives for production of electricity by cogenerators and uses of renewable resources.

Public Water System: A system that provides piped water for human consumption to at least fifteen service connections or regularly serves twenty-five individuals.

Public Water Use: Water supplied from a public-water supply and used for such purposes as firefighting, street washing, and municipal parks and swimming pools.

Publicly Owned Treatment Works (POTWs): A waste treatment works owned by a state, unit of local government, or Indian tribe, usually designed to treat domestic wastewaters.

Pulmonary: Related to or associated with the lungs.

Pulmonary Aspiration: The inhalation of foreign materials such as stomach contents into the lungs.

Pulmonary Edema: Accumulation of fluid in the lungs.

Pulmonary Fibrosis: An increase in fibrous tissue in the lungs.

Pulpwood: Roundwood, whole tree chips, or wood residues that are used for the production of wood pulp.

Pumped-Storage Hydroelectric Plant: A plant that usually generates electric energy during peak load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir through a conduit to turbine generators located in a power plant at a lower level.

Pumping Station: Mechanical device installed in sewer or water system or other liquid-carrying pipelines to move the liquids to a higher level.

Pumping Test: Test that is conducted to determine aquifer yield or well characteristics.

Pumping Well System: In control technology for leaking USTs, the preferred method used to recover free product from the water table when the spill is deep.

Pungent: Affecting the organs of taste or smell with a sharp, acrid sensation.

Purging: Removing stagnant air or water from sampling zone or equipment prior to sample collection.

Pustular: Containing pus.

Pustule: A small elevation of the skin containing pus and having an inflamed base.

Putrefaction: Biological decomposition of organic matter; associated with anaerobic conditions.

Putrescible: Able to rot quickly enough to cause odors and attract flies.

PVC: A polymer of vinyl chloride used instead of rubber in electric cables.

Pyrolysis: The thermal decomposition of biomass at high temperatures (great than 400ºF, or 200ºC) in the absence of air. The end product of pyrolysis is a mixture of solids (char), liquid (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide) with the proportions determined by operating temperature, pressure, oxygen content, and other conditions.

Pyrophoric Material: A material with an autoignition temperature in air at or below 130 degrees F (54.4 degrees C) and 50 percent relative humidity.

Q

QID: Four times per day or four daily doses; from the Latin *quarter in die*.

Quadrillion Btu (Quad): Equivalent to 10 to the 15th power Btu.

Qualified Person: 1. One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved. 2. A person who by reason of experience or training is familiar with the operation to be performed and the hazards involved.

Qualifying Facility (QF): A cogeneration or small power production facility that meets certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC) pursuant to the Public Utility Regulatory Polices Act of 1978 (PURPA).

Qualitative Use Assessment: Report summarizing the major uses of a pesticide including percentage of crop treated, and amount of pesticide used on a site.

Quality Assurance/Quality Assurance: All those actions that provide confidence that quality is achieved. A system of procedures, checks, audits, and corrective actions to ensure that all EPA research design and performance, environmental monitoring an sampling, and other technical and reporting activities are of the highest achievable quality.

Quench Tank: A water-filled tank used to cool incinerator residues or hot materials during industrial processes.

R

Race Condition: Exploits the small window of time between a security control being applied and when the service is used.

Rad: Unit of radiation absorbed dose. One rad is equal to 100 ergs per gram.

Radiant Heat: The result of electromagnetic nonionizing energy that is transmitted through space without the movement of matter within that space.

Radiation: Energetic nuclear particles, including alpha rays, beta rays, gamma rays, e-rays, neutrons, high-speed electrons, and high-speed protons.

Radiation Dose: In the United States, radiation *absorbed dose*, *dose equivalent*, and *exposure* are often measured and stated in the traditional units called *rad, rem*, or *roentgen (R)*. For practical purposes with gamma and x-rays, these units of measure for exposure or dose are considered equal. This exposure can be from an external source irradiating the whole body, an extremity, or other organ or tissue resulting in an *external radiation dose*. Alternately, internally deposited radioactive material may cause an *internal radiation dose* to the whole body or other organ or tissue.

A prefix is often used for smaller measured fractional quantities, such as, milli (m) means 1/1,000. For example, 1 rad = 1,000 mrad. Micro (μ) means 1/1,000,000. So, 1,000,000 μrad = 1 rad, or 10 μR = 0.000010 R.

The SI system (System International) for radiation measurement is now the official system of measurement and uses the “gray” (Gy) and “sievert” (Sv) for absorbed dose and equivalent dose respectively. Conversions are as follows:

- 1 Gy = 100 rad
- 1 mGy = 100 mrad
- 1 Sv = 100 rem
- 1 mSv = 100 mrem

Radioactive transformation event (radiation counting systems) can be measured in units of “disintegrations per minute” (dpm) and, because instruments are not 100 percent efficient, “counts per minute” (cpm). Background radiation levels are typically less than 10 μR per hour, but die to differences in detector size and efficiency, the cpm reading on fixed monitors and various handheld survey meters will vary considerably.

Radiation Poisoning: A form of damage to organ tissue due to excessive exposure to ionizing radiation.

Radiation Standards: Regulations that set maximum exposure limits for protection of the public from radioactive materials.

Radiation Workers: Those personnel listed on the Authorized User Form of the supervisor to conduct work with radioactive materials.

Radiative Inversions: In temperature inversions, a nocturnal phenomenon caused by cooling of the earth’s surface. Inversions prompt the formation of fog and simultaneously trap gases and particulates, creating a concentration of pollutants.

Radioactive Decay: Spontaneous process of unstable nuclei in an atom disintegrating into stable nuclei, releasing radiation in the process.

Radioactive Decay Equations: Radioactive materials emit alpha particles, beta particles, and photon energy, and lose a proportion of their radioactivity with a characteristic half-life. This is known as radioactive decay. To calculate the amount of radioactivity remaining after a given period of time, use the following basic formulae for decay calculations:

Later activity = (earlier activity) e $^{-\lambda}$ (elapsed time)

$$A = A_i e^{-\lambda} t$$

where:

$$\lambda = LN2/T$$

and:

λ= lambda decay constant (probability of an atom decaying in a unit time)
t = time
LN2 = 0.693
T = radioactive half-life (time period in which half of a radioactive isotope Decays)
A = new or later radioactivity level
A_i = initial radioactivity level

In determining time required for a radioactive material to decay (A_o to A) use:

$$t = (- LN\ A/A_i)\ (T/LN2)$$

where:

λ = lambda decay constant (probability of an atom decaying in a unit time)
t = time LN2 = 0.693
T = radioactive half-life (time period in which half of a radioactive isotope decays)
A = new or later radioactivity level
A_i = initial radioactivity level

Basic Rule of Thumb: In seven half lives, reduced to <1%; 10 half lives <0.1%

In determining the rate of radioactive decay, keep in mind that radioactive disintegration is directly proportional to the number of nuclei present. Thus, the radioactive decay rate is expressed in nuclei disintegrated per unit time.

$$A_i = (0.693/T)\ (N_i)$$

where:

A_i = initial rate of decay
N_i = initial number of radionuclei
T = half life

As defined earlier, half-life is defined as the time it takes for a material to lose 50 percent of its radioactivity. The following equation can be used to determine half-life.

$$A = A_i\ (0.5)^{t/T}$$

where:

A = activity at time t
A_i = initial activity
t = time
T = half-life

Radioactive Material: Any material that spontaneously emits ionizing radiation.

Radioactive Substances: Substances that emit ionizing radiation.

Radioactive Waste: Any waste that emits energy as rays, wave streams, or energetic particles. Radioactive materials are often mixed with hazardous waste from nuclear reactors, research institutions, or hospitals.

Radioisotope: Radioactive nuclide of a particular element.

Radionuclide: Radioactive particle, man-made (anthropogenic) or natural, with a distinct atomic weight number. Can have a long life as soil or water pollutant.

Radio Spectrum Pollution: The straying of waves in the radio and electromagnetic spectrums outside their allocations that cause problems for some activities.

Radium and Radon: Radium is highly radioactive and its decay product, radon gas, is also radioactive.

Radius of Influence: 1. The radial distance from the center of a wellbore to the point where there is no lowering of the water table or potentiometric surface (the edge of the cone of depression); 2. the radial distance from an extraction well that has adequate air flow for effective removal of contaminants when a vacuum is applied to the extraction well.

Radius of Vulnerability Zone: The maximum distance from the point of release of a hazardous substance in which the airborne concentration could reach the level of concern under specified weather conditions.

Radon: A naturally occurring radioactive gas, arising from the decay of uranium 238, which may be harmful to human health in high concentrations.

Radon Daughters/Radon Progeny: Short-lived radioactive decay products of radon that decay into longer-lived lead isotopes that can attach themselves to airborne dust and other particles and, if inhaled, damage the linings of the lungs.

Radon Decay Products: A term used to refer collectively to the immediate products of the radon decay chain. These include Po-218, Pb-214, Bi-214, and Po-214, which have an average combined half-life of about thirty minutes.

RADS: Reactive Airways Dysfunction Syndrome.

Rail Carrier Requirements (49 CFR): This section is based on Part 174 and presents the DOT requirements for transporting hazardous materials by rail. The discussion will center on general operating requirements, handling and loading requirements, segregation of hazardous materials, and the positioning of placarded cars in the train.

Rail Carrier General Requirements

- You may not accept hazardous material for transportation unless they are properly classed, described on a shipping paper, packaged, marked, and labeled according to the requirements of the HMR. Hazardous materials shipments by rail must comply with the requirements of Part 174 as well as those contained in Parts 171, 172, 173 and 179 of the HMR. Without the required shipping papers, you must not accept a car containing hazmats for transportation by rail.
- A railroad transporting its own supplies of hazardous materials must meet all other requirements of the HMR, although a shipper's certification is not required on the shipping paper when a railroad is transporting its own supplies. The requirements of the HMR do not apply to railway torpedoes and fusees when carried in engines or rail cars. Torpedoes must be in a closed, metal box when not in use.
- A rail carrier must inspect each rail car containing hazardous materials, at ground level, for required markings, labels, placards, securement of closure, and leakage, at each location where a hazardous material is accepted or placed in a train.
- A carrier must forward shipments of hazardous materials properly and within 48 hours after acceptance (not counting Saturdays, Sundays, and holidays). Carriers that provide only weekly or biweekly service must forward hazardous materials shipments on the first available train. Division 2.1 (flammable gas), Division 2.3 (poisonous gas), or Class 3 (flammable liquid) loaded in a tank car may not be received and held at any point, subject to the forwarding orders.

✔ **Important Point**: A rail carrier may impose additional restrictions on a hazmat shipment when local conditions make acceptance, transportation, or delivery unusually hazardous. The carrier must report additional local restrictions to the Bureau of Explosives for publication.

- You may transport a bulk packaging containing a hazardous material inside a fully closed transport vehicle or freight container, if it is properly secured so it will not change position, slide into other packages or contact the walls of the transport vehicle or freight container, during normal transportation conditions. Bulk packaging not in conformance with the and subject to these requirements, may be transported in container-on-flat-car or trailer-on-flat-car service subject to the conditions in 174.63(c)(1-6).
- You may not transport a cargo tank or multi-unit tank car tank containing a hazmat in trailer-on-flat-car or container-on-flat-car service, unless this service is approved by the Associate Administrator for Safety, Federal Railroad Administration. In the event of an incident resulting in an emergency, you do not need prior approval to move the cargo tank to mitigate the incident's consequences. Such movement must be limited to transportation necessary under emergency conditions.

Segregation of Hazmats

- You must segregate hazardous materials in loading, transportation and storage according to the Segregation Table for Hazardous Materials in 174.81(d). To use the table, match the hazard classes in the left hand column with hazard classes across the top row.
- This table uses three different symbols—the letter *X*, and letter *O*, and an asterisk—to represent information. A blank space also provides information.
- A blank space at the intersection of two classes means there is no restriction. For example, to determine whether class 3 (flammable liquids) and Division 2.1 (flammable gas) materials may be placed together, you would find Class 3 in the left column and then find Division 2.1 in the top row. The blank space at the point of the intersection indicates there are no restrictions for loading, transporting, or storing these two materials.
- An "X" means the materials may not be loaded, transported, or stored together in the same rail car or storage facility. For example, to determine whether Division 1.3 (explosives) and Division 2.1 (flammable gas) materials may be placed together you would find Division 1.3 in the left column and then find

division 2.1 in the top row The "X" at the intersection indicates that these two materials may not be loaded, transported, or stored together in the same rail car or storage facility.

- An "O" at an intersection means these materials may be loaded, transported, or stored together provided there is some method to keep their contents separate in the event of leakage. For example, to determine whether Class 3 (flammable liquids) may be stored with Division 1.4 (explosives), you would find Class 3 in the left column and then find Division 1.4 in the top row. The "O" at the intersection indicates that these two materials may be loaded, transported, or stored together provided there is some method to keep their contents separate in the event of leakage.
- asterisk indicates that segregation among different Class I materials is governed by the Compatibility Table for Class I (explosive) materials in 174.81 (f).

√ **Important Point**: As previously mentioned, some materials have primary and subsidiary hazards. In segregating hazardous materials, you must apply the segregation appropriate to the subsidiary hazard when it is more restrictive than the segregation for the primary hazard. But hazardous materials in the same hazard class may be stowed together, without regard to segregation required by the subsidiary hazard, if the material cannot react dangerously with each other.

Rail Carrier Loading Requirements

When carrier personnel unload a tank car, unloading must be performed by a reliable person who has been trained and is responsible for unloading safely. The brakes must be set and at least one wheel blocked on at least one care being unloaded. If multiple cars are being unloaded, the hand brakes must be set and at least one wheel should be blocked from both directions. Cautions signs, to warn approaching people must be placed on the track or on the car. Pressure must be relieved before opening manhole covers or outlet valve caps, and safety procedures must be followed when breaking seals, opening manhole covers and performing unloading operations. Unloading connections for tank cars must be securely attached to unloading pipers. After unloading is completed, a tank car may not be allowed to stand with unloading connections attached. A tank care must be attended or monitored by the unloader during the period of unloading and while the tank car is connected to the unloading device.

If you load packages in a freight container or transport vehicle, you must load each package containing a hazardous material so that it cannot fall or slide. You must also protect hazardous materials packages so that other freight cannot fill onto or slide into them. If other freight can't protect the packages, blocking and bracing must be used. For blocking and bracing examples, see the bureau of Explosives pamphlets Numbers 6 and 6c. If a hazardous materials package bears orientation markings you must load it so that the markings are pointing in an upright position. You must not use the doors of a freight container or transport vehicle to secure a load containing a hazardous materials package, unless the doors meet the design strength specifications for freight containers and trailers. The specifications are M-930 for freight containers and M-931 for trailers in the Association of American Railroads (AAR) Manual of Standards and Recommended Practices.

√ **Important Point**: All hazardous materials that have leaked from a package in a rail car or on other railroad property must be carefully cleaned up and removed.

√ **Important Point**: You must load Class I (Explosive) materials for rail transportation according to detailed requirements in Subpart E of Part 174, as applicable. The requirements address procedures for properly loading and securing Class I explosives in order to ensure safe rail transportation.

Rail Carrier Shipping Paper Requirements

Requirements for carrying shipping papers and other hazmat-related documents depend on when car movement takes place in a "train." The HMR defines a train as "one or more engines coupled with one or more rail cares, except during switching operations or where the operation is that of classifying and assembling rail car within a railroad yard for the purpose of making or breaking up trains." The Federal Railroad Administration (FRA) has clarified this definition, saying a "train" exists when federal air brake rules apply to train movement or when picking up or setting out cars at interchanges or industry.

In addition to shipping papers, a train crew must also carry a document showing the current position of each ail car containing hazardous materials in the train. This document is called a *train consist*. A train crewmember must update the train consist show changes in the position of cars within a train containing hazardous materials.

Rail Car Marking

You may not use a rail car to transport hazardous materials unless it displays the required markings and placards. Placard and car certificates lost in transit must be replaced at the next inspection point. Those not required must be removed at the next terminal where the train is classified.

Switching placarded railcars requires certain considerations when the use of hand brakes is necessary. Hand brakes must be tested to make sure they're working properly before cutting off cars during switching operations. Cars with switching restrictions must clear the ladder track before other cars can be cut off in motion.

Strict handling restrictions apply to any rail car that is placarded:

- Division 1.1 Explosives
- Division 1.2 Explosives
- Division 2.3, Zone A, Poisonous Gases
- DOT 113 tan cars placarded Division 2.1 Flammable Gas

Note: These placards must be displayed on a white square background.

No rail car moving under its own momentum may strike any placarded flatcar or any flatcar carrying a placarded transport vehicle, freight container, or bulk packaging. A placarded flatcar or a flatcar carrying a transport vehicle, freight container, or bulk packaging may not be coupled into with more force than is necessary to complete the coupling. Most carrier operating rules specify a coupling speed of no more than 4 mph; but this is not a federal regulatory requirement.

✔ **Important Point**: In a train, placarded cars have to be positioned according to strict rules of separation. These rules are listed in a table found in 174.85(d).

The table organizes placards into groups based on hazard classification. Placard groups 1 and 4 apply to rail cars only. Placard groups 2 and 3 are subdivided into rail cars and tank cars, because both types of cars may be used to carry the hazardous materials in these groups.

- Placard Group 1 applies to rail cars only and includes Division 1.1 and 1.2 (Explosives). Cars placarded Division 1.1 and 1.2 explosives face additional restrictions while being handled in a terminal, yard or siding. The must be separated from the engine by at least one non-placarded car, and they must be placed in a location that is safe from danger of fire. The cars may not be placed under a bridge or overhead crossing or near a passenger shed or station except during transfer operations.
- Placard Group 2 is subdivided into rail cars and tank cars, because both types of cars may be used to carry the hazardous materials in these groups, and includes Division 1.3, 1.4, 1.5; class 2 (not including Division 2.3, PG 1, Zone A); Class 3; Class 4; class 5; class 6 (not Division 6.1, PG 1, Zone A); and Class 8.
- Group 3 is subdivided into rail cars and tank cars, because both types of cars may be used to carry the hazardous materials in these groups, and includes Division 2.3 (PG I, Zone a; poisonous gas) and Division 6.1 (PG I, Zone A; poisonous liquid).

✔ **Important Point**: Placard Group 4 applies to rail cars only carrying Class 7 (Radioactive) materials.

Placement Restrictions

Reading down the left side of the tale found in 174.85(d), there are six placement restrictions. The four placard groups read left to right across the top of the table. The table is arranged to show an *X* under the type of placarded car where each restriction applies.

- Restriction #1 reads, "When train length permits, placarded car may not be nearer than the sixth car from the engine or occupied caboose."
- Restriction #2 reads, "When train length does not permit, placarded car must be placed near the middle of the train, but not nearer than the second car from an engine or occupied caboose."
- Restriction #3 says that a placarded car may not be placed next to an open-top car when any of the lading in the open top car protrudes beyond the car ends or would protrude if the lading shifted.
- Restriction #4 says that a placarded car may not be placed next to a loaded flatcar that does not have permanent bulkheads. This restriction does not apply if the flatcar is loaded with closed container on flatcar or trailer on flatcar equipment or if the flatcar is an auto carrier or has other equipment with tie-down devices for securing vehicles.
- Restriction #5 states that a placarded car may not be placed next to any transport vehicle or freight container having an internal combustion engine or an open flame device in operation.
- Restriction #6 explains which placarded cars may not go next to each other. Basically, cars from the same placard group may be placed next to each other and cars from different placard groups may not.

There are additional placement restrictions not covered in the Table. A car placarded RADIOACTIVE must be separated by at least one non-placarded car from a locomotive, an occupied caboose, or a carload of undeveloped film.

✔ **Important Point**: Tank cars containing the residue of hazardous materials must be separated by at least one non-placarded car from a locomotive or occupied caboose.

Escorted cars must be placed next to or ahead of the car occupied by the guards or technical escorts if they are placarded: Division 1.1 or 1.2 (explosives); Division 2.3 (Hazard Zone A, poison gas); and Division 6.1 (PG I, Hazard Zone A, poisonous liquid). If a car occupied by guards or technical escorts has an operating heater or air conditioning equipment, it must be the fourth car behind a car requiring Division 1.1 or 1.2 placards.

✔ **Important Point**: The maximum speed of cars carrying molten metal or molten glass may not exceed 15 miles per hour if the packaging does not meet the requirements in 173.247.

Rail Carrier Restrictions

The railroad industry can and does recommend stricter operating rules than those required by DOT. For example, additional restrictions apply to "key trains" which are: Trains with five tank car loads of Poisonous by Inhalation materials; or trains with twenty or more loaded cars, trailers, containers, and intermodal tanks carrying a combination of:

- Division 2.3 and 6.1 Zone A or B Poisonous by Inhalation Materials
- Division 1.1 and 1.2 Explosives
- Division 2.1 Flammable Gases
- Certain environmentally sensitive chemicals

Key trains are limited to a maximum speed of 50 miles per hour. When practical, they will hold main track at meeting or passing points. A full train inspection is required at any emergency stop. At hot box detector stops, if an alarm sounds, the train must be inspected. If no defect is found, the train must travel no faster than 30 miles per hour to the next detector—or another 30 miles—for another inspection.

The Association of American Railroads (AAR) recommends hat railroads designate certain route as "Key routes." Key routes carry at least 10,000 loads of hazardous materials a year or 4,000 loads of the special materials that make up key trains. It is important to note that key train and key route criteria are not federal requirements.

Leaking packages, other than tank cars, may not be forwarded as is. They must be repaired, reconditioned, or placed in a salvage drum according to the requirements 173.3. A leaking tank car may be moved without making repairs if necessary to safeguard human health or the environment. Movement must be kept to a minimum and any leaking liquid must be prevented from spreading.

✔ **Important Point**: A tank car that no longer conforms to the requirements of the HMR may not be forwarded unless repaired or approved for movement by the associate administrator for Safety, Federal Railroad administration.

A car that's resting unevenly or bulging at the doors or walls may have been damaged inside from a loading shift or mishandling. If the car appears in good condition, the crew can heck the placards and markings to make sure they are properly applied. This should be done before pulling it from the shipper's spot or placing it in a train. The placards must match each other and the information on the shipping papers. Crews can verify placard accuracy by checking the shipping paper for Hazard Class and UN or NA Identification Number.

You may not fill a tank car that is overdue for periodic inspection with a hazardous material and then offer it for transportation. Test dates must be current for both tanks and safety valves. If the car passes the hazmat checks, it can be switched to the local classification yard. There it is given a detailed mechanical inspection of running gear and safety appliances. Then it's placed into a train. Shipping papers and related documents are given to the train crew.

Rail Carrier Incidents/Accidents

Incidents and accidents involving hazardous materials may require notification to the National Response Center (NRC), or, for an etiologic agent, the Centers for Disease Control (CDC). The NRC or CDC must be notified by telephone within 12 hours when, as a direct result of hazardous materials:

- A person is killed, or requires hospitalization
- An evacuation lasting more than one hour occurs
- One or more major transportation route is closed for more than one hour; or
- Aircraft flight patterns are altered

Immediate notification is also required for incidents involving:

- Radioactive contamination
- Etiologic (disease-causing) contamination; or
- More than 450 liters of liquid marine pollutants or 400 kilograms of solid marine pollutants are released.

✔ **Important Point**: The NRC telephone number is 1-800-424-8802. The CDC telephone number is 1-800-232-0124.

A written report is also required within thirty days of the incident whenever the above criteria are met, or whenever there has been an unintentional release of hazardous materials.

Rain Shadow Effect: Phenomenon that occurs as a result of the movement of air masses over a mountain range. As an air mass rises to clear a mountain, the air cools and precipitation forms. Often, both the precipitation and the pollutant load carried by the air mass will be dropped on the windward side of the mountain. The air mass is then devoid of most of its moisture; consequently, the lee side of the mountain receives little or no precipitation and is said to lie in the rain shadow of the mountain range.

Rales: An abnormal respiratory sound.

Rasp: A machine that grinds waste into a manageable material and helps prevent odor.

Raw Sewage: Untreated wastewater and its contents.

Raw Water: Intake water prior to any treatment or use.

Re-entry: (In indoor air program). Refers to air exhausted from a building that is immediately brought back into the system through the air intake and other openings.

Reactive: A substance that reacts violently by catching on fire, exploding, or giving off fumes when exposed to water, air, or low heat.

Reactivity: Refers to those hazardous wastes that are normally unstable and readily undergo violent chemical change but do not explode.

Reactivity Hazard: The ability of a material to release energy when in contact with water. Also, the tendency of a material, when in its pure state or as a commercially produced product, to vigorously polymerize, decompose, condense, or otherwise self-react and undergo violent chemical change.

Reaeration: Introduction of air into the lower layers of a reservoir. As the air bubbles form and rise through the water, the oxygen dissolves into the water and replenishes the dissolved oxygen. The rising bubbles also cause the lower waters to rise to the surface where they take on oxygen from the atmosphere.

Real-Time Monitoring: Monitoring and measuring environmental developments with technology and communications systems that provide time-relevant information to the public in an easily understood format people can use in day-to-day decision-making about their health and the environment.

Reasonable Further Progress: Annual incremental reductions in air pollutant emissions as reflected in a State Implementation Plan that EPA deems sufficient to provide for the attainment of the applicable national ambient air quality standards by the statutory deadline.

Reasonable Maximum Exposure: The maximum exposure reasonably expected to occur in a population.

Reasonable Worst Case: An estimate of the individual dose, exposure, or risk level received by an individual in a defined population that is greater than the 90th percentile but less than that received by anyone in the 98th percentile in the same population.

Reasonably Available Control Measures (RACM): A broadly defined term referring to technological and other measures for pollution control.

Reasonably Available Control Technology (RACT): Control technology that is reasonably available, and both technologically and economically feasible. Usually applied to existing sources in nonattainment areas; in most cases is less stringent than new source performance standards.

Reassortment: The rearrangement of genes from two distinct influenza strains to produce a novel viral strain.

Recarbonization: Process in which carbon dioxide is bubbled into water being treated to lower the pH.

Receiving Waters: A river, lake, ocean, stream, or other watercourse into which wastewater or treated effluent is discharged.

Receptor: Ecological entity exposed to a stressor.

Receptor Population: People who could come into contact with hazardous substances.

Recharge: Water added to an aquifer, naturally by precipitation or runoff, or artificially by spreading or injection.

Recharge Area: The area in which precipitation percolates through to recharge groundwater.

Recharge Rate: The quantity of water per unit of time that replenishes or refills an aquifer.

Recharge Water: Water that is placed in either gravity or pull-plug manure drain systems to assist in the transport of manure out of an animal building.

Reclaimed Wastewater: Treated wastewater that can be used for beneficial purposes, such as irrigating certain plants.

Reclamation: Process of restoring surface environment to acceptable pre-existing conditions. Includes surface contouring, equipment removal, well plugging, revegetation, etc.

Recognition Threshold: Volume of non-odorous air needed to dilute a unit volume of odorous sample air to the point where trained panelists can correctly recognize the odorous air.

Recommended Maximum Contaminant Level (RMCL): The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on human health would occur, and that includes an adequate margin of safety. Recommended levels are nonenforceable health goals.

Reconstructed Source: Facility in which components are replaced to such n extent that the fixed capital cost of the new components exceeds 50 percent of the capital cost of construction a comparable range-new facility. New-source performance standards maybe applied to sources reconstructed after the proposal of the standard if it is technologically and economically feasible to meet the standards.

Reconstruction of Dose: Estimating exposure after it has occurred by using evidence within an organism such as chemical levels in tissue or fluids.

Record of Decision (ROD): A public document that explains which cleanup alternatives(s) will be used at National Priorities List sites where, under CERCLA, Trust Funds pay for the cleanup.

Recovery Factor: The fraction of total resource that can be extracted for productive uses.

Recovery Rate: Percentage of usable recycled materials that have been removed from the total amount of municipal solid waste generated in a specific area or by a specific business.

Recovery Zone: The zone in a stream or river where contamination is reduced by the self-purification process.

Recycle/Reuse: The process of recovery and reuse of materials from waste streams.

Recycled Water: Water that is used more than one time before it passes back into the natural hydrologic system.

Recycling and Reuse Business Assistance Centers: Located in state solid-waste or economic-development agencies, these centers provide recycling businesses with customized and targeted assistance.

Recycling Economic Development Advocates: Individuals hired by state or tribal economic development offices to focus financial, marketing, and permitting resources on creating recycling businesses.

Recycling Mill: Facility where recovered materials are remanufactured into new products.

Recycling Technical Assistance Partnership National Network: A national information-sharing resource designed to help businesses ad manufacturers increase their use of recovered materials

Recycling Technology: The technology available to recycle or reuse waste products; processes such as composting and hot- and cold-mix asphalt incorporation.

Red Border: An EPA document undergoing review before being submitted for final management decision-making.

Red Tide: A proliferation of a marine plankton toxic and often fatal to fish, perhaps stimulated by the addition of nutrients. A tide can be red, green, or brown, depending on the coloration of the plankton.

Red Zone: Areas where significant contamination with chemical, biological, radiological, or nuclear (CBRN) agent has been confirmed or is strongly suspected but area has not been characterized. The Area is presumed to be life threatening from both skin contact and inhalation .

Redemption Program: Program in which consumers are monetarily compensated for the collection of recyclable materials, generally through prepaid deposits or taxes on beverage containers. In some states or localities legislation has enacted redemption programs to help prevent roadside litter.

Reduced Tillage: A management practice whereby the use of secondary tillage operations is significantly reduced.

Reduction: Removal of oxygen from a compound; lowering of oxidation number resulting from a gain of electrons.

Reentry Interval: The period of time immediately following the application of a pesticide during which unprotected workers should not enter a field.

Reference Dose (RfD): The RfD is a numerical estimate of a daily oral exposure to the human population, including sensitive subgroups such as children that is not likely to cause harmful effects during a lifetime. RfD are generally used for health effects that are thought to have threshold or low dose limit for producing effects.

Reformulated Gasoline: Gasoline with a different composition from conventional gasoline (e.g., lower aromatics content) that cuts air pollutants.

Refueling Emissions: Emissions released during vehicle re-fueling.

Refuse: Rubbish and garbage; residential sources.

Refuse Reclamation: Conversion of solid waste into useful products; e.g., composting organic wastes to make soil conditioners or separating aluminum and other metals for recycling.

Regeneration: Manipulation of cells to cause them to develop into whole plants.

Regional Response Team (RRT): Representatives of federal, local, and state agencies that may assist in coordination of activities at the request of the on-scene coordinator before and during a significant pollution incident such as an oil spill, major chemical release, of Superfund response.

Registrant: Any manufacturer or formulator who obtains registration for a pesticide active ingredient or product.

Registration: Formal listing with EPA or a new pesticide before it can be solid or distributed. Under the Federal Insecticide, Fungicide, and Rodenticide Act, EPA is responsible for registration (pre-market licensing) of pesticides on the basis of data demonstrating no unreasonable adverse effects on human health or the environment when applied according to approved label directions.

Registration Standards: Published documents which include summary reviews of the data available on a pesticide's active ingredient, data gaps, and the Agency's existing regulatory position on the pesticide.

Registry: In Windows operating systems, the central set of settings and information required to run the Windows computer.

Regulated Asbestos-Containing Material (RACM): Friable asbestos material or Nonfriable ACM that will be or has been subjected to sanding, grinding, cutting, or abrading or has crumbled or been pulverized or reduced to powder in the course of demolition or renovation operations.

Regulated Medical Waste: Under the Medical Waste Tracking Act of 1988, any solid waste generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals. Included are cultures and stocks of infectious agents; human blood and blood products; human pathological body wastes from surgery and autopsy; contaminated animal carcasses from medical research; waste from patients with communicable disease; and all used sharp implements, such as needles and scalpels, and certain unused sharps.

Regulatory Authority (RA): The level of government that establishes and enforces codes related to the permitting, design, placement, installation, operation, maintenance, monitoring, and performance of onsite wastewater treatment systems.

REL: NIOSH Recommended Exposure Limit. The designation "(skin)" in this section "indicates the potential for dermal absorption; skin exposure should be prevented as necessary through the use of good work practices and gloves, coveralls, goggles, and other appropriate equipment," according to the NIOSH Pocket Guide to Chemicals Hazards.

Relative Ecological Sustainability: Ability of an ecosystem to maintain relative ecological integrity indefinitely.

Relative Humidity: The concentration of water vapor in the air. It is expressed as the percentage that its moisture content represents of the maximum amount that the air could contain at the same temperature and pressure. The higher the temperature the more water vapor the air can hold.

Relative Permeability: The permeability of a rock to gas, NAIL, or water, when any two or more are present.

Relative Risk Assessment: Estimating the risks associated with different stressors or management actions.

Relative Toxicity: The relative toxicity of substances is demonstrated by the table.

Scale of Relative Toxicity

Category	*Concentration*	*Amount for Average Adult*	*Example*
Extremely toxic	<1 mg/kg	taste	botulinum
Highly toxic	1-50 mg/kg	7 drops-teaspoon	nicotine Cyanide
Moderately toxic	50-500 mg/kg	teaspoon-ounce	DDT
Slightly toxic	500-5,000 mg/kg	ounce-pint	salt
Practically non-toxic	5,000-15,000 mg/kg	pint-quart	ethanol
Relatively harmless	>15,000 mg/kg	>1 quart	water

Release: Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment of a hazardous or toxic chemical or extremely hazardous substance.

Rem: Unit of dose equivalent. One rem is approximately equal to one rad of beta, gamma, or x-ray radiation, or 1/20 of alpha radiation.

Remedial Action (RA): The actual construction or implementation phase of a Superfund site cleanup that follow remedial design.

Remedial Investigation: An in-depth study designed to gather data needed to determine the nature and extent of contamination at a Superfund site; establish site cleanup criteria; identify preliminary alternatives for remedial action; and support technical and cost analyses of alternatives. The remedial investigation is usually done with the feasibility study. Together they are usually referred to as the "RI/FS".

Remedial Project Manager (RPM): The EPA or state official responsible for overseeing on-site remedial action.

Remedial Response: Long-term action that stops or substantially reduces a release or threat of a release of hazardous substances that is serious but not an immediate threat to public health.

Remediation: 1. Cleanup of other methods used to remove or contain a toxic spill or hazardous materials from a Superfund site; 2. for the Asbestos Hazard Emerg Response program, abatement methods including evaluation, repair, enclosure, encapsulation, or removal of grater than 3 linear feet or square feet of asbestos-containing material from a building.

Remote Access: The hookup of a remote computing device via communications lines such as ordinary phone lines or wide area networks to access network applications and information.

Remote Sensing: The collection and interpretation of information about an object without physical contact with the object; e.g., satellite imaging, aerial photography, and open path measurements.

Removal Action: Short-term immediate actions taken to address releases of hazardous substances that require expedited response.

Renal: Of, relating to, or in the region of the kidneys.

Renewable Energy[1]: With regard to the current status of the worldwide use of fossil fuels, politics and other persistent forces are pushing for substitute, alternate, and/or renewable fuel sources. This is the case, of course, because of the current and future economic problems that $4+/gal gasoline has generated (especially in the United States) and because of the perceived crisis developing with high carbon dioxide emissions, the major contributing factor of global climate change.

Before proceeding with an introductory discussion of alternative/renewable energy sources, it is important to make a clear distinction be made between the two terms, the current buzzwords, alternative and renewable energy. *Alternative energy* is an umbrella term that refers to any source of usable energy intended to replace fuel sources without the undesired consequences of the replaced fuels. The use of the term "alternative" presupposes an undesirable connotation (for many people fossil fuels has joined that endless list of four-letter words)—that is, fueled energy that does not use up natural resources or harm the environment—against which alternative energies are opposed. Examples of alternate fuels include petroleum as an alternative to whale oil; coal as an alternate to wood; alcohol as an alternate to fossil fuels; coal gasification as alternative to petroleum. These alternate fuels need not be renewable.

Renewable energy is energy generated from natural resources—such as sunlight, wind, water (hydro), ocean thermal, wave and tide action, biomass and geothermal heat—which are naturally replenished (and thus renewable). Renewable energy resources are virtually inexhaustible—they are replenished at the same rate as they are used—but limited in the amount of energy that is available per unit time. If we have not come full circle in our cycling from renewable to nonrenewable we are getting close to that. Consider, for example, that in 1850, about 90 percent of the energy consumed in the United States was from renewable energy resources (hydro power, wind, burning wood, etc.). Now, however, the United States is heavily reliant on the nonrenewable fossil fuels, natural gas, oil, and coal. In 2009, about 7 percent of all energy consumed and about 8.5 percent of total electricity production from renewable energy resources.

Most of the renewable energy is used for electricity generation, heat in industrial processes, heating and cooling buildings, and transportation fuels. Electricity producers (utilities, independent produces, and combined

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[1] Much of the information and data in this section is from EIA's *Renewable Energy Trends* 2004. Accessed 06/12/09 @http:www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends04.html. EIA's (2007) *How Much renewable energy do we use?* Accessed 06/12/09 @ http://tonto.eia.doe.gov/energy_in_brief/renewable_energy.cfm.

heat and power plants) consumed 51 percent of total U.S. renewable energy in 2007 for producing electricity. Most of the rest of the remaining 49 percent of renewable energy was biomass consumed for industrial applications (principally paper-making) by plants producing only heat and steam. Biomass is also used for transportation fuels (ethanol) and to provide residential and commercial space heating. The largest share of the renewable-generated electricity comes from hydroelectric energy (71 percent), followed by biomass (16 percent), wind (9 percent), geothermal (4 percent), and solar (0.2 percent). Wind-generated electricity increased by almost 21 percent in 2007 over 2006, more than any other energy source. Its growth rate was followed closely by solar, which increased by over 19 percent in 2007 over 2006.

Solar Energy

It is fitting to begin our discussion of the various kinds of renewable energy with the sun—the star that symbolizes life, power, strength, force, clarity, and, yes, energy. The sun nourishes our planet. When we consider the sun and solar energy first, we quickly realize that there is nothing new about renewable energy. The sun was the first energy source; it has been around for 4.5 billion years, as long as anything else we are familiar with. On earth without the sun there is nothing—absolutely nothing. The sun provided light and heat to the first humans. During daylight, the people searched for food. They hunted and gathered and probably stayed together for safety. When nightfall arrived and in the dark, we can only imagine that they huddled together for warmth in light of the stars and moon, waiting for the sun and its live-giving and sustaining light to return.

Solar energy (a term used interchangeably with solar power) uses the power of the sun, using various technologies, "directly" to produce energy. Solar energy is one of the best renewable energy sources available because it is one the cleanest sources of energy. Direct solar radiation absorbed in solar collectors can provide space heating and hot water. Passive solar can be used to enhance the solar energy use in buildings for space heating and lighting requirements. Solar energy can also be used to produce electricity, and this is the renewable energy area that is the focus attention in this section.

According to USDOE (2009), the two solar electric technologies with the greatest potential are photovoltaics (PV) and concentrating solar power (CSP).

Photovoltaics (PV)

Photovoltaic (Gr. *photo* light, and *volt*, electricity pioneer Alessandro Volta) technology makes use of the abundant energy in the sun, and it has little impact on our environment. *Photovoltaics* is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the *photoelectric effect* (discovered and described by Becquerel in 1839) that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results (i.e., electricity is the flow of free electrons) that can be used as electricity. The first photovoltaic module (billed as a solar battery) was built by Bell laboratories in 1954. In the 1960s, the space program began to make the first serious use of the technology to provide power aboard spacecraft. Space program use helped this technology make giant advancements in reliability and helped to lower cost. However, it was the oil embargo of the 1970s (the so-called energy crisis) that propelled photovoltaic technology to the forefront of recognition for use other than space applications only. Photovoltaics can be used in a wide range of products, from small consumer items to large commercial solar electric systems.

Solar cells are made of silicon and other semiconductor materials such as germanium, gallium arsenide, and silicon carbide are used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are jarred loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electrical current—that is, again, electron flow is electricity. This electricity can then be used to power a load, such as a light, tool, toaster, and other electrical appliance and/or apparatus.

A number of solar cells electrically connected to each other and mounted n a support panel or frame is called a photovoltaic module. Modules are designed to supply electricity at a certain voltage, such as a common 12-volt system. The current produced is directly dependent on hum much light strikes the module.

Multiple modules can be wired together to form an array. In general, the larger the area of a module or array, the more electricity that will be produced. Photovoltaic modules and arrays produce direct-current (dc) electricity. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination.

Concentrating Solar Power (CSP)

Concentrating solar power (CSP) offers a utility-scale, firm, dispatchable renewable energy option that can help meet a nation's demand for electricity. CSP plants produce power by first using mirrors to focus sunlight to heat a working fluid. Ultimately, this high-temperature fluid is used to spin a turbine or power an engine that drives a generator that produces electricity.

Concentrating solar power systems can be classified by how they collect solar energy, by using linear concentrator, dish/engine, or power tower systems (NREL 2009).

- Linear concentrator—collects the sun's energy using long rectangular, curved (U-shaped) mirrors. The mirrors are tilted toward the sun, focusing sunlight on tubes (or receivers) that run the length of the mirrors. The reflected sunlight heats a fluid flowing through the tubes. The hot fluid then is used to boil water in a conventional steam-turbine generator to produce electricity. There are two major types of linear concentrator systems: parabolic trough systems, where receiver tubes are positioned along the focal line of each parabolic mirror; and linear Fresnel reflector systems, where one receiver tube is positioned above several mirrors to allow the mirrors greater mobility in tracking the sun.
- Dish/engine system—uses a mirrored dish similar to a very large satellite dish. The dish-shaped surface directs and concentrates sunlight onto a thermal receiver, which absorbs and collects the heat and transfers it to the engine generator. The most common type of heat engine used today in dish/engine systems is the Stirling engine (conceived in 1816). This system uses the fluid heated by the receiver to move pistons and create mechanical power. The mechanical power is then used to run a generator or alternator to produce electricity.
- Power tower system—uses a large field of flat, sun-tracking mirrors known as heliostats to focus and concentrate sunlight onto a receiver on the top of a tower. A heat-transfer fluid heated in the receiver is used to generate steam, which, in turn, is used in a conventional turbine generator to produce electricity. Some power towers use water/steam as the hat-transfer fluid. Other advanced designs are experimenting with molten nitrate salt because of its superior heat-transfer and energy-storage capabilities. The energy-storage capability, or thermal storage, allows the system to continue to dispatch electricity during cloudy weather or at night.

Smaller CSP systems can be located directly where the power is needed. For example a single, dish/engine system can produce 3 to 25 kilowatts of power and is well suited for such distributed applications. Larger, utility-scale CSP applications provide hundreds of megawatts of electricity for the power grid. Both linear concentrator and power tower systems can be easily integrated with thermal storage, helping to generate electricity during cloudy periods or at night. Alternatively, these systems can be combined with natural gas, and the resulting hybrid power plants can provide high-value, dispatchable power throughout the day.

Solar energy has some obvious advantages in that the source is free; however, the initial investment in operating equipment is not. Solar energy is also environmentally friendly, requires almost no maintenance, and reduces our dependence on foreign energy supplies. Probably the greatest downside of solar energy use is that in areas without direct sunlight during certain tomes of the year, solar panels cannot capture enough energy to provide heat for home or office. Geographically speaking, the higher latitudes do not receive as much direct sunlight as tropical areas. Because of the position of the sun in the sky, solar panels must be placed in sun-friendly locations such as the U.S. Desert Southwest and the Sahara region of northern Africa.

Wind Energy[2]

Wind energy is the movement of wind to create power. Since early recorded history, people have been harnessing the energy of the wind for milling grain, pumping water and other mechanical power applications. Wind energy propelled boats along the Nile River as early as 5000 B.C. By 200 B.C., simple windmills in china were pumping water, while vertical-axis windmills with woven reed sails were grinding grain in Persia and the Middle East.

The use of wind energy spread around the world and by the eleventh century, people in the Middle East were using windmills extensively for food production; returning merchants and crusaders carried this idea back to Europe. The Dutch refined the windmill and adapted it for draining lakes and marshes in the Rhine River Delta. When settlers took this technology to the New World in the later nineteenth century, they began using windmills to pump water for farms and ranches, and later, to generate electricity for homes and industry. Today, there are several hundred thousand windmills in operation around the world, many of which are used for water pumping. But it is the use of wind energy as a pollution-free means of generating electricity on a significant scale that is attracting most current interest in the subject. As a matter of fact, with the present and pending shortage and high cost of fossil fuels to generate electricity and the green movement toward the use of cleaner fuels, wind energy is the world's fastest-growing energy source and will power industry, businesses and home with clean, renewable electricity for many years to come. In the United States since 1970, wind-based electricity generating capacity has increased markedly although (at present) it remains a small fraction of total electric capacity. But this trend is beginning to change—with the advent of $4/gal of gasoline, high heating and cooling costs, and subsequent increases in the cost of electricity, world-wide political unrest or uncertainty in oil-supplying countries one only needs to travel the "wind corridors" of the United States encompassing

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[2] Much of the information in this section is from USDOE-EERE 2005. *History of wind energy*. Accessed 06/14/09 @http://www1/eere/emergu/gpv/womdamdjudrp/printable_versions/wind_hisotry.htm..

parts of Arizona, New Mexico, Texas, Missouri, and north through the Great Plains to the Pembina Escarpment and Turtle Mountains of North Dakota and elsewhere witness the considerable activity the seemingly exponential increase in wind energy development and wind turbine installations; these machines are being installed to produce and provide electricity to the grid.

When you get right down it, we can classify wind energy as a form of solar energy. As described in Chapter 9, winds are caused by uneven heating of the atmosphere by the sun, irregularities of the earth's surface, and the rotation of the earth. As a result, winds are strongly influenced and modified by local terrain, bodies of water, weather patterns, vegetative cover and other factors. The wind flow, or motion of energy when harvested by wind turbines, can be used to generate electricity.

As with any other source of energy, non-renewable or renewable, there are advantages and disadvantages associated with their use. On the positive side it should be noted that wind energy is a free, renewable resource, so no matter how much is used today, there will still be the same supply in the future. Wind energy is also a source of clean, non-polluting, electricity. One huge advantage of wind energy is that it is a domestic source of energy, produced in the United States or country where installed and where wind is abundant. In the United States, the wind supply is abundant.

Wind turbines can be installed on farms or ranches, thus benefiting the economy I rural areas, where most of the best wind sites are found. Moreover, farmers and ranchers can continue to work the land because the wind turbines use only a fraction of the land.

On the other side of the coin, wind energy does have a few negatives. Wind power must compete with conventional generation sources on a cost basis. Even though the cost of wind power has decreased dramatically in the past ten years, the technology requires a higher initial investment than fossil-fueled generators. The challenge to using wind as a source of power is that the wind is intermittent and it does not always blow when electricity is needed. Wind energy cannot be stored (unless batteries are being used); and not all winds can be harnessed to meet the timing of electricity demands. Another problem is that good sites are often located in remote locations, far from cities where the electricity is needed. Moreover, wind resource development may compete with other uses for the land and those alternative uses may be more highly valued than electricity generation. Finally, in regards to the environment, wind power plants have relatively little impact on the environment compared to other conventional power plants, there is some concern over the noise produced by the rotor blades, aesthetic (visual) impacts, and sometimes birds have been killed by flying into the rotors. Most of these problems have been resolved or greatly reduced through technological development or by properly siting wind plants.

In regards to wind energy and its future, one thing is certain; it continues to be one of the fastest growing energy technologies and it looks set to become a major generator of electricity throughout the world.

Hydropower

When we look ar rushing waterfalls and rivers, we may not immediately think of electricity. But hydroelectric(water-powered) power plants are responsible for lighting many of our homes and neighborhoods. *Hydropower* is the harnessing of water to perform work. The power of falling water has been used in industry or thousands of years (see the Table). The Greeks used water wheels for grinding wheat into flour more than 2,000 years ago. Besides grinding flour, the power of the water was used to saw wood and power textile mills and manufacturing plants.

The technology for using falling water to create hydroelectricity has existed for more than a century. The evolution of the modern hydropower turbine began in the mid-1700s when a French hydraulic and military engineer, Bernard Forest de Belidor wrote a four volume work describing using a vertical-axis versus a horizontal-axis machine.

Water turbine development continued during the 1700s and 1800s. In 1880, a brush arc light dynamo driven by a water turbine was used to provide theatre and storefront lighting in Grand Rapids, Michigan; and in 1881, a brush dynamo connected to a turbine in a flour mill provided street lighting at Niagara Falls, New York. These two projects used direct-current (DC) technology.

Alternating current (AC) is used today. That breakthrough came when the electric generator was coupled to the turbine, which resulted in the worlds, and the Unites States', first hydroelectric plant located on the Fox River in Appleton, Wisconsin, in 1882. The U.S. Library of Congress (2009) lists the Appleton hydroelectric power plant as one of the major accomplishments of the Gilded Age (1878-1889). Soon, people across the United States were enjoying electricity in homes, schools, and offices, reading by electric lamp instead of candlelight or kerosene. Today, we take electricity for granted, not able to imagine life without it.

Ranging in size from small systems (100 kilowatts to 30 megawatts) for a home or village to large projects (capacity greater than 30 megawatts) producing electricity for utilities, hydropower plants are of three types: impoundment, diversion, and pumped storage. Some hydropower plants use dams and some do not. Many dams were built for other purposes and hydropower was added later. In the United States, there are about 80,000 dams of which only 2.400 produce power. The other dams are for recreation, stock/farm ponds, flood control, water

History of Hydropower

Date	*Hydropower Event*
B.C.	Hydropower used by the Greeks to turn water wheels for grinding wheat into flour, more than 2,000 years ago.
Mid-1770s	French hydraulic and military engineer Bernard Forest de Belidor wrote a four-volume work describing vertical- and horizontal-axis machines.
1775	U.S. Army Corps of Engineers founded, with establishment of Chief Engineer for the Continental Army.
1880	Michigan's Grand Rapids electric Light and Power Company, generating electricity by dynamo belted to a water turbine at the Wolverine Chair Factory, lit up 16 brush-arc lamps
1881	Niagara Falls city street amps powered by hydropower.
1882	World's first hydroelectric power plant began operation on the Fox River in Appleton, Wisconsin.
1886	About 45 water-powered electric plants in the U.S. and Canada.
1887	San Bernardino, CA., opens first hydroelectric plant in the west.
1889	Two hundred electric plants in the U.S. use water power for some or all generation.
1901	First Federal Water Power Act.
1902	Bureau of Reclamation established.
1907	Hydropower provided 15% of U.S. electrical generation.
1920	Hydropower provided 25% of U.S. electrical generation. Federal Power Act establishes Federal Power Commission authority to issue licenses for hydro development on public lands.
1933	Tennessee Valley Authority established.
1935	Federal Power Commission authority extended to all hydroelectric projects built by utilities engaged in interstate commerce.
1937	Bonneville Dam, first Federal dam, begins operation on the Columbia River, Bonneville Power Administration established.
1940	Hydropower provided 40% of electrical generation. Conventional capacity tripled in United States since 1920.
1980	Conventional capacity nearly tripled in United States since 190.
2003	About 10% of U.S. electricity comes from hydropower. Today, there is about 80,000MW of conventional capacity and 18,000 MW of pumped storage.

Source: EERE (2008).

supply, and irrigation. The sizes of hydropower plants are described below.

Impoundment

The most common type of hydroelectric power plant is an impoundment facility. An impoundment facility, typically a large hydropower system, uses a dam to store river water in a reservoir. Water released from the reservoir flows thrugh a turbine, spinning it, which in turn activates a generator to produce electricity. The water may be released either to meet changing electricity needs or to maintain a constant reservoir level.

Diversion

A diversion, sometimes called run-of-river, facility channels all or a portion of the flow of a river from its natural course through a canal or penstock. It may not require the use of a dam.

Pumped Storage

When the demand for electricity is low, a pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

Hydropower offers advantages over the other energy sources but faces unique environmental challenges. The advantages of using hydropower begin with that fact that hydropower does not pollute the air like power plants that burn fossil fuels, such as coal and natural gas. Moreover, hydropower does not have to be imported into the United States like foreign oil does; it is produced in the United States. Because hydropower relies on the water cycle, driven by the sun, it's a renewable resource that will be around for at least as long as humans. Hydropower is controllable; that is, engineers can control the flow of water through the turbines to produce electricity on demand. Finally, hydropower impoundment dams create huge lake areas for recreation, irrigation of farm lands, reliable supplies of potable water, and flood control.

Hydropower also has some disadvantages. For example, fish populations can be impacted if fish cannot migrate upstream past impoundment dams to spawning grounds or if they cannot migrate downstream to the ocean. Many dams have installed fish ladders or elevators to aid upstream fish passage. Downstream fish passage is aided by diverting fish from turbine intakes using screens or racks or even underwater lights and sounds, and by maintaining a minimum spill flow past the turbine. Hydropower can also impact water quality and flow. Hydropower plants can cause lo dissolved oxygen (DO) levels in the water, a problem that is harmful to riparian (riverbank) habitats and is addressed using various aeration techniques, which oxygenate the water. Maintaining minimum flows of water downstream of a hydropower installation is also critical for the survival of riparian habitats. Hydropower is also susceptible to drought. When water is not available, the hydropower plants can't produce electricity. Finally, construction of new hydropower facilities impact investors and others by competing with other uses of the land. Preserving local flora and fauna and historical or cultural sites is often more highly valued than electricity generation.

Biomass

Biomass (all the earth's living matter) or *bioenergy* (the energy from plants and plant-derived materials; stored energy from the sun) has been used since people began burning wood to cook food and keep warm. Wood is still the largest biomass energy resource today, but other sources of biomass can also be used. These include food crops grassy and woody plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes. Even the fumes from landfills (which are methane, a natural gas) can be used as a biomass energy source. It excludes organic material which has been transformed by geological processes into substances such as coal or petroleum. The biomass industry is one of the fastest-growing industries in the United States.

A variety of biomass feedstocks can be used to produce transportation fuels, biobased products, and power. Currently, a majority of the ethanol produced in the United States is made from corn or other starch-based crops. However, the current trend in research is to develop biomass fuels from non-foodstocks. For example, the focus is on the development of cellulosic feedstocks—non-grain, on-food-based feedstocks such s switchgrass, corn stover, and woody material—and on technologies to convert cellulosic material into transportation fuels and other products. Using cellulosic feedstocks can not only alleviate the potential concern of diverting food crops to produce fuel, but also has a variety of environmental benefits.

Environmental benefits include the use of biomass energy to greatly reduce greenhouse gas emissions. Burning biomass releases about the same amount of carbon dioxide as burning fossil fuels. However, fossil fuels release carbon dioxide captured by photosynthesis millions of years ago—an essentially "new" greenhouse gas. Biomass, on the other hand, releases carbon dioxide that is largely balanced by the carbon dioxide captured in its own growth (depending how much energy was used to grow, harvest, and process the fuel).

Another benefit of biomass use for fuel is that it can reduce dependence on foreign oil because biofuels are the only renewable liquid transportation fuels available. Finally, biomass energy supports U.S. agricultural and forest-product industries. The main biomass feedstocks for power are paper mill residue, lumber mill scrap, and municipal waste. For biomass fuels, the feedstocks are corn (for ethanol) and soybeans (for biodiesel), both surplus crops. In the near future—and with developed technology—agricultural residues such as corn stover (the stalks, leaves, and husks of the pant) and wheat straw will also be used. Long-term plans include growing and using dedicated energy crops, such as fast-growing trees and grasses that can grow sustainably on land that will not support intensive food crops.

Geothermal Energy[3]

Approximately 4,000 miles below the earth's surface is the earth's core where temperatures can reach 9000º F. This heat—geothermal energy (*geo*, meaning earth, and thermos, meaning *heat*)—flows outward for the core, heating the surrounding area, which can form underground reservoirs of hot water and steam. These reservoirs can be tapped for a variety of uses, such as to generate electricity or heat buildings.

The geothermal energy potential in the uppermost six miles of the earth's crust amounts to 50,000 times the energy of all oil and gas resources in the world. In the United States, most geothermal reservoirs are located in the western states, Alaska, and Hawaii. However, geothermal heat pumps (GHPs), which take advantage of the shallow ground's stable temperature for heating and cooling buildings can be used almost anywhere.

Again, it is important to point out that there is nothing new about renewable energy. From solar power to burning biomass (wood) in the cave and elsewhere, humans have taken advantage of renewable resources from time immemorial. For example, hot springs have been used for bathing since Paleolithic times or earlier (DOE 2009). The early Romans used hot springs to feed public baths and under floor heating. The world's oldest geothermal district heating system, in France, has been operating since the fourteenth century (Lund 2007). The history of geothermal energy use in the United States is interesting and lengthy. In the following a brief chronology of major geothermal events in the United States is provided (DOE 2006).

8,000 B.C. (and earlier)

Paleo-Indians used hot springs for cooking, and for refuge and respite. Hot springs were neutral zones where members of warring nations would bather together in peace. Native Americans have a history with every major hot spring in the United States.

1807

As European settlers moved westward across the continent, they gravitated toward these springs of warmth and vitality. In 1807, the first European to visit the Yellowstone area, John Colter [(c. 1774–c.1813)widely considered to be the first mountain man], probably encountered

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[3] Based on information from DOE (2001). *Renewable Energy: An Overview*. Washington, DC: U.S. Department of Energy.

hot springs, leading to the designation “Colter’s Hell:. Also in 1897, settlers found the city of Hot Springs, Arkansas, where, in 1830, Asa Thompson charged one dollar each for the use of three spring-fed paths n a wooden tub, and the first know commercial use of commercial use of geothermal energy occurred.

1847
William Bell Elliot, a member of John C. Fremont’s survey part, stumbles upon a steaming valley just north of what is not San Francisco, California. Elliot calls the area The Geysers—a misnomer—and things he has found the gates of Hell.

1852
The Geysers is developed into a spa called The Geysers Resort Hotel. Guests include J. Pierpont Morgan, Ulysses S. Grant Theodore Roosevelt, and Mark Twain.

1862
At springs located southeast of The Geysers, businessman Sam Brannan pours an estimated half million dollars into an extravagant development dubbed “Calistoga,” replete with hotel, bathhouse, skating pavilion, and racetrack. Brannan’s was one of any spas reminiscent of those of Europe.

1864
Homes and dwellings have been built near springs through the millennia to take advantage of the natural heat of these geothermal springs, but the construction of the Hot Lake Hotel near La Grande, Oregon, marks the first time that the energy from hot springs is used on a large scale.

1892
Boise, Idaho provides the world’s first district heating system as water is piped from hot springs to town buildings. Within a few years, the system is serving 200 homes and 40 downtown businesses. Today, there are four district heating systems in Boise that provide heat to over 5 million square feet of residential, business, and governmental space. There are now 17 district heating system in the United States and dozens more around the World.

1900
Hot springs water is piped to homes in Klamath Falls, Oregon.

1921
John D. Grant drills a well at The Geysers with the intention of generating electricity. This effort is unsuccessful, but one year later Grant meets with success across the valley at another site, and the United States’ first geothermal power plant goes into operation. Grant uses steam from the first well to build a second well, and, several wells later, the operation is producing 250 kilowatts, enough electricity to light the buildings and streets at the resort. The plant, however, is not competitive with other sources of power, and it soon falls into disuse.

1927
Pioneer Development Company drills the first exploratory wells at Imperial Valley, California.

1930
The first commercial greenhouse use of geothermal energy is undertaken in Boise, Idaho. The operation uses a 1000-foot well drilled in 1926. In Klamath Falls, Charlie Lieb develops the first downhole heat exchanger (DHE) to heat his house. Today, more than 500 DHEs are in use around the country.

1940
The first residential space heating in Nevada begins in the Moan area in Reno.

1948
Geothermal technology moves east when Carl Nielsen develops the first ground-source heat pump, for use at his residence. J.D. Krocker, an engineer in Portland, Oregon, pioneers the first commercial building use of a groundwater heat pump.

1960
The country’s first large-scale geothermal electricity-generating plant begins operation. Pacific Gas and Electric operates the plant located at the Geysers. The first turbine produces 11 megawatts (MW) of net power and operates successfully for more than 30 years. Today, 69 generating facilities are in operation at 18 resource sites around the country.

1978
Geothermal Food Processors, Inc. opens the first geothermal food-processing (crop-drying) plant in Brady Hot Springs, Nevada. The Load Guaranty Program provides $3.5 million for the facility.

1979
The first electrical development of a water-dominated geothermal resource occurs, at the east Mesa field in the Imperial Valley in California. The Plant is named for B.C. McCabe, the geothermal pioneer who, with his Magma Power Company did field development work at several sites, including The Geysers.

1980
TAD’s Enterprises of Nevada pioneers the use of geothermal energy for the cooking, distilling, and drying

processes associated with alcohol fuels production. UNOCAL builds the country's first flash plant, generating 10 MW at Brawley, California.

1982
Economical electrical generation begins at California's Salton Sea geothermal field through the use of crystallizer-clarifier technology. The technology resulted from a government/industry effort to manage the high-salinity brines at the site.

1984
A 20-MW plant begins generating power at Utah's Roosevelt hot Springs. Nevada's first geothermal electricity is generated with a 1.3-MW binary power plant begins operation.

1987
Geothermal fluids are used in the first geothermal-enhanced heap leaching project for gold recovery, near Round Mountain, Nevada.

1989
The world's firs hybrid (organic Rankine/gas engine) geopressure-geothermal power plant begins operation at Pleasant Bayou, Texas, using both the heat and the methane of a geopressured resource.

1992
Electrical generation begins at the 25-MW geothermal plant in the Puna field of Hawaii.

1993
A 23-MW binary power plant is completed at Steamboat Springs, Nevada.

1995
Integrated Ingredients dedicates a food-dehydration facility that processes 15 million pounds of dried onions and garlic per year at Empire, Nevada. A DOE low-temperature resource assessment of 10 western states identifies nearly 9000 thermal wells and springs and 271 communities collocated with a geothermal resource greater than 50.

2002
Organized by GeoPowering the West, geothermal development working groups are active in five states—Nevada, Idaho, New Mexico, Oregon, and Washington. Group members represent all stakeholder organizations. The working groups are identifying barriers to geothermal development in their state, and bringing together all interested parties to arrive at mutually beneficial solutions.

2003
The Utah Geothermal Working Group is formed.

Geothermal energy can be and already is accessed by drilling water or steam wells in a process similar to drilling for oil. Geothermal energy is an enormous, underused heat and power resource that is clean (emits little or no greenhouse gases), reliable (average system availability of 95 percent), and homegrown (making us less dependent on foreign oil).

Geothermal resources range from shallow ground to hot water and rock several miles below the Earth's surface, and even farther down to the extremely hot molten rock called magma. Mile-or-more-deep wells can be drilled into underground reservoirs to tap steam and very hot water that can be brought to the surface for use in a variety of applications. In the U.S., most geothermal reservoirs are located in the western states, Alaska, and Hawaii.

Ocean Energy

The ocean can produce two types of energy: *thermal energy* from the sun's heat, and *mechanical energy* from the tides and waves.

Open thermal energy can be used for many applications, including electricity generation. Electricity conversion systems use either the warm surface water or boil the seawater to turn a turbine, which activates a generator.

The electricity conversion of both tidal and wave energy usually involves mechanical devices. It is important to distinguish tidal energy from hydro power. Recall that hydro power is derived from the hydrological climate cycle, powered by solar energy, which is usually harnessed via hydroelectric dams. In contrast, tidal energy is the result of the interaction of the gravitational pull of the moon and, to a lesser extent, the sun, on the seas. Processes that use tidal energy rely on the twice-daily tides, and the resultant upstream flows and downstream ebbs in estuaries and the lower reaches of some rivers, as well, in some cases, tidal movement out at sea. A dam is typically used to convert tidal energy into electricity by forcing the water through turbines, activating a generator. Meanwhile, wave energy, a very large potential resource to be tapped, uses mechanical power to directly activate a generator, to transfer to a working fluid, water, or air, which then drives a turbine/generator.

Hydrogen[4]

Containing only one electron and one proton, Hydrogen, chemical symbol H, is the simplest element on earth.

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[4] Information in this section from USDOE 2008, Hydrogen, Fuel Cells & Infrastructure Technologies Program. Accessed @ http://www1.eere.energy.gov/hydrogenandfuelcells/production/basics.html.

Hydrogen as is a diatomic molecule—each molecule has two atoms of hydrogen (which is why pure hydrogen is commonly expressed as H_2). Although abundant on earth as an element, hydrogen combines readily with other elements and is almost always found as part of another substance, such as water hydrocarbons, or alcohols. Hydrogen is also found in biomass, which includes all plants and animals.

- Hydrogen is an energy carrier, not an energy source. Hydrogen can store and deliver usable energy, but it doesn't typically exist by itself in nature; it must be produced from compounds that contain it.
- Hydrogen can be produced using diverse, domestic resources including nuclear; natural gas and coal; and biomass and other renewables including solar, wind, hydro-electric or geothermal energy. This diversity of domestic energy sources makes hydrogen a promising energy carrier and important to our nation's energy security. It is expected and desirable for hydrogen to be produced using a variety or resources and process technologies (or pathways).
- DOE focuses on hydrogen-production technologies that result in near-zero, net greenhouse gas emissions and use renewable energy sources, nuclear energy, and coal (when combined with carbon sequestration). To ensure sufficient clean energy for our overall energy needs, energy efficiency is also important.
- Hydrogen can be produced via various process technologies, including thermal (natural gas reforming, renewable liquid and bio-oil processing, and biomass and coal gasification), electrolytic (water splitting using a variety of energy resources), and photolytic (splitting water using sunlight via biological and electrochemical materials).
- Hydrogen can be produced in large, central facilities (50-300 miles form point of use), smaller semi-central (located within 25-100 miles of use) and distributed (near or at point of use). Learn more about distributed vs. centralized production.
- In order for hydrogen to be successful in the market place, it must be cost-competitive with the available alternatives. In the light-duty vehicle transportation market, this competitive requirement means that hydrogen needs to be available untaxed at \$2-\$3/gge (gasoline gallon equivalent). This price would result in hydrogen fuel cell vehicles having the same cost to the consumer on a cost-per-mile-driven basis as a comparable conventional internal-combustion engine or hybrid vehicle.
- DOE is engaged in research and development of a variety of hydrogen production technologies. Some are further along in development than others—some can be cost-competitive for the transition period (beginning in 2015), and others are considered long-term technologies (cost-competitive after 2030).

Infrastructure is required to move hydrogen from the location where it's produced to the dispenser at a refueling station or stationary power site. Infrastructure includes the pipelines, trucks, railcars, ships, and barges that deliver fuel, as well as the facilities and equipment needed to load and unload them.

Delivery technology for hydrogen infrastructure is currently available commercially, and several U.S. companies deliver bulk hydrogen today. Some of the infrastructure is already in place because hydrogen has long been used in industrial applications, but it's not sufficient to support widespread consumer use of hydrogen as an energy carrier. Because hydrogen has a relatively low volumetric energy density, its transportation, storage, and final delivery to the point of use comprise a significant cost and result in some of the energy inefficiencies associated with using it as an energy carrier.

Options and trade-offs for hydrogen delivery from central, semi-central, and distributed production facilities to the point of use are complex. The choice of a hydrogen production strategy greatly affects the cost and method of delivery.

For example, larger, centralized facilities can produce hydrogen at relatively low costs due to economies of scale, but the delivery costs for centrally produced hydrogen are higher than the delivery costs for semi-central or distributed production options (because the point of use is farther away). In comparison, distributed production facilities have relatively low delivery costs, but the hydrogen production costs are likely to be higher—lower volume production means higher equipment costs on a per-unit-of-hydrogen basis.

Key challenges to hydrogen delivery include reducing delivery cost, increasing energy efficiency, maintaining hydrogen purity, and minimizing hydrogen leakage. Further research is needed to analyze the trade-offs between the hydrogen production options and the hydrogen delivery options taken together as a system. Building a national hydrogen delivery infrastructure is a big challenge. It will take time to develop and will likely include combinations of various technologies. Delivery infrastructure needs and resources will vary by region and type of market (e.g., urban, interstate, or rural). Infrastructure options will also evolve as the demand for hydrogen grows and as delivery technologies develop and improve.

Hydrogen Storage

Storing enough hydrogen on-board a vehicle to achieve a driving range of greater than 300 miles is a significant challenge. On a weight basis, hydrogen has nearly three times the energy content of gasoline (120 MJ/kg for hydrogen versus 44 MJ/kg for gasoline). However, on a volume basis the situation is reversed (8 MJ/liter for liquid hydrogen versus 32 MJ/liter for gasoline). ON-board hydrogen storage in the range of 5 – 13 kg H_2 is required to encompass the full platform of light-duty vehicles.

Hydrogen can be stored in a variety of ways, but for hydrogen to be a competitive fuel for vehicles, the hydrogen vehicle must be able to travel a comparable distance to conventional hydrocarbon-fueled vehicles.

Hydrogen can be physically stored as either a gas or a liquid. Storage as a gas typically requires high-pressure tanks (5000 -10,000 psi tank pressure). Storage of hydrogen as a liquid requires cryogenic temperatures because the boiling point of hydrogen at one atmosphere pressure -252.8ºC.

Hydrogen can also be stored on the surfaces of solids (by adsorption) or within solids (by absorption). In adsorption, hydrogen is attached to the surface of material either as hydrogen molecules or as hydrogen atoms. In absorption, hydrogen is dissociated into H-atoms, and then the hydrogen atoms are incorporated into the solid lattice framework.

Hydrogen storage in solids may make it possible to store large quantities of hydrogen in smaller volumes at low pressures and at temperatures close to room temperature. It is also possible to achieve volumetric storage densities greater than liquid hydrogen because the hydrogen molecule is dissociated into atomic hydrogen within the metal hydride lattice structure.

Finally, hydrogen can be stored through the reaction of hydrogen –containing materials with water (or other compound such as alcohols). In this case, the hydrogen is effectively store din both the material and in the water. The term “chemical hydrogen storage” or chemical hydrides is used to describe this form of hydrogen storage. It is also possible to store hydrogen in the chemical structures of liquids and solids.

Hydrogen Fuel Cell

The fuel cell uses the chemical energy of hydrogen to cleanly and efficiently produce electricity with water and heat as byproducts. Fuel cells are unique in terms of variety of their potential applications; they can provide energy for systems as large as a utility power station and as small as a laptop computer.

Fuel cells have several benefits over conventional combustion-based technologies currently used in many power plants and passenger vehicles. They produce much smaller quantities of greenhouse gases and none of the air pollutants that create smog and cause health problems. If pure hydrogen is used as a fuel, fuel cells emit only heat and water as byproducts.

A *fuel cell* is a device that uses hydrogen (or hydrogen-rich fuel) and oxygen to create electricity by an electrochemical process. A single fuel cell consists of an electrolyte and two catalyst-coated electrodes (a porous anode and cathode). While there are different fuel cell types, all fuel cells work similarly:

- Hydrogen, or a Hydrogen-rich fuel, is fed to the anode where a catalyst separates hydrogen’s negatively charged electrons from positively charge ions (protons).
- At the cathode, oxygen combines with electrons and, in some cases, with species such as protons or water, resulting in water or hydroxide ions, respectively.
- For polymer electrolyte membrane and phosphoric acid fuel cells, protons move through the electrolyte to the cathode to combine with oxygen and electrons, producing water and heat.
- For alkaline, molten carbonate, and solid oxide fuel cells, negative ions travel through the electrolyte to the anode where they combine with hydrogen to generate water and electrons.
- The electrons from the anode cannot pass through the electrolyte to the positively charged cathode; they must travel around it via an electrical circuit to reach the other side of the cell. This movement of electrons is an electrical current.

Renewable Energy Resources: Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Renewable energy resources include: biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action.

Renewable Energy Production Incentive (REPI): Incentive established by the Energy Policy Act available to renewable energy power projects owned by a state or local government or nonprofit electric cooperative.

Renewable Portfolio Standard (RPS): A mandate requiring that renewable energy provide a certain percentage of total energy generation or consumption.

Renewable Resources: Resources that can be depleted in the short run if used or contaminated too rapidly, but that normally are replaced through natural processes.

Repeat Compliance Period: Any subsequent compliance period after the initial one.

Replacement Air (also, compensating Air, Make-Up Air): Air supplied to a space to replace exhausted air.

Reportable Quantity (RQ): The minimum amount of a hazardous material that, if spilled while in transport, must be reported immediately to the National Response Center. Minimum reportable quantities range from 1 pound to 5,000 pounds per 24 hour day.

Repowering: Rebuilding and replacing major components of a power plant instead of building a new one.

Representative Sample: A sample of a universe or whole, such as a waste pile, lagoon, or groundwater that can be expected to exhibit the average properties of the whole.

Reregistration: The reevaluation and relicensing of existing pesticides originally registered prior to current scientific and regulatory standards. EPA reregisters pesticides through its Registration Standards Program.

Reserve Capacity: Extra treatment capacity built into solid waste and wastewater treatment plants and interceptor sewers to accommodate flow increases due to future population growth.

Reservoir: 1. A large and deep standing body of freshwater, such as a pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water. 2. A natural underground container of liquids, such as water or steam (or, in the petroleum context, oil or gas).

Residence time: Amount of time the ventilation air is in contact with the biofilter media.

Residential Sources of MSW: Municipal solid wastes from households consisting primarily of paper, glass, vegetable waste, and paperboard, ash, tin cans, etc.

Residential Use: Pesticide application in an around houses, office buildings, apartment buildings, motels, and other living or working areas.

Residential Waste: Waste generated in single and multi-family homes, including newspapers, clothing, disposable tableware, food packaging, cans, bottles, food scraps, and yard trimmings other than those that are diverted to backyard composting.

Residual: Amount of pollutant remaining in the environment after a natural or technological process has taken place; e.g., the sludge remaining after initial wastewater treatment, or particulates remaining in air after it passes through a scrubbing or other process.

Residual Risk: The extent of health risk for air pollutants remain after application of Maximum Achievable Control Technology (MACT).

Residual Saturation: Saturation level below which fluid drainage will not occur.

Residuals: The solids generated and retained during the treatment of domestic sewage in treatment system components, including sludge, scum, and pumpings form grease traps, septic tanks, aerobic treatment units, and other components of an onsite or cluster system.

Residue: Bark and woody materials that are generated in primary wood-using mills when roundwood products are converted to other products. Examples are slabs, edgings, trimmings, sawdust, shavings, veneer cores and clippings, and pulp screenings. Includes bark residues and wood residues (both coarse and fine materials) but excludes logging residues.

Resistance: For plants and animals, the ability to withstand poor environmental conditions or attacks by chemicals or disease. May be inborn or acquired.

Resistivity Survey: The measurement of the ability of a material to resist or inhibit the flow of an electrical current, measured in ohm-meters. Resistivity is measured by the voltage between two electrodes while an electrical current is generated between two other electrodes. Resistivity surveys can be used to delineate the boundaries of geothermal fields.

Resource: Something that serves a need, is useful, and available at a particular cost.

Resource Base: All of a given material in the Earth's rust, whether its existence is known or unknown, and regardless of cost considerations.

Resource Conservation and Recovery Act (RCRA): Known as the Cradle-to-Grave Act it is a federal law enacted in 1976 to deal with both municipal and hazardous waste problems and to encourage resource recovery and recycling.

Resource Exhaustion: Attacks that tie up finite resources on a system, making them unavailable to others.

Resource Management System (RMS): A combination of conservation practices and management identified by the primary use of land or water that, when installed, will at a minimum protect the resource base.

Resource Recovery: The process of obtaining matter or energy form materials formerly discarded.

Respirable dust: Measurement of the dust particles that a filter collects in and near animal facilities that are small enough to enter the human respiratory system.

Respirable dust level: Measurement of the dust particles that a filter collects in and near animal facilities that are small enough to enter the human respiratory system.

Respirator: A face mask that filters out harmful gases and particles from air, enabling a person to breathe and work safely. That is, a device that has met the requirements of 42 CFR part 84, has been designed to protect the wearer form inhalation of harmful atmospheres, and has been approved by the National institute of Occupational safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA).

Respirator Fit-Testing: Respiratory Protection provides standards for respirator fit testing. The goal of respirator fit-testing is to (1) provide the employee with a face seal on a respirator that exhibits the most protective and comfortable fit and (2) to instruct the employee on the proper use of respirators and their limitations.

Respiratory Hazard: Any hazard that enters the human body by inhalation.

Response: That portion of incident management in which personnel are involved in controlling a hazardous material incident (ANSI/NFPA 471).

Response Action: 1. Generic term for actions taken in response to actual or potential health-threatening environmental event such as spills, sudden releases, and asbestos abatement/management problems. 2. A CERCLA-authorized action involving either a short-term removal action or a long-term removal response. This may include but is not limited to; removing hazardous materials from a site to an EPA-approved hazardous waste facility for treatment, containment or treating the waste on-site, identifying and removing the sources of groundwater contamination and halting further migration of contaminants. 3. Any of the following actions taken in school buildings in response to AHERA to reduce the risk of exposure to asbestos: removal, encapsulation, enclosure, repair, and operations and maintenance.

Responsible Management Entity (RME): An entity responsible for managing a comprehensive set of activities dedicated by the regulatory authority; a legal entity that has the managerial, financial, and technical capacity to ensure the long term cost effective operation of onsite and/or cluster water treatment systems in accordance with applicable regulations and performance requirements (e.g., a wastewater utility or wastewater management district).

Responsiveness Summary: A summary of oral and/or written public comments received by EPA during aa comment period on key EPA documents, and EPA's response to those comments.

Restoration: The returning of all affected groundwater to its premining quality for its premining used by employing the best practical technology.

Resuscitation: Restoration of consciousness.

Restricted Area: Area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials.

Restricted Entry Interval: The time after a pesticide application during which entry into the treated area is restricted.

Restricted Use: A pesticide may be classified (under FIFRA regulations) for restricted use if it requires special handling because of the toxicity, and, if so, it may be applied only by trained, certified applicators or those under their direct supervision.

Restricted Wastes: Wastes that have LDR treatment standards, but can be land disposed without treatment because of an exemption (e.g., a capacity variance).

Restriction Enzymes: Enzymes that recognize specific regions of a long DNA molecule and cut it at those points.

Retrofit: Addition of a pollution control device on an existing facility without making major changes to the generating plant. Also called backfit.

Return Air: Air that is returned from the primary space to the fan for recirculation.

Return Flow: 1. That part of a diverted flow that is not consumptively used and returned to its original soruce or another body of water. 2. (Irrigation)—Drainage water form irrigated farmlands that re-enters the water system to be used further downstream.

Reuse: To use a product again and again in the same form, as when returnable glass bottles are washed and refilled.

Reverse Engineering: Acquiring sensitive data by disassembling and analyzing the design of a system component.

Reverse Osmosis: 1. (Desalination)—The process of removing salts from water sing a membrane. With reverse osmosis, the product water passes through a fine membrane that the salts ar unable to pass through, while the salt waste (brine) is removed and disposed. This process differs from electrodialysis, where the salts are extracted from the feedwater by using a membrane with an electrical current to separate the ions. The positive ions go through one membrane, while the negative ions flow through a different membrane, leaving the end product of freshwater. 2. (Water Quality)—An advanced method of water or wastewater treatment that relies on a semi-permeable membrane to separate water from pollutants. An external force is used to reverse the normal osmotic process resulting in the solvent moving from a solution of higher concentration to one of lower concentration.

Reversible Effect: An effect which is not permanent; especially adverse effects which diminish when exposure to a toxic chemical stops.

Ribonucleic Acid (RNA): A molecule that carries the genetic message from DNA to a cellular protein-producing mechanism.

Ribosomes: In bacterial cytoplasm, minute, rounded bodies made of RNA, loosely attached to the plasma membrane; they are the site of protein synthesis and are part of the translation process.

Riffles: Refer to shallow, high velocity flow over mixed gravel-cobble (bar-like) substrate.

Rigging Equipment and Attachments: OSHA's 29 CFR 1926.251 Standard makes the point that rigging equipment for handling material must not be loaded in excess of its recommended safe working load (Note: Check Tables H-1 through H-20 in the Standard).

OSHA points out that all such equipment must be inspected prior to its use on each shift and as necessary during its use, to ensure safety. Any rigging equipment found to be defective must be immediately removed from service.

Rigging equipment not in use that presents a hazard must be removed from the immediate working area to ensure the safety of employees.

Safety professionals must ensure that all special custom-design grabs, hooks, clamps, or other lifting accessories are marked to indicate their safety working loads. Each device must be proof tested to 125 percent of its rated load before allowing its use.

Whenever a sling is used, the following practices must be observed:

- Slings must not be shortened with knots, bolts or other makeshift devices.
- Sling legs must not be kinked.
- Slings used in a basket hitch must have the loads balanced to prevent slippage.
- Slings must be padded or protected from the sharp edges of their loads.
- Shock loading is prohibited
- A sling must not be pulled from under a load when the load is resting on the sling.
- Hands or fingers must not be placed between the sling and its load while the sling is being tightened around the load.

Rigging Safety: The facility safety professional or other designated official needs to realize that special safety precautions apply to rigging operations, and to properly using and storing fiber ropes, rope slings, wire ropes, chains, and chain slings. Safety Professionals should know the properties of the various types used, the precautions for use, and the maintenance required. In addition, the safety engineer must be familiar with the requirements of OSHA's Rigging Equipment for Material Handling Standard (29 CFR 1926.251).

Rigging operations are inherently dangerous. Any time any type of load is lifted, the operation is dangerous in itself. When heavy loads are lifted several feet and suspended in air while they are moved from one place to another, the dangers increase exponentially.

Ringlemann Chart: A series of shaded illustrations used to measure the opacity of air pollution emissions, ranging from light grey through black; used to set and enforce emissions standards.

Riot Control/Tear Agent: A substance that causes intense irritation to the eyes and upper respiratory tract, including profuse tearing.

Riparian Habitat: Areas adjacent to rivers and steams with a differing density, diversity, and productivity of plant and animal species relative to nearby uplands.

Riparian Water Rights: The rights of an owner whose land abuts water. They differ from state to state and often depend on whether the water is a river, lake, or ocean. The doctrine of riparian rights is an old one, having its origins in English common law. Specifically, persons who own land adjacent to a stream have the right to make reasonable use of the stream. Riparian users of a stream share the streamflow among themselves, and the concept of priority of use (Prior Appropriation Doctrine) is not applicable. Riparian rights cannot be solid or transferred for use on nonriparian land.

Risk: 1. The combination of the expected frequency (event/year) and consequence (effects/event) of a single accident or a group of accidents; the result of a loss-probability occurrence and the acceptability of that loss. 2. The product of the level of threat with the level of vulnerability. It establishes the likelihood of a successful attack.

Risk Analysis: The analysis of an organization's information resources, existing controls and computer system vulnerabilities. It establishes a potential level of damage in dollars and/or other assets.

Risk (Adverse) for Endangered Species: Risk to aquatic species if anticipated pesticide residue levels equal one-fifth of LD10 or one-tenth of LC50; risk to terrestrial species if anticipated pesticide residue levels equal one-fifth of LC10 or one-tenth of LC50.

Risk Assessment: A process that uses scientific principles to determine the level of risk that actually exists in a contaminated area.

Risk Characterization: The final step in the risk assessment process, it involves determining a numerical risk factor. This step ensures that exposed populations are not at significant risk.

Risk Communication: The exchange of information about health or environmental risks among risk assessors and managers, the general public, news media, interest groups, etc.

Risk Definitions (Environmental Assessment):

- COC (chemical of concern)—chemical or constituent released identified for evaluation.
- Exposure Route—the manner in which a chemical comes in contact with an organism.
- Intrusive Assessment—physical (digging, boring, drilling, bulldozing, etc.) inspection of site.
- Non-intrusive Assessment—paper audit.
- Point of Exposure—the location at which an individual may come in contact with the chemical.
- Receptor—persons that are or may be affected by a release. In the case of ecological receptors these may include individual organisms, populations, communities or habitats and ecosystems.
- Risk Assessment—is a scientific process of evaluating the adverse effects caused by a substance, activity, lifestyle, or natural phenomenon.
- Source—physical structure or operating unit that may have or cause a release.
- Source Area—the location of highest concentrations in environmental media.
- Surficial Soil—concerns the loose sedimentary materials that overlie bedrock and which are found at or near the Earth's surface. It includes most materials that can be dug with a shovel or mechanical excavator. Common examples are sand, gravel, silt, clay, till, and peat.
- Transport Mechanism—the combination of chemical, physical and biological processes that move a chemical from the source to the point of exposure.

Risk Estimate: A description of the probability that organism exposed to a specific dose of a chemical or other pollutant will develop an adverse response, e.g., cancer.

Risk Exposure: The way people come into contact with a hazardous substance. Three routes of exposure are breathing (inhalation), eating or drinking (ingestion), or contact with the skin (dermal contact).

Risk Factor: Characteristics (e.g., race, sex, age, obesity) or variable s (e.g., smoking, occupational exposure level) associated with increased probability of a toxic effect.

Risk for Non-Endangered Species: Risk to species if anticipated pesticide residue levels are equal to or greater than LC50.

Risk Management: The professional assessment of all loss potentials in an organization's structure and operations, leading to the establishment and administration of a comprehensive loss control program.

Risk Management Planning (RMP)[5]:

> *". . . community residents and industry officials do not consider the importance of accident prevention until after an accident occurs . . . . By then, the ghosts of Bhopal's victims must whisper, the only response can be: Too late. Too late."*
>
> —(Minter, 1996).

On May 24, 1996, the U.S. Environmental Protection Agency (USEPA) finalized the Risk Management Program (RMP) under Section 112(r) of the 1990 Clean Air Act Amendments. On June 20, 1996, EPA promulgated the new rule. The rule, under 40 CFR Part 68 is entitled *Accidental Release Prevention Provisions: Risk Management Programs*. Covered sources had until June 21, 1999 to compile data, devise a Risk Management Plan, institute a Risk Management Program to comply with RMP and submit the Risk Management Plan to the EPA for review and approval.

NOTE: As with OSHA's PSM, distinguishing between a plan and a program is important. Specifically, the plan is the information and the document that the facility submits to the regulatory agency (EPA for RMP) and maintains on-site for use by facility personnel. The program, however, is the system that backs up the plan, and helps to ensure that the facility is operated according to the rule. The viable program is more than just a vehicle to be used in improving the facility's safety profile; it should also provide dividends in productivity, efficiency, and profitability. Keep in mind that to be beneficial (i.e., to reduce accidents and injuries), the program, as with any other management tool, must be upgraded and improved on a continuing basis.

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[5] Adapted from F.R. Spellman's *Guide to Compliance for PSM/RMP*. Lancaster, PA: Technomic Publishing Company, 1997.

Risk-based Targeting: The direction of resources to those areas that have been identified as having the highest potential or actual adverse effect on human health and/or the environment.

Risk Reduction: Actions that can decrease the likelihood that individual, groups, or communities will experience disease or other health conditions.

Risk Specific Dose: he dose associated with s specified risk level.

River: A natural stream of water of considerable volume, larger than a brook or creek.

River Basin: The land area drained by a river and its tributaries.

Rivers & Harbors Act (1899): Initiated the first legislative authority given to a federal agency (U.S. Army Corp of Engineers) to prevent dumping wastes into rivers and harbors

Rock: Any naturally formed, consolidate or unconsolidated material (but not soil) consisting of two or more minerals.

Rodenticide: A chemical or agent used to destroy rats or other rodent pests, or to prevent them form damaging food, crops etc.

Roentgen: Unit of radiation exposure. One roentgen is equal to 0.00025 Coulombs of electrical charge per kilogram of air.

Root Cause: The determination of the causal factors preceding structures, systems, and components (SSC) failure or malfunction—that is, discovery of the principal reason why the failure or malfunction happened lends to the identification of the root cause. The preceding failure or malfunction causal factors are always events or conditions that are necessary and sufficient to produce or contribute to the unwanted results. The types of causal factors are: (1) direct causes, (2) contributing causes and (3) root causes. The direct cause is the immediate event or condition that caused the failure or malfunction. Contributing causes are conditions or vents that collectively increase the likelihood of the failure or malfunction, but that individually do not cause them. Thus, root causes are vents or conditions that, if corrected or eliminated, would prevent the recurrence of the failure malfunction by identifying and correcting faults (often hidden) before an SSC fails to malfunctions.

Root Cause Analysis: Any methodology that identifies the causal factors that, if corrected would prevent recurrence of the accident.

Ropes, Slings, Chains: Because of the dangers inherent in any rigging and lifting operation, safety professionals must check out and ensure the safety of every element involved. This may seem like common sense to some, but others might be surprised to find out how often rigging mistakes are made, by assuming that the only factor that need be considered is the safe operation of hoisting equipment to lift a given load. The attachments used to secure the hook to the load are often overlooked and thus the cause of failure and injuries.

Rope Slings: Ropes used in rigging (for slings) are usually divided into two main classes: fiber rope slings and wire rope slings. Fiber ropes are further divided into natural and synthetic fibers, depending on their construction. Many types of slings have been designed to serve many different purposes. Slings normally have a fixed length. They may be made from various materials and have the form of rope, belts, mesh or fabric.

Natural fiber ropes and slings are usually made from manila, sisal, or henequen fibers. Most natural fiber ropes and slings used in industry today are made from manila fibers, because of its superior breaking strength, consistency between grades, excellent wear properties in both fresh and salt water atmospheres, and elasticity. The main advantages of natural fiber ropes are their price, and their ability to form or bend around angles of the object being lifted. The disadvantages of using natural fiber ropes are susceptibility to cuts and abrasions, their reduced capability or inability to be used to lift materials at elevated temperatures, and that hot or humid conditions may reduce their service life. Fiber ropes should never be used in atmospheres where they may come in contact with acids and caustics, since these substances will degrade the fibers.

Safe working loads of various sizes and classifications natural fiber ropes can be determined from tables in the 1926.251 OSHA Standard.

Synthetic fiber rope slings are made from synthetic fibers (such as nylon, polyester, polypropylene, polyethylene, or a combination of these) to obtain the desired properties. Synthetic fiber ropes have many of the same qualities as natural fiber rope slings, but are in much wider use throughout the industry because they can be engineered to fit a particular operation. Synthetic fiber ropes have many advantages, including increased strength and elasticity over natural fiber rope. Synthetic fiber rope also stands up better to shock loading, and has better resistance to abrasion than natural fiber rope. One of the key advantages of synthetic fiber rope is that it does not swell when wet. It is also more resistant to acids, caustics, alcohol-based solvents, bleaching solutions and their atmospheres. As with the use of natural fiber rope, synthetic fiber rope also has some disadvantages, including damage from excessive heat (they can melt), from alkalis, susceptibility to abrasion damage, and the real possibility for worker injury if sudden breakage under load occurs. They also cost more than natural ones.

Rootkit: A collection of tools (programs) that a hacker uses to mask intrusion and obtain administrator-level access to a computer or computer network.

Rotary Kiln Incinerator: An incinerator with a rotating combustion chamber that keeps waste moving, thereby allowing it to vaporize for easier burning.

Rotifers: A minute multicellular aquatic organism with a wheellike ring of cilia at the anterior end.

Rough Fish: Fish not prized for sport of eating; such as gar and suckers. Most are more tolerant of changing environmental conditions than are game or food species.

Route of Exposure: The avenue by which a chemical comes into contact with an organism, e.g., inhalation, ingestion, dermal contact, injection.

Router: Device to interconnect logical networks by forwarding information to other networks based upon IP addresses.

Rubbish: Combustible waste, paper, cartons, rags, wood scraps, combustible floor sweepings; domestic, commercial, and industrial sources.

Run: Somewhat smoothly flowing segment of the steam.

Runner: The rotating part of the turbine that converts the energy of falling water into mechanical energy.

Running Losses: Evaporative emissions from internal combustion engine as a result of driving; losses also occur when the fuel is heated by the road surface, and when fuel is forced from the fuel tank while the vehicle is being operated and the fuel tank becomes hot.

Run-On: Water moving by surface flow onto a designated area. Run-on occurs when surface water from an area at a higher elevation flows down onto an area of concern, such as a feedlot, vegetated filter strip, or riparian zone.

Runoff: Excess water produced during fire fighting or from rain. Part of precipitation or irrigation water that appears in surface streams or water bodies; expressed as volume (acre-inches) or rate of flow (gallons per minute, cubic feet per second).

S

S: Sulfur.

Saccharin: A chemical sometimes used to check for general sealing of a respirator during fit testing.

Sacrificial Anode: An easily corroded material deliberately installed in a pipe or intake to give it up (sacrifice it) to corrosion while the rest of the water supply facility remains relatively corrosion-free.

Safe: Condition of exposure under which there is a practical certainty that not harm will result to exposed individuals.

Safe Drinking Water Act (SDWA): Mandated the USEPA to establish drinking-water standards for all public water systems serving twenty-five or more people, or having fifteen or more connections.

Safe Water: Water that does not contain harmful bacteria, toxic material, or chemicals, and is considered safe for drinking even if it may have taste, odor, color, and certain mineral problems.

Safe Yield: The annual amount of water that can be taken from a source of supply over a period of years without depleting that source beyond its ability to be replenished naturally in "wet years."

Safety: A general term denoting an acceptable level of risk of, relative freedom from, and low probability of harm.

Safety Data Sheet (SDS): Chemical information sheets provided by the chemical manufacturer that include information such as: chemical and physical characteristics; long and short term health hazards; spill control procedures; personal protective equipment (PPE) to be used when handling the chemical; reactivity with other chemicals; incompatibility with other chemicals; and manufacturer's name, address, and phone number. Employee access to and understanding of SDS are important parts of the Hazard Communication Program.

The following information is required on an SDS, which, as previously stated, must be in English.

1. Specific identity of each hazardous chemical or mixture ingredient and common product names.
2. Physical and chemical characteristics of the hazardous material including:
   a. Density or specific gravity of liquid or solid
   b. Density of gas or vapor relative to air
   c. Boiling point
   d. Melting point
   e. Flash point
   f. Flammability range
   g. Apor pressure
3. Physical hazard data such as stability, reactivity, flammability, corrosivity, explosivity.
4. Health hazard data including acute and chronic health effects, and target organ effects.
5. Exposure limits such as OSHA Permissible Exposure Limits (PELs).
6. Carcinogenicity of material.
7. Precautions to be taken, including use of PPE.
8. Emergency and first aid procedures. This includes spill cleanup information and EPA spill reportability information.
9. Supplier or manufacturer data including:
   a. Name
   b. Address
   c. Telephone Number
   d. Data prepared.

Safety Factor: Based on experimental data, the amount added (e.g., 1000-fold) to ensure worker health and safety.

Safety Standard: A set of criteria specifically designed to define a safe product, practice, mechanism, arrangement, process or environment, produced by a body representative of all concerned interests, and based upon currently available scientific and empirical knowledge concerning the subject or scope of the standard.

Saline Water: Water with excessive salt content. Here are some parameters for saline water:

Fresh water—Less than 2,000 parts per million (ppm)
Slightly saline water—From 1,000 ppm to 3,000 ppm
Moderately saline water—From 3,000 ppm to 10,000 ppm
Highly saline water—From 10,000 ppm to 35,000 ppm

Salinity: A measure of the quantity or concentration of dissolved salts in water.

Salt Spreading: The practice of spreading salt on roadways during winter to help reduce ice and snow accumulation; road salts contaminate soil during runoff.

Salt Water Intrusion: The invasion of fresh surface or ground water by salt water. If it comes from the ocean it may be called sea water intrusion.

Salts: 1. Compounds made up of the positive ion of a base and the negative ion of an acid. 2. Minerals that water picks up as it passes through the air, over and under the ground or from households and industry

Salvable Dead Tree: A downed or standing dead tree that is considered currently or potentially merchantable by regional standards.

Salvage: The utilization of waste materials.

Sample: A portion or piece of a whole. A selected subset of a population or subset of whatever is being student. Fro example, in a study of people the sample is a number of people chosen from a larger population . An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample Size: The number of units chosen form a population or an environment.

Sampling: Collection of a small part of an entity and drawing conclusions about the whole in water quality considerations, sampling consists of collecting a representative part of a water body for testing from which conclusions can be drawn about the water body as a whole.

Sampling Frequency: The interval between the collection of successive samples.

Sanctions: Actions taken by the federal government for failure to provide or implement a State Implementation Plant (SIP). Such action may include withholding of highway funds and a ban on construction of new sources of potential pollution.

Sand Filters: Devices that remove some suspended solids from sewage. Air and bacteria decompose additional wastes filtering through the sand so that leaner water drains from the bed.

Sanitary Landfill: A method of solid waste disposal designed to minimize water pollution from runoff and leaching; waste is covered with a layer of soil within a day after being deposited at the landfill site.

Sanitary Sewers: Underground pipes that carry off only domestic or industrial waste, not storm water.

Sanitary Survey: An on-site review of he water sources, facilities, equipment, operation and maintenance of a public water system to evaluate the adequacy of those elements for producing an distributing safe drinking water.

Sanitary Wastewater: Separate sewer system designed to remove domestic wastes from residential areas.

Sanitary Water (Also known as gray water): Water discharged form sinks, showers, kitchens, or other non-industrial operations, but not from commodes.

Sanitation: Control of physical factors in the human environment that could harm development, health, or survival.

Saprolite: A soft, clay-rich, thoroughly decomposed rock formed in place by chemical weathering of igneous or metamorphic rock. Formed in humid, tropical, or subtropical climates.

Saprophytes: Organism that use enzymes to feed on waste products of living organisms or tissues of dead organisms.

SARA: Superfund Amendments and Reauthorization Act of 1986; see *CERCLA*.

Saturated Zone: Subsurface soil saturated with water; the water table.

Saturation: The condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

SCBA: Self-Contained Breathing Apparatus.

Scaffold Safety: The Occupational Safety and Health Administration (OSHA) regulates scaffolding used in both General Industry and Construction. Those involved with a scaffolding operation has a responsibility to instruct each employee who may use scaffolding in the recognition and avoidance of unsafe conditions, proper construction, use, placement, and care.

Scale: Salts that have precipitated out of water. Calcium carbonate, barium sulfate and calcium sulfate are common in oil fields.

Scaling: When carbonate hard water is heated, calcium carbonate and magnesium hydroxide are precipitated out of solution, forming a rock-hard scale that clogs hot-water pipes and reduces the efficiency of boilers, water heaters, and heat exchangers.

Scentometer: Hand-held device that can be used to measure ambient odor levels in the field.

Scfm: Standard cubic feet per minute. A measure of air flow at standard conditions, i.e., dry air at 29.92 in. HG (760 mm Hg) (gauge), 68° F (20° C).

Science: The observation, identification, description, experimental investigation, and theoretical explanation of natural phenomena.

Science Advisory Board (SAB): A group of external scientists who advise EPA on science and policy.

Scientific Method: 1. A systematic form of inquiry that involves observation, speculation, and reasoning. 2. The *scientific method* (the scientist's toolbox) is an orderly method—a set of techniques (we call them tools)—used in scientific research generally to investigate natural phenomena. The method consists of identifying the problem, gathering data, formulating hypotheses, performing experiments, interpreting results, and reaching a conclusion. Generally speaking, the scientific method is often used to define science. We have no problem with this approach, provided that when illustrating or describing the scientific method to the uninitiated we point out and make clear that the methodology won't necessarily fit perfectly into any round or square hole; it is not a perfect cookie cutter mold (Trefil, 2008). This makes sense when you consider our earlier definition of science where we pointed out that it is an investigation into the natural world and the knowledge gained through the process—science is not a collection of facts or a fact finding methodology. The scientific method is classically portrayed as the linear set of steps shown in

Observation → Question →Hypothesis → Experiment → Data Collection → Conclusion

The problem with the scientific method portrayed above is that the reader may assume that this representation, because of its linearity, is written in stone and therefore is to be followed step by step. In the real world, however, this is not the case. Science is not a linear process because it does not have to start with an observation or a question. Moreover, science often does not include experiments. Science is more fluid and dynamic (never static) and evolves around input obtained from the natural world, from studying the work of others, from interfacing with colleagues, or from experience (Capri & Egger, 2009).

Earlier we stated that in our opinion the scientific method is the scientists' toolbox. So, the obvious question is, what is in the toolbox? Not only are the standard tools diagrammed above: observations, questions, hypotheses, experiments, data collection and conclusions, but also several others. These additional tools include facts, deductive inferences, inductive inferences, theories, multiple working hypotheses, evidence, Ockham's Razor, natural law, paradigm, serendipity, luck, the unknown, the unanticipated and the unexpected.

Wow! Sounds like a heavy toolbox doesn't it? Well, it is heavy but skill gained through experience lightens the load, and makes lifting it easier. Let's take a closer look at these tools and see how they are applied by the scientist in the performance of his or her endeavors.

Scientists' Toolbox: Additional Tools

Fact—a truth known by actual experience or observation. The luster of gold, the electrical conductivity of copper, the number of bones in the human spine, the existence of fossil dinosaurs, and the like are all facts.

Is it a fact that an atom consists of protons, neutrons and electrons? Is it a fact that Leonardo da Vinci painted the Mona Lisa? Is it a fact that the sun will set tomorrow? None of us has observed any of these things. The first is an inference from a variety of different observations. The second is reported by those who lived close enough in time and space to the event that we trust their account. And, the third is an inductive inference after repeated observations.

Deductive inference—process by which a conclusion is logically inferred from certain premises.

This is an important tool in the scientific method toolbox because it is often more accurate than the six major tools of the scientific method alone; it allows for mistakes to be quickly detected and corrected. The great mathematician Euclid developed many mathematical proofs with mistakes in them that have been detected and corrected, but the theorems of Euclid, all of them, have stood the test of time for more than two thousand years (Euclid 1956).

Inferences are valid or invalid—never both!

Greek philosophers defined a number of three-part inferences, *syllogisms*, which can be used as building blocks for more complex reasoning. Many readers may be familiar with the examples given below. You may have seen syllogisms on college entrance examinations. We begin with the most famous of them all.

Syllogism 1
All men are mortal
Socrates is a man

Therefore Socrates is mortal.

To be valid, it must be impossible for both its premises to be true and its conclusion to be false (a fallacy). An argument can be valid even though the premises are false. Note, for example, that the conclusion of the following argument would have to be true if the premises were true, (even though they are, in fact, false):

Syllogism 2
Everyone who eats lobster is from Maine.
Alice eats lobster.

Therefore, Alice is from Maine.

The argument is not sound. In order for a deductive argument to be sound, it must not only be valid, the premises must be true as well.

Inductive inference—a conclusion based on (i.e., inferred from) multiple observations. Shoot a particular kind of artillery shell on a particular target at a particular barrel elevation numerous (*n*) times, and you can, by induction from those examples, make an inference and a prediction about what will happen the next time you fire the artillery piece. However, your prediction is not a fact, in that you won't know by actual observation the result of the n+1th drop until it has happened.

Hypothesis—a proposed explanation for an observable phenomenon. For a hypothesis to be put forward as a scientific hypothesis, the scientific method (the toolbox) requires that one can test it. Two important words in the definition of hypothesis are *observed* and *testable*. If you want to know about something, you need to look at it (if possible) and see how it operates. If you are able to observe the operation of something, will it always operate in this manner? It must be testable; others must observe and test and come to the same conclusion that you did. Otherwise, it did not occur as you assumed it did. After shooting the artillery piece from the same barrel elevation several times, you may think shooting it from a greater barrel elevation will lead to a different response, and you may predict that different response. Your response is a hypothesis, and you can test it by changing the elevation of the barrel and observing the result. At that point you will have conducted an experiment to test your hypothesis.

Multiple working hypotheses—method of research where one considers not just a single hypothesis but instead multiple hypotheses that might explain the phenomenon under study. Each hypothesis is then tested. The development of multiple hypotheses prior to the research lets one avoid the trap of narrow-mindedly focusing on just one hypothesis. However, absence of an alternative explanation is no assurance that the truth has been discovered. For example, you boat is missing from where you docked it.

What happened to the boat?
It sank.
It drifted out to sea.
It was stolen.
Your friend borrowed it.

Everyone loves dinosaurs so let's use them as an example of multiple working hypotheses.

Extinction of the dinosaurs
Asteroid impact?
Disease?
Climate change?
Volcanic eruptions?
Competition with mammal?

Theory—a coherent set of propositions that explain a class of phenomena supported by extensive factual evidence, and that may be used for prediction of future observations. For our artillery piece example, a theory would emerge only after a large number of tests of different kinds of artillery shells at different elevations. The theory would try to explain why assorted varieties of shells strike the target differently (wind affect, aerodynamics, etc.), and it ought to be useful in predicting how different shells would behave if fired at different elevations the same way. Over time, scientists have predicted lots of familiar theories:

- Darwin's theory of natural selection
- Copernicus's theory of the heliocentric solar system
- Newton's theory of gravity
- Einstein's theory of relativity

In regards to theories, seems like everyone has one. Because of our tendency to state our opinion on just everything and anything, we often hear "That's just a theory". For example, when the Washington Redskins beat their hated rivals, the Dallas Cowboys, everyone has a theory (sometimes presented in heated prostrations) why the Skins so easily trashed the Cowboys. In discussions about evolution, natural selection, predicted sea level rise, global climate change, and global warming "that's just a theory" is stated even more forcefully—sometimes vehemently.

At least, that is our theory.

Evidence—one of the principal underpinnings of a theory, it consists of the physical observations and measurements made to understand a phenomenon. Keep in mind that opinions and theories are not evidence.

Ockham's Razor—for those familiar with the 1950's classic television show *Dragnet*, Joe Friday's standard saying of "Just the facts, ma'am" is the gist of Ockham's Razor. William of Ockham, an English monk who died in 1349 developed, in regards to theories and hypotheses, the following philosophical statement:

"Our explanations of things should minimize unsupported assumptions."

Some have reduced Ockham's Razor to the acronym KISS—keep it simple stupid! Others have interpreted Ockham's Razor as stating "the simplest explanation is the best explanation". Both of these interpretations are incorrect. The easiest or simplest explanation is not always accurate. Let's say we see a large house standing in the middle of a river. One of our hypotheses for the presence of the house might be that the Abominable Snowperson picked it up off its foundation, carried it to the river and set it down in the middle of the river. Another hypothesis might be that the river over-flowed its banks, flooded the floodplain, floated the house and set it down in the middle of the river. Ockham's Razor tells us to reject the first and retain the second for further consideration. Because we have no evidence for the Abominable Snowperson—he/she is an unsupported assumption. We do have modern evidence that overflowing rivers can transport large houses.

Another classic example often used to make the same point concerns Devils Tower in Wyoming. Native American legend (20 tribes have potential cultural affiliation with Devils Tower) tells that this landform originated when a huge bear's claw's scraped away the sides of the mountain when the bear tried to attack and Indian maiden. A simple explanation, for sure, but it assumes the existence of a huge bear capable of clawing the sides of a mountain to carve something like Devils Tower. We reject the Native American story as nothing more than folklore or myth because the existence of such a bear is an unsupported assumption.

Natural law—is based on nineteenth-century science which presumed it could arrive at absolutely true, immutable, and universal statements about nature (natural laws). For example, Newton's studies and conclusions about gravity led to what were considered "laws of gravity". However, in the twentieth century Einstein's theory of relativity showed that Newton's findings needed slight corrections. Thus it became apparent that it would be wisest to treat even our most trusted ideas, of which Newton's had been one, as theories rather than absolute laws. It may very well be that another genius, the likes of Newton and/or Einstein, will come along in the future to prove many of our other most trusted scientific ideas or findings incorrect.

Paradigm and Paradigm Shift—we view paradigm as a model, exemplar, prototype or way of thinking so ingrained in people's thoughts and behavior that they aren't even conscious of it. In science, historian Thomas Kuhn (1996) gave the word paradigm its contemporary meaning when he adopted it to refer to the set of practices that define a scientific discipline during a particular period of time. In his book *The Structure of Scientific Revolutions* Kuhn defines a scientific paradigm as:

- *what* is to be observed and scrutinized
- the kind of *questions* that are supposed to be asked and probed for answers in relation to this subject
- *how* these questions are to be structured
- *how* the results of scientific investigations should be interpreted
- *how* is an experiment to be conducted, and what equipment is available to conduct the experiment.

How do paradigms and the scientific method interrelate or mix? Keep in mind that in our opinion a paradigm is just one of the tools in the scientific method's toolbox. This makes sense when you consider that paradigm is a more specific approach (a tool) to viewing reality than the much more generalized scientific method (the toolbox).

With time, experiment, accident and experience things change. Science, like life, is dynamic, constantly changing or adapting. So, when in 1900 Lord Kelvin famously stated, "There is nothing new to be discovered in physics now. All that remains is more and more precise measurement," he was a bit premature. Just five years later, Albert Einstein published his paper on special relativity, which challenged the very simple set of rules laid down by Newtonian mechanics, which had been used to describe force and motion for over two hundred years. Einstein's special relativity paper is an example of a paradigm shift. Other paradigm shifts in science, according to Kuhn (1996) include:

- the transition from a Ptolemaic cosmology (Earth is the center of the universe) to a Copernican one (the Sun is the center of the universe).
- the unification of classical physics by Newton into a coherent mechanical worldview.
- the transition between the Maxwellian Electromagnetic worldview and the Einsteinian Relativistic worldview.
- the transition between the worldview of Newtonian physics and the Einsteinian Relativistic worldview.
- the development of Quantum mechanics, which overthrew classical mechanics.
- the development of Darwin's theory of evolution by natural selection, which overturned Lamarckian theories of evolution by inheritance of acquired characteristics.
- the acceptance of Plate tectonics as the explanation for large-scale geologic changes.

You might think the scientist's toolbox, the scientific method, is for scientists only. Not true! We all use the toolbox all the time. For instance:

- Observe: The car won't start.
- Think of a question: What is wrong with the car?
- Predict the answer (hypothesis): The car won't run because the battery is dead.
- Plan the experiment: I will have the battery tested.
- Collect data: The car battery is dead.
- Analyze results: The car won't start because the battery is dead.

Just as with mechanics and carpenters, scientists don't always use the same tools. Individual scientific toolboxes are stocked to fit the situation and the person. Almost always, however, they contain the basic six ingredients—observation, forming the question, presenting the hypothesis, testing phase, results, analyzing the results—or modifications or variations of. Keep in mind, however, that observation and testing are the key tools in the scientist's toolbox.

We all know that mechanical tools in the wrong hands can be dangerous to the operator or damaging to whatever is being worked on. The same is true when using tools in the scientific toolbox. To ensure that the results are valid to the natural world, the toolbox must be used objectively to remove personal and cultural biases. In addition, the tools must be used consistently and allow for observable and measurable results. All tools should be focused on describing and explaining observed phenomena. Finally, the test should enable researchers to prove it incorrect by observable data within the experiment and it must be reproducible.

Scrap: Materials discarded from manufacturing operations that may be suitable for reprocessing.

Scrap Metal Processor: Intermediate operating facility where recovered metal is sorted, cleaned of contaminants, and prepared for recycling.

Screen-out: Team used to describe a fracturing job where proppant placement has failed.

Screening: The purpose of *screening* is to remove large solids such as rags, cans, rocks, branches, leaves, roots, etc. from the flow before the flow moves on to downstream processes. A *bar screen* traps debris as wastewater influent passes through. Typically, a bar screen consists of a series of parallel, evenly spaced bars or a perforated screen placed in a channel. The wastestream passes through the screen and the large solids (*screenings)* are trapped on the bars for removal.

Screening Risk Assessment: A Risk Assessment performed with few data and many assumptions to identify exposures that should be evaluated more carefully for potential risks.

Scroll Case: A spiral-shaped steel intake guiding the flow into the wicket gates located just prior to the turbine.

Scrubber: An air pollution device that uses a spray of water or reactant or a dry process to trap pollutants in emissions.

Sea Level Rise: The natural rise of sea level that occurs in cyclical patterns throughout history; may be the result of man's impact on global warming.

Sea States (In Marine Engineering): In engineering applications, sea states are often characterized by the following two parameters:

- The significant wave height $H_{1/3}$—the mean wave height of the one third highest waves.
- The mean wave period, T_1.

Second Law of Thermodynamics: Natural law that dictates that in any conversion of heat energy to useful work, some of the initial energy input is always degraded to a lower-quality, more dispersed, less useful form of energy, usually low-temperature heat that flows into the environment; you can't break even in terms of energy quality.

It also suggests that any transformation of energy will be less than 100 percent efficient (i.e., the transfers of energy from one trophic level to another are not perfect); some energy is dissipated during each transfer.

Secondary Containment: A method using two containment systems so that if the first is breached, the second will contain all of the fluid in the first. For USTs, secondary containment consists of either a double-walled tank or a liner system.

Secondary Drinking Water Standards: The unenforceable guidelines based on both aesthetics, including taste, odor, and color of drinking water, as well as nonaesthetic characteristics such as corrosivity and hardness.

Secondary Effect: Action of a stressor on supporting components of the ecosystem, which in turn impact the ecological component of concern.

Secondary Exposure Pathways: In on site remediation, occurs as a minor component during site operations and exhibits significant decreases with time as treatment progresses (for example, wind-blown dust).

Secondary Materials: Materials that have been manufactured and used at least once and are to be used again.

Secondary Pollutants: Pollutants formed from the interaction of primary pollutants with other primary pollutants or with atmospheric compounds such as water vapor.

Secondary Porosity: The porosity created through alteration of rock, commonly by processes such as, dissolution and fracturing.

Secondary Standards: Refers to NAAQS requirement to protect public welfare, including effects on soils, water, crops, vegetation, man-made (anthropogenic) material, animals, wildlife, weather, visibility, and climate; damage to property; transportation hazards; economic values, and personal comfort ad well-being.

Secondary Treatment (of sewage): The removal of impurities from water by the digestive action of various small organisms in the presence of air or oxygen. Secondary treatment follows primary treatment and involves the biological process of reducing suspended, colloidal, and dissolved organic matter in effluent from primary treatment systems and which generally removes 80 to 95 percent of the Biochemical Oxygen Demand (BOD) and suspended matter. Secondary wastewater treatment may be accomplished by biological or chemical-physical methods. Activated sludge and trickling filters are two of the most common means of secondary treatment. It is accomplished by bringing together waste, bacteria, and trickling filters or in the activated sludge process. This treatment removes floating and settleable solids and bout 90 percent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment.

Secure Maximum Contaminant Level: Maximum permissible level of a contaminant in water delivered to the free flowing outlet of the ultimate user, or of contamination resulting from corrosion of piping and plumbing caused by water quality.

Security Assessment: A security test intensified in scope and effort, the purpose of which is to obtain an advanced and very accurate idea of how well the organization has implemented security mechanisms, and to some degree, policy.

Security: Physical Assets Monitoring and Control Devices

Aboveground, Outdoor Equipment Enclosures

Many industrial facilities and systems consist of multiple components spread over a wide area, and typically include a centralized operations area, as well as satellite offices or building complexes that are typically distributed at multiple locations throughout the community. However, in recent years, system designers have favored placing critical operational equipment—especially assets that require regular use and maintenance—aboveground.

One of the primary reasons for doing so is that locating this equipment aboveground eliminates the safety risks associated with confined space entry, which is often required for the maintenance of equipment located blow-ground. In addition, space restrictions often limit the amount of equipment that can be located inside, and there are concerns that some types of equipment (chemical processing units) can, under certain circumstances, discharge chemicals and off-gases that could flood pits, vaults, or equipment rooms. Therefore, many pieces of critical equipment are located outdoors and aboveground.

Many different system components can be installed outdoors and aboveground. Examples of these types of components could include:

- Backflow prevention devices
- Air release and control valves
- Pressure vacuum breakers
- Pumps and motors
- Chemical storage and feed equipment
- Meters
- Sampling equipment
- Instrumentation

Much of this equipment is installed in remote locations and/or in areas where the public can access it.

One of the most effective security measures for protecting aboveground equipment is to place it inside a building. When/where this is not possible, enclosing the equipment or parts of the equipment using some sort of commercial or homemade add-on structure may help to prevent tampering with the equipment. These types of add-on structures or enclosures, which are designed to protect the equipment both from the elements and from unauthorized access or tampering, typically consist of a box-like structure that is placed over the entire component, or over critical parts of the component (i.e., valves, etc.), and is then secured to delay or prevent intruders from tampering with the equipment. The enclosures are typically locked or otherwise anchored to a solid foundation, which makes it difficult for unauthorized personnel to remove the enclosure and access the equipment.

Standardized aboveground enclosures are available in a wide variety of materials, sizes, and configurations. Many options and security features are also available for each type of enclosure, and this allows system operators the flexibility to customize an enclosure for a specific application and/or price range. In addition, most manufacturers can custom-design enclosures if standard, off-the-shelf enclosures do not meet a user's needs.

Many of these enclosures are designed to meet certain standards. For example, the American Society of Sanitary Engineers (ASSE) has developed Standard #1060, *Performance Requirements for Outdoor Enclosures for Backflow Prevention Assemblies*. If an enclosure will be used to house backflow preventer, this standard specifies the acceptable construction materials for the enclosure, as well as the performance requirements that the enclosure should meet, including specifications for freeze protection, drainage, air inlets, access for maintenance, and hinge requirements. ASSE #1060 also states that the enclosure should be lockable to enhance security.

Did You Know?

A backflow prevention device is used to protect water supplies from contamination or pollution.

Equipment enclosures can generally be categorized into one of four main configuration, which include:

- One piece, drop over enclosures
- Hinged or removable top enclosures
- Sectional enclosures
- Shelters with access locks

All enclosures, including those with integral floors, must be secured to a foundation to prevent them from being moved or removed. Un- or poorly-anchored enclosures may be blown off the equipment being protected, or may be defeated by intruders. In either case, this may result in the equipment beneath the enclosure becoming exposed and damaged. Therefore, ensuring that the enclosure is securely anchored will increase the security of the protected equipment.

The three basic types of foundations that can be used to anchor the aboveground equipment enclosure are concrete footers, concrete slabs-on-grade, or manufactured fiberglass pads. The most common types of foundations utilized for equipment enclosures are standard or slab-on-grade footers; however, local climate and soil conditions may dictate whether either of these types of foundations can be used. These foundations can be either precast or poured in place at the installation site. Once the foundation is installed and properly cured, the equipment enclosure is bolted or anchored to the foundation to secure it in place.

An alternative foundation, specifically for use with smaller Hot box enclosures, is a manufactured fiberglass pad known as the Glass PadTM. The glass PadTM has the center cut out so that it can be dropped directly over the piece of equipment being enclosed. Once the pad is set level on the ground, it is backfilled over a two-inch flange located around its base. The enclosure is then placed on top of the foundation, and is locked in place with either a staple- or a slotted-anchor, depending on the enclosure configuration.

One of the primary attributes of a security enclosure is its strength and resistance to breaking and penetration. Accordingly, the materials from which the enclosure is constructed will be important in determining the strength of the enclosure, and thus its usefulness for security applications. Enclosures are typically manufactured for either fiberglass or aluminum. With the exception of the one piece, drop-over enclosure, which is typically fabricated from fiberglass, each configuration described above can be constructed from either material. In addition, enclosures can be custom-manufactured from polyurethane, galvanized steel, or stainless steel. Galvanized or stainless steel is often offered as an exterior layer, or "skin," for an aluminum enclosure. Although they are typically utilized in underground applications, precast concrete structures can also be used as aboveground equipment enclosures. However, precast structures are much heavier and more difficult to maneuver than are their fiberglass and aluminum counterparts. Concrete is also brittle, and that can be a security concern, however, products can be applied to concrete structures to add strength and minimize security risks (i.e., epoxy coating). Because precast concrete structures can be purchased from any concrete producers, this document does not identify specific vendors for these types of products.

In addition to the construction materials, enclosure walls can be configured or reinforced to give them added strength. Adding insulation is one option that can strengthen the structural characteristics of an enclosure; however, some manufacturers offer additional features to add strength to exterior walls. For example, while most enclosures are fabricated with a flat wall construction, some vendors manufacture fiberglass shelters with ribbed exterior walls. These ribs increase the structural integrity of the wall and allow the fabrication of standard shelters up to twenty feet in length. Another vendor has developed a proprietary process that uses a series of integrated fiberglass beams that are placed throughout a foam inner core to tie together the interior and exterior walls and roof. Yet another vendor constructs aluminum enclosures with horizontal and vertical redwood beams for structural support.

Other security features that can be implemented on aboveground, outdoor equipment enclosures include locks, mounting brackets, tamper-resistant doors, and exterior lighting.

Active Security Barriers (Crash Barriers)

Active security barriers (also known as crash barriers) are large structures that are placed in roadways at entrance and exit points to protected facilities to control vehicle access to these areas. These barriers are placed perpendicular to traffic to block the roadway, so that the only way that traffic can pass the barrier is for the barrier to be moved out of the roadway. These types of barriers are typically constructed from sturdy materials, such as concrete or steel, such that vehicles cannot penetrate through them. They are also designed at a certain height off the roadway so that vehicles cannot go over them.

The key difference between active security barriers, which include wedges, crash beams, gates, retractable bollards, and portable barricades; and passive security barriers, which include non-moveable bollards, jersey barriers, and planters, is that active security barriers are designed so that they can be raised and lowered or moved out of the roadway easily to allow authorized vehicles to pass them. Many of these types of barriers are designed so that they can be opened and closed automatically (i.e., mechanized gates, hydraulic wedge barriers), while others are easy to open and close manually (swing crash beams, manual gates). In contrast to active barriers, passive barriers are permanent, non-movable barriers, and thus they are typically used to protect the perimeter of a protected facility, such as sidewalks and other areas that do not require vehicular traffic to pass them. Several of the major types of active security barriers such as wedge barriers, crash beams, gates, bollards, and portable/removable barricades are described below.

Wedge barriers are plated, rectangular steel buttresses approximately 2-3 feet high that can be raised and lowered from the roadway. When they are in the open position, they are flush with the roadway and vehicles can pass over them. However, when they are in the closed (armed) position, they project up from the road at a 45 degree angle, with the upper end pointing towards the oncoming vehicle and the base of the barrier away from the vehicle. Generally, wedge barriers are constructed from heavy gauge steel, or concrete that contains an impact-dampening iron rebar core that is strong and resistant to breaking or cracking, thereby allowing them to withstand the impact from a vehicle attempting to crash through them. In addition, both of these materials help to transfer the energy of the impact over the barrier's entire volume, thus helping to prevent the barrier from being sheared off its base. In addition, because the barrier is angled away from traffic, the force of any vehicle impacting the barrier is distributed over the entire surface of the barrier and is not concentrated at the base, which helps prevent the barrier from breaking off at the base. Finally, the angle of the barrier helps hang up any vehicles attempting to drive over it.

Wedge barriers can be fixed or portable. Fixed wedge barriers can be mounted on the surface of the roadway ("surface-mounted wedges") or in a shallow mount in the road's surface, or they can be installed completely below the road surface. Surface-mounted wedge barricades operate by rising from a flat position on the surface of the roadway, while shallow-mount wedge barriers rise from their resting position just below the road surface. In contrast, below-surface wedge barriers operate by rising from beneath the road surface. Both the shallow-mounted and surface-mounted barriers require little or no excavation, and thus do not interfere with buried utilities. All three barrier mounting types project above the road surface and block traffic when they are raised into the armed position. Once they are disarmed and lowered, they are flush with the road, thereby allowing traffic to pass Portable wedge barriers that are moved into place on wheels that are removed after the barrier has been set into place.

Installing rising wedge barriers requires preparation of the road surface. Installing surface-mounted wedges does not require that the road be excavated; however, the road surface must intact and strong enough to allow the bolts anchoring the wedge to the road surface to attach properly. Shallow-mount and below-surface wedge barricades require excavation of a pit that is large enough to accommodate the wedge structure, as well as any arming/disarming mechanisms. Generally, the bottom of the excavation pit is lined with gravel to allow for drainage. Areas not sheltered from rain or surface runoff can install a gravity drain or self priming pump. The Table lists the pros and cons of wedge barriers.

Crash beam barriers consist of aluminum beams that can be opened or closed across the roadway. While there are several different crash beam designs, every

Pros and Cons of Wedge Barriers

Pros	*Cons*
Can be surface-mounted or completely installed below the roadway surface.	Installations below the surface of the roadway will require construction that may interfere with buried utilities.
Wedge barriers have a quick response time (normally 3.5-10.5 seconds, but can be 1-3 seconds in emergency situations. Because emergency activation of the barrier causes more wear and tear on the system than does normal activation, it is recommended for use only in true emergency situations.	Regular maintenance is needed to keep wedge barrier fully operational.
Surface or shallow-mount wedge barricades can be utilized in locations with a high water table and/or corrosie soils.	Improper use of the system may result in authorized vehicles being hung up by the barrier and damaged. Guards must be trained to use the system properly to ensure that this does not happen. Safety technologies may also be installed to reduce the risk of the wedge activating under an authorized vehicle.
All three wedge barrier designs have a high crash rating, thereby allowing them to be employed for higher security applications.	
These types of barrier are extremely visible, which may deter potential intruders.	

Source: USEPA, 2005.

crash beam system consists of an aluminum beam that is supported on each side of the made by a solid footing or buttress, which is typically constructed from concrete, steel, or some other strong material. Beams typically contain an interior steel cable (typically at least one inch in diameter) to give the beam added strength and rigidity. The beam is connected by a heavy duty hinge or other mechanism to one of the footings so that it can swing or rotate out of the roadway when it is open, and can swing back across the road when it is in the closed (armed) position, blocking the road and inhibiting access by unauthorized vehicles. The non-hinged end of the beam can be locked into its footing, thus providing anchoring for the beam on both sides of the road and increasing the beam's resistance to any vehicles attempting to penetrate through it. In addition, if the crash beam is hit by a vehicle, the aluminum beam transfers the impact energy to the interior cable, which in turn transfers the impact energy through the footings and into their foundation, thereby minimizing the chance that the impact will snap the beam and allow the intruding vehicle to pass through.

Crash beam barriers can employ drop-arm, cantilever, or swing beam designs. Drop-arm crash beams operate by raising and lowering the beam vertically across the road. Cantilever crash beams are projecting structures that are opened and closed by extending the beam from the hinge buttress to the receiving buttress located on the opposite side of the road. In the swing beam design, the beam is hinged to the buttress such that it swings horizontally across the road. Generally, swing beam and cantilever designs are used at locations where a vertical lift beam is impractical. For example, the swing beam

Pros and Cons of Crash Beams

Pros	*Cons*
Requires little maintenance, while providing long-term durability.	Crash beams have a slower response time (normally 9.5-15.3 seconds, but can be reduced to 7-10 seconds in emergency situations) than do other types of active security barriers, such as wedge barriers. Because emergency activation of the barrier causes more wear and tear on the system than does normal activation, it is recommended for use only in true emergency situations.
No excavation is required in the roadway itself to install crash beams.	All three crash beam designs possess a low crash rating relative to other types of barriers, such as wedge barriers, such as wedge barriers, and thus they typically are used for lower security applications.
	Certain crash barriers may not be visible to oncoming traffic and therefore may require additional lighting and/or other warning markings to reduce the potential for traffic to accidentally run into the beam.

Source: USEPA, 2005.

or cantilever designs are utilized at entrances and exits with overhangs, trees, or buildings that would physically block the operation of the drop-arm beam design.

Installing any of these crash beam barriers involves the excavation of a pit approximately 48 inches deep for both the hinge and the receiver footings. Due to the depth of excavation, the site should be inspected for underground utilities before digging begins. The Table lists the pros and cons of crash beams.

In contrast to wedge barriers and crash beams, which are typically installed separately from a fence line, *gates* are often integrated units of a perimeter fence or wall around a facility.

Gates are basically movable pieces of fencing that can be opened and closed across a road. When the gate is in the closed (armed) position, the leaves of the gate lock into steel buttresses that are embedded in concrete foundation located on both sides of the roadway, thereby blocking access to the roadway. Generally, gate barricades are constructed from a combination of heavy gauge steel and aluminum that can absorb an impact from vehicles attempting to ram through them. Any remaining impact energy not absorbed by the gate material is transferred to the steel buttresses and their concrete foundation.

Gates can utilize a cantilever, linear, or swing design. Cantilever gates are projecting structures that operate by extending the gate from the hinge footing across the roadway to the receiver footing. A linear gate is designed to slide across the road on tracks via a rack and pinion drive mechanism. Swing gates are hinged so that they can swing horizontally across the road.

Installation of the cantilever, linear, or swing gate designs described above involve the excavation of a pit approximately 48 inches deep for both the hinge and receiver footings to which the gates are attached. Due to the depth of excavation, the site should be inspected for underground utilities before digging begins. The Table lists the pros and cons of gates.

Bollards are vertical barriers at least 3 feet tall and 1 to 2 feet in diameter that are typically set 4 to 5 feet apart from each other so that they block vehicles from passing between them. Bollards can either be fixed in place, removable, or retractable. Fixed and removable bollards are passive barriers that are typically used along building perimeters or on sidewalks to prevent vehicles from them, while allowing pedestrians to pass them. In contrast to passive bollards, retractable bollards are active security barriers that can easily be raised and lowered to allow vehicles to pass between them. Thus, they can be used in driveways or on roads to control vehicular access. When the bollards are raised, they protect above the road surface and block the roadway; when they are lowered, they sit flush with the road surface, and thus allow traffic to pass over them. Retractable bollards are typically constructed from steel or other materials that have a low weight-to-volume ratio so that they require low power to raise and lower. Steel is also more resistant to breaking than is a more brittle material, such as concrete, and is better able to withstand direct vehicular impact without breaking apart.

Retractable bollards are installed in a trench dug across a roadway—typically at an entrance or gate. Installing retractable bollards requires preparing the road surface. Depending on the vendor, bollards can be installed either in a continuous slab of concrete, or in individual excavations with concrete poured in place. The required excavation for a bollard is typically slightly wider and slightly deeper than the bollard height when extended aboveground. The bottom of the excavation is typically lined with gravel to allow drainage. The bollards are then connected to a control panel which controls the raising and lowering of the bollards. Installation typically requires mechanical, electrical, and concrete work;

Pros and Cons of Gates

Pros	*Cons*
All three gate designs possesses an intermediate crash rating, thereby allowing the to be utilized for medium to higher security applications.	Gates have a slower response time (normally 10-15 seconds, but can be reduced to 7-10 seconds in emergency situations) than do other types of active security barriers, such as wedge barriers. Because emergency activation of the barrier causes more wear and tear on the system than does normal activation, it is recommended for use only in true emergency situations.
Requires very little maintenance. Can be tailored to blend in with perimeter fencing. Gate construction requires no roadway excavation. Cantilever gates are useful for roads with high crowns or drainage gutters. These types of barriers are extremely visible, which may deter intruders. Gates can also be used to control pedestrian traffic.	

Source: USEPA, 2005.

Pros and Cons of Retractable Bollards

Pros	*Cons*
Bollards have a quick response time (normally 3 to 10 seconds, but can be reduced to 1-3 seconds in emergency situations).	Bollard installations will require construction below the surface of the roadway, which may interfere with buried utilities.
Bollards have an intermediate crash rating, which allows them to be utilized for medium to higher security applications.	Some maintenance is needed to ensure barrier is free to move up and down.
	The distance between bollards must be decreased (i.e., more bollards must be installed along the same perimeter) to make these systems effective against small vehicles (i.e., motorcycles).

Source: USEPA, 2005.

if utility personnel with these skills are available, then the utility can install the bollards themselves. The Table lists the pros and cons of retractable bollards.

Portable/removable barriers, which can include removable crash beams and wedge barriers, are mobile obstacles that can be moved in and out of position on a roadway. For example, a crash beam may be completely removed and stored off-site when it is not needed. An additional example would be wedge barriers that are equipped with wheels that can be removed after the barricade is towed into place.

When portable barricades are needed, they can be moved into position rapidly. To provide them with added strength and stability, they are typically anchored to buttress boxes that are located on either side of the road. These buttress boxes, which may or may not be permanent, are usually filled with sand, water, cement, gravel, or concrete to make them heavy and aid in stabilizing the portable barrier. In addition, these buttresses can help dissipate any impact energy from vehicles crashing into the barrier itself.

Because these barriers are not anchored into the roadway, they do not require excavation or other related construction for installation. In contrast, they can be assembled and made operational in a short period of time. The primary shortcoming to this type of design is that these barriers may move if they are hit by vehicles. Therefore, it is important to carefully assess the placement and anchoring of these types of barriers to ensure that they can withstand the types of impacts that may be anticipated at that location. The Table lists the pros and cons of portable/removable barricades.

Because the primary threat to active security barriers is that vehicles will attempt to crash through them, their most important attributes are their size, strength, and crash resistance. Other important features for an active security barrier are the mechanisms by which the barrier is raised and lowered to allow authorized vehicle entry, and other factors, such as weather resistance and safety features.

Alarms

An *alarm system* is a type of electronic monitoring system that is used to detect and respond to specific types of events—such as unauthorized access to an asset, or a possible fire. In industrial and business facilities, alarms are also used to alert operators/employees when process operating or monitoring conditions go out of preset parameters (i.e., process alarms). These types of alarms are primarily integrated with process monitoring and reporting systems (i.e., SCADA systems). Note that this discussion does not focus on alarm systems that are not related to a utility's processes.

Alarm systems can be integrated with fire detection systems, IDSs, access control systems, or closed Circuit Television (CCTV) systems, such that these systems automatically respond when the alarm is triggered. For example, a smoke detector alarm can be set up to

Pros and Cons of Portable/Removable Barricades

Pros	*Cons*
Installing portable barricades requires no foundation or roadway excavation.	Portable barriers may move slightly when hit by a vehicle, resulting in a lower crash resistance.
Can be moved in and out of position in a short period of time.	Portable barricades typically require 7.75 to 16.25 seconds to move into place, and thus they are considered to have a medium response time when compared with other active barriers.
Wedge barriers equipped with wheels can be easily towed into place.	
Minimal maintenance is needed to keep barriers fully operational.	

Source: USEPA, 2005.

automatically notify the fire department when smoke is detected; or an intrusion alarm can automatically trigger cameras to turn on in a remote location so that personnel can monitor that location.

An alarm system consists of sensors that detect different types of events; an arming station that is used to turn the system on and off; a control panel that receives information, processes it, and transmits the alarm; and an annunciator that generates a visual and/or audible response to the alarm. When a sensor is tripped it sends a signal to a control panel, which triggers a visual or audible alarm and/or notifies a central monitoring station. A more complete description of each of the components of an alarm system is provided below.

Detection devices (also called *sensors*), are designed to detect a specific type of event (such as smoke, intrusion, etc.). Depending on the type of event they are designed to detect, sensors can be located inside or outside of the facility or other asset. When an event is detected, the sensors use some type of communication method (such as wireless radio transmitters, conductors, or cables) to send signals to the control panel to generate the alarm. For example, a smoke detector sends a signal to a control panel when it detects smoke.

Alarms use either normally closed (NC) or normally open (NO) electric loops, or “circuits,” to generate alarm signals. These two types of circuits are discussed separately below.

In NC loops or circuits, all of the system’s sensors and switches are connected in series. The contacts are “at rest” in the closed (on) position, and current continually passes through the system. However, when an event triggers the sensor, the loop is opened, breaking the flow of current through the system and triggering the alarm. NC switches are used more often than are NO switches because the alarm will be activated if the loop or circuit is broken or cut, thereby reducing the potential for circumventing the alarm. This is known as a “supervised” system.

In NO loops or circuits, all of the system’s sensors and switches are connected in parallel. The contacts are “at rest” in the open (off) position, and no current passes through the system. However, when an event triggers the sensor, the loop is closed. This allows current to flow through the loop, powering the alarm. NO systems are not “supervised” because the alarm will not be activated if the loop or circuit is broken or cut. However, adding an end-of-line resistor to an NO loop will cause the system to alarm if tampering is detected.

An *arming station*, which is the main user interface with the security system, allows the user to arm (turn on), disarm (turn off), and communicate with the system. How a specific system is armed will depend on how it is used. For example, while IDSs can be armed for continuous operation (24 hours/day), they are usually armed and disarmed according to the work schedule at a specific location so that personnel going about their daily activities do not set off the alarms. In contrast, fire protection systems are typically armed 24hours/day.

A *control panel*, which receives information from the sensors and sends it to an appropriate location, such as to a central operations station or to a 24-hour monitoring facility. Once the alarm signal is received at the central monitoring location, personnel monitoring for alarms can respond (such as by sending security teams to investigate or by dispatching the fire department).

An *annunciator*, which responds to the detection of an event by emitting a signal. This signal may be visual, audible, electronic, or a combination of these three. For example, fire alarm signals will always be connected to audible annunciators, whereas intrusion alarms may not be.

Alarms can be reported locally, remotely, or both locally and remotely. Local and remotely- (centrally-) reported alarms are discussed in more detail below.

A *local alarm* emits a signal at the location of the event (typically using a bell or siren). A “local only” alarm emits a signal at the location of the event but does not transmit the alarm signal to any other location (i.e., it does not transmit the alarm to a central monitoring location). Typically, the purpose of a “local only” alarm is to frighten away intruders, and possibly to attract the attention of someone who might notify the proper authorities. Because no signal is sent to a central monitoring location, personnel can only respond to a local alarm if they are in the area and can hear and/or see the alarm signal.

Fire alarm systems must have local alarms, including both audible and visual signals. Most fire alarm signal and response requirements are codified in the National Fire Alarm Code, National Fire Protection Association (NFPA) 72. NFPA 72 discusses the application, installation, performance, and maintenance of protective signaling systems and their components. In contrast to fire alarms, which require a local signal when fire is detected, many IDSs do not have a local alert device, because monitoring personnel do not wish to inform potential intruders that they have been detected. Instead, these types of systems silently alert monitoring personnel that an intrusion has been detected, thus allowing monitoring personnel to respond.

In contrast to systems that are set up to transmit “local only” alarms when the sensors are triggered, systems can also be set up to transmit signals to a *central location*, such as to a control room or guard post at the utility, or to a police or fire station. Most fire/smoke alarms are set up to signal both at the location of the event and at a fire station or central monitoring station. Many insurance companies require that facilities install certified systems that include alarm communication to a central station. For example, systems certified by the Underwriters

Laboratory (UL) require that the alarm be reported to a central monitoring station.

The main differences between alarm systems lie in the types of event detection devices used in different systems. **Intrusion sensors**, for example, consist of two main categories: perimeter sensors and interior (space) sensors. *Perimeter intrusion sensors* are typically applied on fences, doors, walls, windows, etc., and are designed to detect an intruder before he or she accesses a protected asset (i.e., perimeter intrusion sensors are used to detect intruders attempting to enter through a door, window, etc.). In contrast, *interior intrusion sensors* are designed to detect an intruder who has already accessed the protected asset (i.e., interior intrusion sensors are used to detect intruders once they are already within a protected room or building). These two types of detection devices can be complementary, and they are often used together to enhance security for an asset. For example, a typical intrusion alarm system might employ a perimeter glass-break detector that protects against intruders accessing a room through a window, as well as an ultrasonic interior sensor that detects intruders that have gotten into the room without using the window. The Table lists and describes types of perimeter and interior sensors.

Fire Detection/Fire Alarm Systems consist of different types of fire detection devices and fire alarm systems available. These systems may detect fire, heat, smoke, or a combination of any of these. For example, a typical fire alarm system might consist of heat sensors, which are located throughout a facility and which detect high temperatures or a certain change in temperature over a fixed time period. A different system might be outfitted with both smoke and heat detection devices. A summary of several different types of fire/smoke/heat detection sensors is provided in the Table.

Once a sensor in an alarm system detects an event, it must communicate an alarm signal. The two basic types of alarm communication systems are hardwired and wireless. Hardwired systems rely on wire that is run from the control panel to each of the detection devices and annunciators. Wireless systems transmit signals from a transmitter to a receiver through the air—primarily using radio or other waves. Hardwired systems are usually lower-cost, more reliable (they are not affected by terrain or environmental factors), and significantly easier to troubleshoot than are wireless systems. However, a major disadvantage of hardwired systems is that it may not be possible to hardwire all locations (for example,

Perimeter and Interior Sensors

Type of Perimeter Sensor	*Description*
Foil	Foil is a thin, fragile, lead-based metallic tape that is applied to glass windows and doors. The tape is applied to the window or door, and electric wiring connects this tape to a control panel. The tape functions as a conductor and completes the electric circuit with the control panel. When an intruder breaks the door or window, the fragile foil breaks, opening the circuit and triggering an alarm condition.
Magnetic switches (reed switches)	The most widely-used perimeter sensor. They are typically used to protect doors, as well as windows that can be opened (windows that cannot be opened are more typically protected by foil alarms).
Glass break detectors	Placed on glass and sense vibrations in the glass when it is disturbed. The two most common types of glass-break detectors are shock sensors and audio discriminators.
Type of Interior Sensor	*Description*
Passive infrared (PIR)	Presently the most popular and cost effective interior sensors. PIR detectors monitor infrared radiation (energy in the form of heat) and detect rapid changes in temperature within a protected area. Because infrared radiation is emitted by all living things, these types of sensors can be very effective.
Quad PIRs	Consist of two dual-element sensors combined in one housing. Each sensor has a separate lens and a separate processing circuitry, which allows each lens to be set up to generate a different protection pattern
Ultrasonic detectors	Emit high frequency sound waves, and sense movement in a protected area by sensing changes in these waves. The sensor emits sound waves that stabilize and set a baseline condition in the area to be protected. Any subsequent movement within the protected area by a would-be intruder will cause a change in these waves, thus creating an alarm condition.
Microwave detectors	Emit ultra high frequency radio waves, and the detector senses any changes in these waves as they are reflected throughout the protected space. Microwaves can penetrate through walls, and thus a unit placed in one location may be able to protect multiple rooms.
Dual technology devices	Incorporate two different types of sensor technology (such as PIR and microwave technology) together in one housing. When both technologies sense an intrusion, an alarm is triggered.

Source: USEPA, 2005.

Fire/Smoke/Heat Detection Sensors

Detector Type	*Description*
Thermal detector	Sense when temperatures exceed a set threshold (fixed temperature detectors) or when the rate of change of temperature increases over a fixed time period (rate-of-rise detectors).
Duct detector	Is located within the haring and ventilation ducts of the facility. This sensor detects the presence of smoke within the system's return or supply ducts. A sampling tube can be added to the detector to help span the width of the duct.
Smoke detectors	Sense invisible and/or visible products of combustion. The two principle types of smoke detectors are photoelectric and ionization detectors. The major differences between these devices are described below: • Photoelectric smoke detectors react to visible particles of smoke. These detectors are more sensitive to the cooler smoke with large smoke particles that is typical of smoldering fires. • Ionization smoke detectors are sensitive to the presence of ions produced by the chemical reactions that take place with few smoke particle, such as those typically produced by fast burning/flaming fires.
Multi-sensor detectors	Are a combination of photoelectric and thermal detectors. The photoelectric sensor serves to detect smoldering fires, while the thermal detector senses the eat give off from fast burning/flaming fires.
Carbon monoxide (CO) detectors	Are used to indicate the outbreak of fire by sensing the level of carbon monoxide in the air. The detector has an electrochemical cell which senses carbon monoxide, but not some or other products of combustion.
Beam detectors	Are designed to protect large, open spaces such as industrial warehouses. These detectors consist of three parts: the transmitter, which projects a beam of infrared light; the receiver, which registers the light and produces an electrical signal; and the interface, which processes the signal and generates alarm of fault signals. In the event of a fire, smoke particles obstruct the beam of light. Once a preset threshold is exceeded, the detector will go into alarm.
Flame detectors	Sense either ultraviolet (UV) or infrared (IR) radiation emitted by a fire.
Air-sampling detectors	Actively and continuously sample the air from a protected space and are able to sense the pre-combustion stages of incipient fire.

Source: USEPA, 2005.

it may be difficult to hardwire remote locations). In addition, running wires to their required locations can be both time consuming and costly. The major advantage to using wireless systems is that they can often be installed in areas where hardwired systems are not feasible. However, wireless components can be much more expensive when compared to hardwired systems. In addition, in the past, it has been difficult to perform self-diagnostics on wireless systems to confirm that they are communicating properly with the controller. Presently, the majority of wireless systems incorporate supervising circuitry, which allows the subscriber to know immediately if there is a problem with the system (such as a broken detection device or a low battery), or if a protected door or window has been left open.

Exterior Intrusion-Buried Sensors

Buried sensors are electronic devices that are designed to detect potential intruders. The sensors are buried along the perimeters of sensitive assets and are able to detect intruder activity both above- and below-ground. Some of these systems are composed of individual, stand-alone sensor units, while other sensors consist of buried cables.

There are four types of buried sensors that rely on different types of triggers. These are: pressure or seismic; magnetic field; ported coaxial cable; and fiber-optic cables. These four sensors are all covert and terrain-following, meaning they are hidden from view and follow the contour of the terrain. The four types of sensors are described in more detail below. The Table presents the distinctions between the four types of buried sensors.

Types of Buried Sensors

Type	*Description*
Pressure or Seismic	Responds to disturbances in the soil.
Magnetic Field	Responds to a change in the local magnetic field caused by the movement of nearby metallic material.
Ported Coaxial Cables	Responds to motion of a material with a high dielectric constant or high conductivity near the cables.
Fiber-Optic Cables	Responds to a change in the shape of the fiber that can be sensed using sophisticated sensors and computer signal processing.

Source: Adapted from Garcia, M.L., 2001.

Exterior Intrusion Sensors

An exterior intrusion sensor is a detection device that is used in an outdoor environment to detect intrusions into a protected area. These devices are designed to detect an intruder, and then communicate an alarm signal to an alarm system. The alarm system can respond to the intrusion in many different ways, such as by triggering an audible or visual alarm signal, or by sending an electronic signal to a central monitoring location that notifies security personnel of the intrusion.

Intrusion sensor can be used to protect many kinds of assets. Intrusion sensors that protect physical space are classified according to whether they protect indoor, or "interior" space (i.e., an entire building or room within a building), or outdoor, or "exterior" space (i.e., a fence line or perimeter). Interior intrusion sensors are designed to protect the interior space of a facility by detecting an intruder who is attempting to enter, or who has already entered a room or building. In contrast, exterior intrusion sensors are designed to detect an intrusion into a protected outdoor/exterior area. Exterior protected areas are typically arranged as zones or exclusion areas placed so that the intruder is detected early in the intrusion attempt before the intruder can gain access to more valuable assets (e.g., into a building located within the protected area). Early detection creates additional time for security forces to respond to the alarm.

Exterior intrusion sensors are classified according to how the sensor detects the intrusion within the protected area. The three classes of exterior sensor technology include:

- Buried line sensors
- Fence-associated sensors
- Freestanding sensors

1. Buried-Line Sensors—As the name suggests, buried line sensors are sensors that are buried underground, and are designed to detect disturbances within the ground—such as disturbances caused by an intruder digging, crawling, walking, or running on the monitored ground. Because they sense ground disturbances, these types of sensors are able to detect sense ground disturbances, these types of sensors are able to detect intruder activity both on the surface and below ground. Individual types of exterior buried line sensors function in different ways, including, by detecting motion, pressure, or vibrations within the protected ground, or by detecting changes in some type of field (e.g., magnetic field) that the sensors generate within the protected ground. Specific types of buried line sensors include pressure or seismic sensors, magnetic field sensors, ported coaxial cables, and fiber-optic cables. Details on each of these sensor types are provided below.
   - *Buried-line pressure* or *seismic sensors* detect physical disturbances to the ground—such as vibrations or soil compression—caused by intruders walking, driving, digging, or otherwise physically contacting the protected ground. These sensors detect disturbances from all directions and, therefore, can protect an area radially outward from their location; however, because detection may weaken as a function of distance from the disturbance, choosing the correct burial depth from the design area will be crucial. In general, sensors buried at a shallow depth protect a relatively small area but have a high probability of detecting intrusion within that area, while sensors buried at a deeper depth protect a wider area but have a lower probability of detecting intrusion into that area.
   - *Buried line magnetic field sensors* detect changes in a local magnetic field that are caused by the moment of metallic objects within that field. This type of sensor can detect ferric metal objects worn or carried by an intruder entering a protected area on foot as well as vehicles being driven into the protected area.
   - *Buried line ported coaxial cable sensors* detect the motion of any object (i.e., human body, metal, etc.) possessing high conductivity and located within close proximity to the cables. An intruder entering into the protected space creates an active disturbance in the electric field, thereby triggering an alarm condition.
   - *Buried line fiber-optic cable sensors* detect changes in the attenuation of light signals transmitted within the cable. When the soil around the cable is compressed, the cable is distorted, and the light signal transmitted through the cable changes, initiating an alarm. This type of sensor is easy to install because it can be buried at a shallow burial depth (only a few centimeters) and still be effective.
2. Fence-Associated Sensors—Fence-associated sensors are either attached to an existing fence, or are installed in such a way as to create a fence. These sensors detect disturbances to the fence—such as those caused by an intruder attempting to climb the fence, or by an intruder attempting to cut or lift the fence fabric. Exterior fence-associated sensors include fence-disturbance sensors, taut-wire sensor fences, and electric field or capacitance sensors. Details on each of these sensor types are provided below.
   - *Fence-disturbance sensors* detect the motion or vibration of a fence, such as that, that can be caused by an intruder attempting to climb or cut through the fence. In general, fence disturbance sensors are used on chain link fences or on other fence types where a moveable fence fabric is hung between fence posts.

- *Taut-wire sensor fences* are similar to fence-disturbance sensors except that instead of attaching the sensors to a loose fence fabric, the sensors are attached to a wire that is stretched tightly across the fence. These types of systems are designed to detect changes in the tension of the wire rather than vibrations in the fence fabric. Taut-wire sensor fences can be installed over existing fences, or as stand-alone fence systems.
- *Electric field or capacitance sensors* detect changes in capacitive coupling between wires that are attached to, but electrically isolated from, the fence. As opposed to other fence-associated intrusion sensors, both electric field and capacitance sensors generate an electric field that radiates out from the fence line, resulting in an expanded zone of protection relative to other fence-associated sensors, and allowing the sensor to detect an intruders' presence before they arrive at the fence line. Note: proper spacing is necessary during installation of the electric field sensor to detect a would-be intruder from slipping between largely spaced wires.

3 *Free-Standing Sensors*—These sensors, which include active infrared, passive infrared, bistatic microwave, monostatic microwave, dual-technology, and video motion detection (VMD) sensors, consist of individual sensor units or components that can be set up in a variety of configurations to meet a user's needs. They are installed above-ground, and depending on how they are oriented relative to each other, they can be used to establish a protected perimeter or a protected space. More details on each of these sensor types are provided below.

- *Active infrared sensors* transmit infrared energy into the protected space, and monitor for changes in this energy caused by intruders entering that space. In a typical application, an infrared light beam is transmitted from a transmitter unit to a receiver unit. If an intruder crosses the beam, the beam is blocked, and the receiver unit detects a change in the amount of light received, triggering an alarm. Different sensors can see single- and multiple-beam arrays. Single-beam infrared sensors transmit a single infrared beam. In contrast, multiple-beam infrared sensors transmit two or more beams parallel to each other. This multiple-beam sensor arrangement creates an infrared "fence."
- *Passive infrared (PIR) sensors* monitor the ambient infrared energy in a protected area, and evaluate changes in that ambient energy that may be caused by intruders moving through the protected area. Detection ranges can exceed 100 yards on cold days with size and distance limitations dependent upon the background temperature. PIR sensors generate a non-uniform detection pattern (or "curtain") that has areas (or "zones") of more sensitivity and areas of less sensitivity. The specific shape of the protected area is determined by the detector's lenses. The general shape common too many detection patterns is a series of long "fingers" emanating from the PIR and spreading in various directions. When intruders enter the detection area, the PIR sensor detects differences in temperature due to the intruder's body heat, and triggers an alarm. While the PIR leaves unprotected areas between its fingers, an intruder would be detected if he passed from a non-protected area to a protected area.
- *Microwave sensors* detect changes in received energy generated by the motion of an intruder entering into a protected area. Monostatic microwave sensors incorporate transmitter and a receiver in one unit, while bistatic sensors separate the transmitter and the receiver into different units. Monostatic sensors are limited to a coverage area of 400 feet, while bistatic sensors can cover an area up to 1,500 feet. For bistatic sensors, a zone of no detection exists in the first few feet in front of the antennas. This distance from the antennas to the point at which the intruder is first detected is known as the offset distance. Due to this offset distance, antennas must be configured so that they overlap one another (as opposed to being adjacent to each other), thereby creating long perimeters with a continuous line of detection.
- *Dual-technology sensors* consist of two different sensor technologies incorporated together into one sensor unit. For example, a dual technology sensor could consist of a passive infrared detector and a monostatic microwave sensor integrated into the same sensor unit.
- *Video motion detection* (VMD) *sensors* monitor video images from a protected area for changes in the images. Video cameras are used to detect unauthorized intrusion into the protected area by comparing the most recent image against a previously established one. Cameras can be installed on towers or other tall structures so that they can monitor a large area.

Fences

A fence is a physical barrier that can be set up around the perimeter of an asset. Fences often consist of individual pieces (such as individual pickets in a wooden fence, or individual sections of a wrought iron fence) that are fastened together. Individual sections of the fence are fastened together using posts, which are sunk into the ground to provide stability and strength for the sections of the fence hung between them. Gates are installed between individual sections of the fence to allow access inside the fenced area.

Many fences are used as decorative architectural features to separate physical spaces for each other. They may also be used to physically mark the location of a boundary (such as a fence installed along a properly line). However, a fence can also serve as an effective means for physically delaying intruders from gaining access to a water or wastewater asset. For example, many utilities install fences around their primary facilities, around remote pump stations, or around hazardous materials storage areas or sensitive areas within a facility. Access to the area can be controlled through security at gates or doors through the fence (for example, by posting a guard at the gate or by locking it). In order to gain access to the asset, unauthorized persons could either have to go around or through the fence.

Fences are often compared with walls when determining the appropriate system for perimeter security. While both fences and walls can provide adequate perimeter security, fences are often easier and less expensive to install than walls. However, they do not usually provide the same physical strength that walls do. In addition, many types of fences have gaps between he individual pieces that make up the fence (i.e., the spaces between chain links in a chain link fence or the space between pickets in a picket fence). Thus, many types of fences allow the interior of the fenced area to be seen. This may allow intruders to gather important information about the locations or defenses of vulnerable areas within the facility.

There are numerous types of materials used to construct fences, including chain link iron, aluminum, wood, or wire. Some types of fences, such as split rails or pickets, may not be appropriate for security purposes because they are traditionally low fences, and they are not physically strong. Potential intruders may be able to easily defeat these fences either by jumping or climbing over them or by breaking through them. For example, the rails in a split fence may be able to be broken easily.

Important security attributes of a fence include the height to which it can be constructed, the strength of the material comprising the fence, the method and strength of attaching the individual sections of the fence together at the posts and the fence's ability to restrict the view of the assets inside the fence. Additional considerations should include the ease of installing the fence and the ease of removing and reusing sections of the fence. The Table provides a comparison of the important security and usability features of various fence types.

Some fences can include additional measures to delay, or even detect, potential intruders. Such measures may include the addition of barbed wire, razor wire, or other deterrents at the top of the fence. Barbed wire is sometimes employed at the base of fences as well. This can impede a would-be intruder's progress in even reaching the fence. Fences may also be fitted with security cameras to provide visual surveillance of the perimeter. Finally, some facilities have installed motion sensors along their fences to detect movement on the fence. Several manufacturers have combined these multiple perimeter security features into one product and offer alarms, and other security features.

Comparison of Different Fence Types

Specifications	*Chain Link*	*Iron*	*Wire (Wirewall)*	*Wood*
Height limitations	12′	12′	12′	8′
Strength	Medium	High	High	Low
Installation Requirements	Low	High	High	Low
Ability to Remove/Reuse	Low	High	Low	High
Ability to Replace/ Repair	Medium	High	Low	High

Source: USEPA, 2005.

The correct implementation of a fence can make it a much more effective security measure. Security experts recommend the following when a facility constructs a fence:

- The fence should be at least 7-9 feet high.
- Any outriggers, such as bared wire, that are affixed on top of the fence should be angled out and away from the facility, and not in towards the facility. This will make climbing the fence more difficult, and will prevent ladders from being placed against the fence.
- Other types of hardware can increase the security of the fence. This can include installing concertina wire along the fence (this can be done in front of the fence or at the top of the fence), or adding intrusion sensors, camera, or other hardware to the fence.
- All undergrowth should be cleared for several feet (typically 6 feet) on both sides of the fence. This will allow for a clearer view of the fence by any patrols in the area.
- Any trees with limbs or branches hanging over the fence should be trimmed so that intruders cannot use them to go over the fence. Also, it should be noted that fallen trees can damage fences, and so management of trees around the fence can be important. This can be especially important in areas where fence goes through a remote area.
- Fences that do not block the view from outside the fence to inside the fence allow patrols to see inside the fence without having to enter the facility.
- "No Trespassing" signs posted along fence can be a valuable tool in prosecuting any intruders who claim that the fence was broken and that they did not

enter through the fence illegally. Adding signs that highlight the local ordinances against trespassing can further persuade simple troublemakers for illegally jumping/climbing the fence.

Locks

A lock is a type of physical security device that can be used to delay or prevent a door, a window, a manhole, a filing cabinet drawer, or some other physical feature from being opened, moved, or operated. Locks typically operate by connecting two pieces together—such as by connecting a door to a door jamb or a manhole to its casement. Every lock has two modes—engaged (or "locked"), and disengaged (or "opened"). When a lock is disengaged, the asset on which the lock is installed can be accessed by anyone, but when the lock is engaged, only access to the locked asset.

Locks are excellent security features because they have been designed to function in many ways and to work on many different types of assets. Locks can also provide different levels of security depending on how they are designed and implemented. The security provided by a lock is dependent on several factors, including its ability to withstand physical damage (i.e., can it be cut off, broken, or otherwise physically disabled) as well as its requirements for supervision or operation (i.e., combinations may need to be changed frequently so that they are not compromised and the locks remain secure). While there is no single definition of the "security" of a lock, locks are often described as minimum, medium, or maximum security. Minimum security locks are those that can be easily disengaged (or "picked") without the correct key or code, or those that can be disabled easily (such as small padlocks that can be cut with bolt cutters). Higher security locks are more complex and thus are more difficult to pick, or are sturdier and more resistant to physical damage.

Many locks such as many door locks, only need to be unlocked from one side. For example, most door locks need a key to be unlocked only from the outside. A person opens such devices, called single-cylinder locks, from the inside by pushing a button or by turning a knob or handle. Double-cylinder locks require a key to be locked or unlocked from both sides.

Security Policy: A set of rules and practices that specify or regulate how a system or organization provides security services to protect sensitive and critical system resources.

Secure Landfill: A land site for the storage of hazardous solid and liquid wastes normally placed in containers and buried in a restricted-access area that is continually monitored. Such landfills are located above geologic strata that are supposed to prevent the leaching of wastes into groundwater.

Sedation: Induced state of relaxation, especially by the use of sedative drugs.

Sediment: Usually applied to material in suspension in water or recently deposited from suspension. In the plural the word is applied to all kinds of deposits from the waters of streams, lakes, or seas.

Sediment Delivery Ratio (SDR): Fraction of eroded soil that actually reaches a water body.

Sediment Delivery: Sediment arriving at a specific location.

Sediment Yield: Quantity of sediment leaving a specified land area.

Sedimentary (rock form): (Sediments) Soil particles dislodged by rain drops that travel via runoff into streams, rivers, lakes, or oceans and are deposited there. (Sedimentary rock) rock formed of sediment and specifically: (1) sandstone and shale, and (2) rocks formed by or form secretions of organism, such as most limestone. Many sedimentary rocks show distinct layering, which is the result of different types of sediment being deposited in succession.

Sedimentation: Letting solids settle out of wastewater by gravity during treatment.

Sedimentation Tanks: Units in which water or wastewater containing settleable solids is retained to remove by gravity a part of the suspended matter. Also called sedimentation basin, settling basin, settling tank, or settling terrace.

Sediments: Soil, sand, and minerals washed from land into water, usually after rain. They pile up in reservoirs, rivers and harbors, destroying fish ad wildlife habitat, and including the water so that sunlight connot reach aquatic plants. Careless farming, mining, and building activities will expose sediment materials, allowing them to wash off of the land after rainfall.

Seepage: 1. The slow movement of water through small cracks, pores, interstices, etc., of a material into or out of a body of surface or subsurface water. 2. The loss of water by infiltration into the soil from a canal, ditches, lateral, watercourse, reservoir, storage facilities, or other body of water, or from a field.

Seismic: Pertaining to, of the nature of, or caused by an earthquake or earth vibration, natural or man-made.

Seismicity: The phenomena of earth movements. Also the frequency, distribution and intensity of earthquakes.

Seismometer: Electrical device that is used on the surface and within wellbores to measure the magnitude and direction of seismic events.

Seizure: A sudden attack (as of a disease). A sudden change in behavior due to excessive electrical activity in the brain.

Selecting and/or Maintenance: Workplace activities such as constructing, installing, setting up, adjusting, inspecting, modifying, and maintaining and/or servicing machines or equipment. These activities include lubrication, cleaning or unjamming of machines or equipment, and making adjustments or tool changes, where the employee may be exposed to the unexpected energization or startup of the equipment or release of hazardous energy.

Selective Pesticide: A chemical designed to affect only certain types of pests. Leaving other plants and animals unharmed.

Self-Potential: Self-potential in geothermal systems measures currents induced in the subsurface because of the flow of fluids.

Self-Purification: The natural phenomenon occurring in running water systems (streams and rivers) whereby physical, chemical, and biological processes work to self-purify the water.

Self-Supplied Water: Water withdrawn from a surface- or ground-water source by a user rather than being obtained form a public supply. An example would be homers getting their water form their own well.

Semi-Confined Aquifer: An aquifer partially confined by soil layers of low permeability through which recharge and discharge can still occur.

Semivolatile Organic Compounds: Organic compounds that volatize slowly at standard temperature (20 degrees C and 1 atm pressure).

Senescence: The aging process. Sometimes used to describe lakes or other bodies of water in advanced stages of eutrophication. Also used to describe plants and animals.

Sensitive Information: As defined by the federal government, any unclassified information that, if compromised, could adversely affect the national interest or conduct of federal initiatives.

Sensitizers: Chemicals that in very low dose trigger an allergic response.

Separation: A hazardous waste treatment technology (filtration and separation) whereby filtration is used to separate solid particles from a liquid stream through use of semi-porous media. Driven by a pressure difference across the media, and caused by gravity, centrifugal force, vacuum, or elevated pressure.

Sepsis: A toxic condition resulting from the spread of infection.

Septage: Septic tank pumpings; the mixed liquid and solid contents pumped form septic tanks and dry wells used for receiving domestic type sewage.

Septic System: An on-site system designed to teat and dispose of domestic sewage. A typical septic system consists of tank that receives waste form a residence or business and a system of tile lines or a pit for disposal of the liquid effluent (sludge) that remains after decomposition of the solids by bacteria in the tank and must be pumped out periodically.

Septic Tank: A tank used to detain domestic wastes to allow the settling of solids prior to distribution to a leach field for soil absorption. Septic tanks are used when a sewer line is not available to carry them to a treatment plant. A settling tank in which settled sludge is in immediate contact with sewage flowing through the tank, and wherein solids are decomposed by anaerobic bacterial action.

Septic Zone: In the self-purification process that takes place in running water bodies (streams or rivers), the zone characterized by heavy organic pollution and low DO levels.

Sequela: A secondary consequence or result; aftereffect. (Plural = sequelae.)

Sequencing Batch Reactor: An in-vessel, self-contained system with alternate aerobic and anaerobic stages of biological treatment to biodegrade organic matter, convert nitrogen to nitrogen gas, and precipitate phosphorus in the settled sludge.

Serum: The clear yellowish fluid obtained upon separating whole blood into its solid and liquid component after it has been allowed to clot.

Server: The control computer on a local area network that controls software access to workstations, printers and other parts of the network.

Severe: Serious (for a health effect); of high intensity (for an exposure).

Service Connector: The pipe that carries tap water form a public water main to a building.

Service Line Sample: A one-liter sample of water that has been standing for at least 6 hours in a service pipeline and is collected according to federal regulations.

Service Pipe: The pipeline extending from the water main to the building served or to the consumer's system .

Set-Back : 1.Specified distance from surface waters or potential conduits to surface waters where manure, litter, and process wastewater may not be applied. 2. Setting a thermometer to a lower temperature when the building is unoccupied to reduce consumption of heating energy. Also refers to setting the thermometer to a higher temperature during unoccupied periods in the cooling season.

Setting Up: Any work performed to prepare a machine or equipment to perform its normal production operation.

Settleable Solids: Matter in wastewater that either settles to the bottom or floats to the top during a preselected settling period.

Settling Chamber: A series of screens placed in the way of flue gases to slow the stream of air, thus helping gravity to pull particles into a collection device.

Settling Tank: A holding area for wastewater, where heaver particles sink to the bottom for removal and disposal.

Sewage: The waste and wastewater produced by residential and commercial sources and discharged into sewers.

Sewage sludge: Settled sewage solids combined with varying amounts of water and dissolved materials that are removed from sewage by screening, sedimentation, chemical precipitation, or bacterial digestion.

Sewer: A system of underground pipes that collect and deliver wastewater to treatment facilities or streams.

Sewerage: The entire system of sewage collection, treatment, and disposal.

Shading Coefficient: The amount of the sun's heat transmitted through a given window compared with that to a standard 1/8-inch-thick pane of glass under the same conditions.

Shale: A very common sedimentary rock composed of clay-sized particles. Black shales are source rocks for petroleum.

Shall, Should, and May: Shall is used to denote a requirement; should is used to denote a recommendation; and may is used to denote permission, neither a requirement nor a recommendation.

Share: A resource made public on a machine, such as a directory (file share) or printer (printer share).

Sharps: Hypodermic needles, syringes (with or without the attached needle), Pasteur pipettes, scalpel blades, blood vials, needles with attached tubing, and culture dishes used in animal or human patient care or treatment, or in medical, research or industrial laboratories. Also included are other types of broken or unbroken glassware that were in contact with infectious agents, such as used slides and cover slips, and unused hypodermic and suture needles, syringes, and scalpel blades.

Shear strength: How well a member can withstand two equal forces acting in opposite directions.

Sheet Erosion: Soil erosion occurring from a thin, relatively uniform layer of soil particles on the soil surface. Also called interrill erosion.

Sheet Piling: In in-situ isolation/containment technology, the physical driving of rigid sheets, pilings of wood, steel, or concrete into the ground to form a barrier for containment.

Shelter In Place: Protect people without evacuating by keeping them inside a building with windows and doors closed and external ventilation systems shut off until a hazardous situation has resolve.

Shelterbelts: Extended windbreak of living tress and shrubs established and maintained to direct, diffuse, and filter odor plumes.

Shielding for Beta Radiation: Shielding for beta radiation is best accomplished by using materials with a low atomic number (low z materials) to reduce Bremsstrahlung radiation (i.e., secondary x-radiation produced when a beta particle is slowed down or stopped by a high-density surface). The thickness is critical to stop maximum energy range, and varies with the type of material used. Typical shielding material includes lead, water, wood, plastics, cement, Plexiglas, and wax.

Shielding for Gamma and X-Rays: Shielding gamma and x-radiation depends on energy level. Protection follows an exponential function of shield thickness. At low energies, absorption can be achieved with millimeters of lead. At high energies, shielding can attenuate gamma radiation.

Shipping Paper: A shipping order, bill of lading, manifest or other shipping document serving a similar purpose and containing the information required by Sections 172.202, 172.203, and 172.204 (49 CFR 171.8).

Shock: A state of profound depression of the vital processes of the body that is characterized by paleness (pallor), rapid but weak pulse, rapid and shallow respiration, reduced total blood volume, and low blood pressure and that is caused usually be severe especially crushing injuries, hemorrhage, burns, or major surgery.

Shock Hazard: A dangerous condition associated with the possible release of energy caused by contact or approach to live parts.

Shock Load: The arrival at a water treatment plant of raw water containing unusual amounts of algae, colloidal matter, color, suspended solids, turbidity, or other pollutants.

Short-Circuiting: When some of the water in tanks or basins flows faster than the rest, may result in shorter contact, reaction, or settling times than calculated or presumed.

Short Term Exposure Limit (STEL): The time weighted average concentration to which workers can be exposed continuously for a short period of time (typically 15 minutes) without suffering irritation, chronic or irreversible tissue damage, or impairment for self-rescue.

Sick Building Syndrome: Sick Building Syndrome (SBS) describes situations in which more than 20 percent of the building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, because all other probable causes have been ruled out. The 20 percent figure is arbitrarily set, as some workers will always complain about adverse health effects associated with occupancy of a building. However, if the figure is 20 percent or more, some determinable cause may be determined, then remedied. Symptoms include headaches; eye, nose, and throat irritation; dry cough; dry or itchy skin; dizziness and nausea; difficulty in concentration; fatigue; and sensitivity to odors (USEPA, 2001).

SBS is attributed to inadequate ventilation, chemical contaminants from indoor and outdoor sources, and biological contaminants such as molds, bacteria, pollens, and viruses. Passon et al (1996), in their paper *Sick-Building Syndrome and Building Related illnesses* explain how increased air tightness of buildings in the 1970s, used as a means of reducing energy consumption, has created environmental conditions conducive to the "proliferation of microorganisms [including mold] in indoor environments." Once growth has occurred, harmful organisms can be spread by improperly designed and maintained ventilation systems (USEPA, 2001).

Signal: The volume or product-level change produced by a leak in a tank.

Signal Words: The American National Standards Institute (ANSI) levels of chemicals hazards are identified using **signal** words:

DANGER—substances which are extremely flammable, corrosive or highly toxic.
POISON—substances which are highly toxic.
CAUTION/WARNING—substances which are moderately or slightly toxic.
NOTICE—is the preferred signal word to address practices not related to personal injury.

Did You Know?

Accident prevention signs (danger, warning, caution and notice) are specified in OSHA's 29 CFR 1910.145.

Significant Chemical and Biological Toxins and Effects: Note that from the industrial hygiene point of view, toxicology is primarily concerned with exposure to and the harmful effects of chemicals in the occupational setting. In the definitions that follow we also include key biological agents along with certain chemical agents because of the nature of our present circumstances in regards to worldwide terrorism. Typically, under normal circumstances (whatever they may be?), the industrial hygienist does not concern him/herself with smallpox, anthrax, botulinum, etc. The problem is that these are not "normal" times. One of the industrial hygienist's principal tasks is to "anticipate" hazards in the workplace. The possibility of and the potential for deliberate exposure to both chemical and biological toxins in today's workplace (e.g., Anthrax in the post office), though cowardly, uncivilized, and beastly acts of terrorism, is very real. Moreover, exposure to toxins from bloodborne pathogens, foodborne disease, etc. can occur anywhere, including in the workplace. In a sidebar footnote, concerning the foodborne disease issue, note that the landmark Delaney Clause, adopted in 1958 in the U.S. as part of the Food Additives Amendment, required that any food additive be found "safe" before the FDA approves it for use in food. This means that no chemical can be used as a food additive if there is a known potential for it to cause cancer. The industrial hygienist must be aware of eating habits in the workplace because of the possibility of inadvertent mixing of workplace chemicals (contaminants) with the worker's brown-bag lunch.

The bottom line: at present, we think it is prudent for today's industrial hygienist to "anticipate" (and expect) worker exposure to workplace contaminants—no matter the source.

Before defining chemical and biological agents of interest, it is important to note an important point made by Stelljes (2000):

> "There are several hundred thousand chemicals either naturally produced or manufactured that have some use for humans.
> We have adequate human toxicology information for less than 100 of these, and adequate animal toxicology information for less than 1,000,
> Therefore, we do not have adequate information for almost all chemicals."

- *Anthrax*—Anthrax is an acute infectious disease caused by a spore-forming bacterium called Bacillus anthracis. It is generally acquired following contact with anthrax-infected animals or anthrax-contaminated animal products. Can also be acquired following a deliberate terrorist act.
- *Asbestos*—Asbestos is the name given to a group of six different fibrous minerals (amosite, chrysotile, crocidolite, and the fibrous varieties of tremolite, actinolite, and anthophyllite) that occur naturally in the environment. Asbestos minerals have separable long fibers that are strong and flexible enough to be spun and woven and are heat resistant. Because of these characteristics, asbestos has been used for a wide range of manufactured goods, mostly in building materials (roofing shingles, ceiling and floor tiles, paper products, and asbestos cement products), friction products (automobile clutch, brake, and transmission parts), heat-resistant fabrics, packaging, gaskets, and coatings. Some vermiculate or talc products may contain asbestos. Exposure to asbestos fibers can cause mesothelioma or asbestosis.
- *Avian Flu*—Avian influenza is a highly contagious disease of birds which is currently epidemic amongst poultry in Asia. Despite the uncertainties, poultry experts agree that immediate culling of infected and exposed birds is the first line of defense for both the protection of human health and the reduction of further losses in the agricultural sector.
- *Bloodborne Pathogens and Needlestick Prevention*—OSHA estimates that 5.6 million workers in the health care industry (sharps) and related occupations are at risk of occupational exposure to bloodborne pathogens, including human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV), and others.
- *Botulism*—Cases of botulism are usually associated with consumption of preserved foods. However, botulinum toxins are currently among the most common compounds explored by terrorists for use as biological weapons.
- *Carbon monoxide*—Carbon monoxide is a vapor that can pass across the alveoli into the lungs through inhalation. Carbon monoxide causes carboxyhemoglobin formation (CO binds strongly with hemoglobin), replacing oxygen in red blood cells, leading to asphyxiation.
- *Cotton dusts*—Cotton dust is often present in the air during cotton handling and processing. Cotton dust may contain many substances including ground-up plant matter, fiber, bacteria, fungi, soil, pesticides, non-cotton matter, and other contaminants that may have accumulated during growing, harvesting, and subsequent processing or storage periods.

  The OSHA Cotton Dust Standard 1910.1043 specifically lists the operations that are covered; operations not specifically listed are not covered by the standard. Covered operations include: yarn manufacturing, textile waste houses, slashing and weaving operations, waste recycling, and garneting.

  Occupational exposure to cotton dusts can cause byssinosis (tightness in chest, chronic bronchitis).
- *Cyanide*—Cyanide is a rapidly acting, potentially deadly chemical that can exist in various forms. Cyanide can be a colorless gas, such as hydrogen cyanide (HCN) or cyanogens chloride (CNCl), or a crystal form such as sodium cyanide (NaCN) or potassium cyanide (KCN). Cyanide sometimes is described as having a "bitter almond" smell, but it does not always give off an odor, and not everyone can detect this odor. Cyanide is released from natural substances in some foods and in certain plants such as cassava. Cyanide is contained in cigarette smoke and the combustion products of synthetic materials such as plastics. Combustion products are substances given off when things burn. In manufacturing, cyanide is used to make paper, textiles, and plastics. It is present in the chemicals used to develop photographs. Cyanide salts are used in metallurgy for electroplating, metal cleaning, and removing gold from its ore. Cyanide gas is used to exterminate pests and vermin in ships and buildings. If accidentally ingested, chemicals found in acetonitrile-base products that are used to remove artificial nails can produce cyanide.
- *Foodborne Disease*—Foodborne illnesses are caused by viruses, bacteria, parasites, toxins, metals, and prions (microscopic protein particles). Symptoms range from mild gastroenteritis to life-threatening neurologic, hepatic, and renal syndromes.
- *Hantavirus*—Hantaviruses are transmitted to humans from the dried droppings, urine, or saliva of mice and rats. Animal laboratory workers and persons working in infested buildings are at increased risk to this disease.

- *Isocyanates* (MIC)—Methyl isocyanate (MIC) is used to produce carbarnate pesticides. Methyl isocyanate is extremely toxic to humans from acute (short-term) exposure. In Bhopal, India, accidental acute inhalation exposure to methyl isocyanate result in the deaths of several thousand people and adverse health effects in greater than 170,000 survivors. Pulmonary edema was the probably cause of death in most cases, with many deaths resulting from secondary respiratory infections.
- *Legionnaires' Disease*—Legionnaires' disease is a bacterial disease commonly associated with water-based aerosols. It is often the result of poorly maintained air condition cooling towers and portable water systems.
- *Mercuric Nitrate*—"Mad Hatter's" downfall; attacks the central nervous system (CNS).
- *Methyl Alcohol*—Methanol; wood alcohol; Columbian spirits; Carbinol. Causes eye, skin, upper respiratory irritation; headache; drowsiness, dizziness; nausea, vomit; dilation of the pupils, visual disturbance, blindness; excessive seating, dermatitis; Ingestion ACUTE: abdominal; shortness of breath; vomiting; cold clammy extremities; blurring of vision, hyperemia of the optic disc.
- *Methylene Chloride*—Employees exposed to methylene chloride are at increased risk of developing cancer, adverse effects on the heart, central nervous system and liver, and skin or eye irritation. Exposure may occur through inhalation, by absorption through the skin, or through contact with the skin. Methylene chlorine is a solvent which is used in many different types of work activities, such as paint stripping, polyurethane foam manufacturing, cleaning, and degreasing.
- *Molds and Fungi*—Molds and fungi produce and release millions of spores small enough to be air-, water-, or insect-borne which may have negative effects on human health including allergic reactions, asthma, and other respiratory problems.
- *Organochlorine Insecticides*—One of the many chlorinated insecticides, e.g., DDT, dieldrin, chlordane, BHC, Lindane, etc.—neurotoxins.
- *Organophosphate (OP) Insecticides*—Chlorpyrifos, dimethoate, Malathion and trichlorfon are organophosphate (OP) insecticides. These insecticides interfere with nerve-impulse transmission, blocking the action of cholinesterase enzymes essential to proper nerve function. Symptoms of OP poisoning include headache, sweating, nausea and vomiting, diarrhea, loss of coordination and, in extreme cases, death.
- *Paradichlorobenzene*—Paradichlorobenzene is a mild respiratory irritant and hepatotoxic and is used on in tobacco growing as a plant bed treatment for disease control. It is also used as a fumigant for clothes moths in fabric, and for ant control. Used on apricots, cherries, nectarines, peaches, and plums for insect control. Also used as a fumigant and repellent in combination with other materials to control squirrels, moles, gophers, and rats and to repel cats and dogs.
- *PCBs*—PCBs belong to a family of organic compounds known as chlorinated hydrocarbons. Most PCBs were sold for use as dielectric fluids (insulating liquids) in electrical transformers and capacitors. When released into the environment, PCBs do not easily break apart and form new chemical arrangements (i.e., they are not readily biodegradable). Instead they persist for many years, bioaccumulate, and bioconcentrate in organisms. Exposure to PCBs in humans can cause chloracne (a painful, disfiguring skin ailment), liver damage, nausea, dizziness, eye irritation, and bronchitis.
- *Plague*—The World Health Organization reports 1,000 to 3,000 cases of plague every year. A bioterrorist release of plague could result in a rapid spread of the pneumonic form of the disease, which could have devastating consequences.
- *Ricin*—Ricin is one of the most toxic and easily produced plant toxins. It has been used in the past as a bioterrorist weapon and remains a serious threat.
- *Severe Acute Respiratory Syndrome* (SARS)—SARS is an emerging, sometimes fatal, respiratory illness. According to the Centers for Disease Control and Prevention (CDC), the most recent human cases of SRS were reported in China in April 2004 and there is currently no known transmission anywhere in the world.
- *Silica*—Silicosis (fibrosis).
- *Smallpox*—Smallpox is a highly contagious disease unique to humans. It is estimated that no more than 20 percent of the population has any immunity from previous vaccination.
- *Thalidomide*—Thalidomide is probably one of the most well known teratogens. Teratogens are agents that cause offspring to be born with abnormalities (e.g., heart malformation, cleft palate, undeveloped or underdeveloped limbs). Teratogens cause their damage when the fertilized embryo is first forming an organ. At that time the teratogen interferes with the proper development of that organ. By contrast, mutagens cause birth defect by altering sperm or egg cell DNA before the egg is fertilized.
- *Tri-ortho-cresyl Phosphate* (TOCP) (Jamaica Ginger)—According to the American Botanical Council (1995), early in the year 1930, a strange new paralytic illness was affecting relatively large numbers of individuals. Victims of the disease would typically notice numbness in the legs, followed by weakness and eventual paralysis with "foot drop." In most cases, this was followed within about a week by a similar process in the arms, resulting in many cases in wrist drop." The disease was rarely fatal, but

recovery was very slow and in many cases the damage to the nervous system left the patient with permanent disabilities. It did not take long after the first appearance of the illness to link it to the consumption of fluid extract of Jamaica ginger, commonly referred to as ”Jake” by many who used the product. During investigation of the incidents, chemists soon discovered the presence of a cresol compound, a substance that they had never before encountered in adulterated fluid extracts of ginger. Later, it was certain that the compound was tri-ortho-cresyl phosphate (TOCP) and that this substance was present to the extent of about 2 percent in samples allegedly associated with paralysis.

- *Tularemia*—Tularemia is also known as “rabbit fever” or “deer fly fever.” Tularemia is a zoonotic disease and is extremely infectious. Relatively few bacteria are required to cause the disease, which is why it is an attractive weapon for use in bioterrorism.
- *Vinyl Chloride*—Most vinyl chloride is used to make polyvinyl chloride (PVC) plastic and vinyl products. Acute (short-term) exposure to high levels of vinyl chloride in air has resulted in central nervous system effects (CNS), such as dizziness, drowsiness, and headaches in humans. Chronic (long-term) exposure to vinyl chloride through inhalation and oral exposure in humans has resulted in liver damage. Cancer is a major concern from exposure to vinyl chloride via inhalation, as vinyl chloride exposure has been shown to increase the risk of a rare form of liver cancer in humans. USEPA has classified vinyl chloride as a Group A, human carcinogen.
- *Viral Hemorrhagic Fevers* (VHFs)—Viral hemorrhagic fevers (VHFs) refer to a group of illnesses that are caused by several distinct families of viruses. In general, the term “viral hemorrhagic fever” is used to describe a severe multi-system syndrome. Characteristically, the overall vascular system is damaged, and the body’s ability to regulate itself is impaired. These symptoms are often accompanied by hemorrhage (bleeding); however, the bleeding is itself rarely life-threatening. While some types of hemorrhagic fever viruses can cause relatively mild illnesses, many of these viruses cause severe, life-threatening disease.

Significant Deterioration: Pollution resulting from a new source in previously “clean” areas.

Significant Municipal Facilities: Those publicly owned sewage treatment plants that discharge a million gallons per day or more an dare therefore considered by states to have the potential to substantially affect the quality of receiving waters.

Significant Potential Source of Contamination: A facility or activity that stores, uses, or produces compounds with potential for significant contaminating impact if released into the source water of a public water supply.

Significant Violations: Violations by point source dischargers of sufficient magnitude or duration to be a regulatory priority.

Silage Liquor: The liquid drained or leached from fodder prepared by storing and fermenting green forage plants in a silo.

Silica: Crystalline silica (SiO_2) is a major component of the earth’s crust and the cause of silicosis.

Silica Exposure: Crystalline silica (SiO_2) is a major component of the earth’s crust. In pure, natural form, SiO_2 crystals are minute, very hard, translucent, and colorless. “Crystalline” refers to the orientation of SiO_2 molecules in a fixed pattern as opposed to a nonperiodic, random molecular arrangement defined as amorphous (e.g., diatomaceous earth). Most mined minerals contain some SiO_2. Therefore, silica exposure occurs in a wide variety of settings, such as mining, quarrying and stone cutting operations; ceramics and vitreous enameling; and in use of filters for paints and rubber. The wide use and multiple applications of silica in industrial applications combine to make silica a major occupational health hazard (silicosis) that can lead to death (see Tables below).

Risk by Occupation

Occupation	*PMR*
Miscellaneous metal and plastic machine operators	168.44
Hand molders and shapers, except jewelers	64.12
Crushing and grinding machine operators	50.97
Hand molding, casting, and forming occupations	35.70
Molding and casting machine operators	30.60
Mining machine operators	19.61
Mining occupations (not elsewhere classified)	15.33
Construction trades (not elsewhere classified)	14.77
Grinding, abrading, buffing, and polishing machine operators	8.47
Heavy equipment mechanics	7.72
Miscellaneous material moving equipment operators	6.92
Millwrights	6.56
Crane and tower operators	6.02
Brickmasons and stonemasons	4.71
Painters, construction and maintenance	4.50
Furnace, kiln, oven operators, except food	4.10
Laborers, except construction	3.79
Operating engineers	3.56
Welders and cutters	3.01
Machine operators, not specified	2.86
Not specified mechanics and repairers	2.84
Supervisors, production occupations	2.73
Construction laborers	2.14
Machinists	1.79
Janitors and cleaners	1.78

The first column is the occupation title. The second column (PMR) is the observed number of deaths from silicosis per occupation, divided by the expected number of deaths. Therefore, a value of one indicates no additional risk. A value of ten indicates a risk ten times greater than the normal risk of silicosis. The first table provides risk by occupation and the second provides risk by industry.

Risk by Industry

Industry	*PMR*
Metal mining	69.51
Miscellaneous nonmetallic mineral and stone products	55.31
Nonmetallic mining and quarrying, except fuel	49.77
Iron and steel foundries	31.15
Pottery and related products	30.73
Structural clay products	27.82
Coal mining	9.26
Blast furnaces, steelworks, rolling and finishing mills	6.49
Miscellaneous fabricated metal products	5.87
Miscellaneous retail stores	4.63
Machinery, except electrical, (not elsewhere classified)	3.96
Other primary metal industries	3.63
Industrial and miscellaneous chemicals	2.72
Not specified manufacturing industries	2.67
Construction	1.82

Source: Work-Related Lung Disease Surveillance Report (1996). National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, Table 3-8; DHHA (NIOSH) *Publication No. 96-134*. Publications Dissemination, EID, National Institute for Occupational Safety and Health, 4676 Columbia Parkway Cincinnati, OH.

In accordance with the Occupational Safety and Health Administration's (OSHA) standard for air contaminants (29 CFR 1910.1000), employee exposure to airborne crystalline silica shall not exceed an 8-hour time-weighted average limit (variable), as stated in 29 CFR 1910.1000, Table Z-3, or a limit set by a state agency whenever a state-administered Occupational Safety and Health Plan is in effect.

As mandated by OSHA, the first mandatory requirement is that employee exposure be eliminated through the implementation of feasible engineering controls (e.g., dust suppression and ventilation). After all such controls are implemented and they do not control to the permissible exposure, each employer must rotate its employees to the extent possible to reduce exposure. Only when all engineering or administrative controls have been implemented, and the level of respirable silica still exceeds permissible exposure limits, may an employer rely on a respirator program pursuant to the mandatory requirements of 29 CFR1910.134. Generally, where working conditions or other practices constitute recognized hazards likely to cause death or serious physical harm, they must be corrected.

Silicon: A semiconductor material made from silica, purified for photovoltaic applications.

Silt: Sedimentary materials composed of fine or intermediate-size mineral particles.

Single-Breath Canister: Small one-liter canister designed to capture a single breath. Used in air pollutant ingestion research.

Single Crystal Silicon (Czochralski): An extremely pure form of crystalline silicon produced by the Czochralski method of dipping a single crystal seed into a pool of molten silicon under high vacuum conditions and slowly withdrawing a solidifying single crystal boule rod of silicon. The boule is sawed into thin wafers and fabricated into single-crystal photovoltaic cells.

Sinkhole: A depression in the earth's surface caused by dissolving of underlying limestone, salt, or gypsum. Drainage is provided through underground channels that may be enlarged by the collapse of a cavern roof.

Sinking: Controlling oil spills by using an gent to trap the oil an sink it to the bottom of the body of water where the agent and the oil are biodegraded.

Sinks: Areas, whether natural or artificial, where the products or effluents from production and consumption in one place are physically exported to another for storage or dispersal.

SIP Call: EPA action requiring a state t resubmit all of part of its State implementation Plan to demonstrate attainment of the required national ambient air quality stands within the statutory deadline. A SIP Revision is a revision of a SIP altered at the request of EPA or on a state's initiative.

Site: An area or place within the jurisdiction of EPA and/or a state.

Site Assessment Program: A means of evaluating hazardous waste sites through preliminary assessments and site inspections to develop a hazard ranking system score.

Site Inspection: The collection of information from a Superfund site to determine the extent and severity of hazards posed by the site. It follows and is more extensive than a preliminary assessment. The purpose is to gather information necessary to score the site, using the Hazard Ranking System, and to determine if it presents an immediate threat requiring prompt removal.

Site Safety Plan: A crucial element in all removal actions, it includes information on equipment being used, precautions to be taken, and steps to taken in the event of an on-site emergency.

Siting: The process of choosing a location for a facility.

Skimming: Using a machine to remove oil or scum from the surface of the water.

Slings: In the following we present a few example problems involving forces that the safety professional might be called upon to calculate. In our examples, we use lifting slings under different conditions of loading.

NOTE: Slings are commonly used between cranes, derricks, and/or hoists and the load, so that the load may be lifted and moved to a desired location. For the safety engineer, knowledge of the properties and limitations of the slings, the type and condition of material being lifted, the weight and shape of the object being lifted, the angle of the lifting sling to the load being lifted, and the environment in which the lift is to be made are all important considerations to be evaluated—before the transfer of material can take place safely.

Example
Problem: Let us assume a load of 2000 pounds supported by a two-leg sling; the legs of the sling make an angle of 60° with the load. What force is exerted on each leg of the sling?

NOTE: In solving this type of problem, you should always draw a rough diagram as shown below.

Solution: A resolution of forces provides the answer. We use the trigonometric method to solve this problem, but remember that it may also be solved using the graphic method. Using the trigonometric method with the parallelogram law, the problem could be solved as follows:

We could consider the load (2000 pounds) as being concentrated and acting vertically, which can be indicated by a vertical line. The legs of the slings are at a 60° angle, which can be shown as **ab** and **ac**. The parallelogram can now be constructed by drawing lines parallel to **ab** and **ac**, intersecting at **d**. The point where **cb** and ad intersect can be indicated as **e**. The force on each leg of the sling (**ab** for example) is the resultant of two forces, one acting vertically **(ae**), the other horizontally (**be**), as shown in the force diagram. Force **ae** is equal to one half of **ad** (the total force acting vertically, 2000 pounds, so **ae** = 1000. This value remains constant regardless of the angle **ab** makes with **bd,** because as the angle increases or decreases, **ae** also increases or decreases. But **ae** is always **ad/2**. The force **ab** can be calculated by trigonometry using the right triangle a**be:**

$$\text{Sine of an angle} = \frac{\text{opposite side}}{\text{hypotenuse}}$$

$$\text{therefore, sine 60 degrees} = \frac{\text{ae}}{\text{ab}}$$

$$\text{transposing, ab} = \frac{\text{ae}}{\text{sine 60 degrees}}$$

$$\text{substituting known value, ab} = \frac{1000}{.866} = 1155$$

The total weight on each leg of the sling at a 60° angle from the load is 1155 pounds. Note that the weight is more than half the load, because the load is made up of two forces—one acting vertically, the other horizontally. An important point to remember is—the smaller the angle, the greater the load (force) on the sling. For example, at a 15° angle, the force on each leg of a 2000-pound load increases to 3864 pounds.

Example
Problem: We have a 3000-lb. load to be lifted with a 2-leg sling whose legs are at a 30° angle with the load. The load (force) on each leg of the sling is:
Solution:

$$\text{Sine A} = \frac{a}{c}$$

$$\text{Sine } 30 = 0.500$$

$$a = \frac{3000 \text{ lb}}{2} = 1500$$

$$c = \frac{a}{\text{Sine A}}$$

$$c = \frac{1500}{0.5}$$

$$c = 3000$$

Example
Problem: Given a 2 rope sling supporting 10,000 pounds, what is the load (force) on the left sling? Sling angle to load is 60°.
Solution:

$$\text{Sine A} = \frac{a}{c}$$

$$\text{Sine A} = \frac{60}{0.866}$$

$$a = \frac{10{,}000}{2}$$

$$c = \frac{a}{\text{Sine A}}$$

$$c = \frac{5{,}000}{0.866}$$

$$c = 5{,}774 \text{ lb}$$

Slope: Inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.

Slot Velocity: The average velocity of air through a slot. Slot velocity is calculated by dividing the total volume flow rate by the slot area (usually, $V_s = 2{,}000$ fpm).

Sloughing: Separating or casting off dead tissue from living tissue, as in a wound.

Slow Sand Filtration: Passage of raw water through a bed of sand at low velocity, resulting in substantial removal of chemical and biological contaminants.

Sludge: A dense, slushy, liquid-to-semi-fluid product that accumulates as an end result of an industrial or technological process designed to purify a substance. Industrial sludges are produced from the processing of energy-related raw materials, chemical products, water, mined ores, sewerage, and other natural and man-made products. Sludges can also form from natural processes, such as the run off produced by rain fall, and accumulated on the bottom of bogs, streams, lakes, and tidelands.

Sludge Digester: Tank in which complex organic substances like sewage sludges are biologically dredged. During these reactions, energy is released and much of the sewage is converted to methane, carbon dioxide, and water.

Slurry: A watery mixture of insoluble matter resulting from some pollution control techniques.

Slurry Walls: In situ isolation/containment, fixed underground physical barriers formed in an excavated trench by pumping slurry, usually a bentonite or cement and water mixture.

Small Quantity Generator (SQG): Persons or enterprises that produce 220–2200 pounds per month of hazardous waste; they are required to keep more records than conditionally exempt generators. The largest category of hazardous waste generators, SQGs, include automotive shops, dry cleaners, photographic developers, and many other small business.

Smog: Term used to describe visible air pollution; a dense, discolored haze containing large quantities of soot, ash, and gaseous pollutants such as sulfur dioxide and carbon dioxide.

Smoke: Particles that result from incomplete combustion.

Smurf: An attack that works by spoofing the target address and sending a ping to the broadcast address for a remote network, which results in a large amount of ping replies being sent to the target.

Sniffer: A tool that monitors network traffic as it received in a network interface.

Sniffing: A synonym for "passive wiretapping."

***Snow, Dr. John*[1] :**

He wandered the foggy, filthy, corpse-ridden streets of 1854 London searching, making notes, always looking . . . seeking a murdering villain—and find the miscreant, he did. He took action; he removed the handle from a water pump. And, fortunately for untold thousands of lives, his was the correct action—the lifesaving action.

He was a detective—of sorts. No, not the real Sherlock Holmes—but absolutely as clever, as skillful, as knowledgeable, as intuitive—and definitely as driven. His real name: Dr. John Snow. His middle name? Common Sense. Snow's master criminal, his target—a mindless, conscienceless, brutal killer: cholera.

Let's take a closer look at this medical super sleuth and at his quarry, the deadly killer cholera—and at Doctor Snow's actions to contain the spread of cholera. More to the point, let's look at Dr. Snow's subsequent impact on water treatment (disinfection) of raw water used for potable and other purposes.

An unassuming—and creative—London obstetrician, Dr. John Snow (1813–1858) achieved prominence in the mid-nineteenth century for proving his theory (in his *On the Mode of Communication of Cholera*) that cholera is a contagious disease caused by a "poison" that reproduces in the human body and is found in the vomitus and stools of cholera patients. He theorized that the main (though not the only) means of transmission was water contaminated with this poison. His theory was not held in high regard at first, because a commonly held and popular counter-theory stated that diseases are transmitted by

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[1] This section is adapted for F.R. Spellman, *Choosing Disinfection Alternatives for Water/Wastewater Treatment*, Boca Raton, FL: CRC Press.

inhalation of vapors. Many theories of cholera's cause were expounded. In the beginning, Snow's argument did not cause a great stir; it was only one of many hopeful theories proposed during a time when cholera was causing great distress. Eventually, Snow was able to prove his theory. We describe how Snow accomplished this later, but for now, let's take a look at Snow's target: Cholera.

Cholera

According to the U.S. Centers for Disease Control (CDC), cholera is an acute, diarrheal illness caused by infection of the intestine with the bacterium Vibrio cholera. The infection is often mild or without symptoms, but sometimes can be severe. Approximately 1 in 20 infected persons have severe disease symptoms characterized by profuse watery diarrhea, vomiting, and leg cramps. In these persons, rapid loss of body fluids leads to dehydration and shock. Without treatment, death can occur within hours.

Did You Know?

You don't need to be a rocket scientist to figure out just how deadly cholera was during the London cholera outbreak of 1854. Comparing the state of "medicine" at that time to ours is like comparing the speed potential of a horse and buggy to a state-of-the-art NASCAR race car today. Simply stated: cholera was the classic epidemic disease of the nineteenth century, as the plague had been for the fourteenth. Its defeat was a reflection of both common sense and of progress in medical knowledge—and of the enduring changes in European and American social thought.

How does a person contract cholera? Good question. Again, we refer to the CDC for our answer. A person may contract cholera (even today) by drinking water or eating food contaminated with the cholera bacterium. In an epidemic, the source of the contamination is usually feces of an infected person. The disease can spread rapidly in areas with inadequate treatment of sewage and drinking water. Disaster areas often pose special risks. The aftermath of Hurricane Katrina in New Orleans caused, for example, concern for a potential cholera problem.

Cholera bacterium also lives in brackish river and coastal waters. Shellfish eaten raw have been a source of cholera, and a few people in the United States have contracted cholera after eating raw shellfish from the Gulf of Mexico. The disease is not likely to spread directly from one person to another; therefore, casual contact with an infected person is not a risk for transmission of the disease.

Flashback to 1854 London

The information provided in the preceding section was updated and provided by CDC in 1996. Basically, for our purposes, CDC confirms the fact that cholera is a waterborne disease. Today, we know quite a lot about cholera and its transmission, how to prevent infection and how to treat it. But what did they know about cholera in the 1850s? Not much—however, one thing is certain: They knew cholera was a deadly killer. That was just about all they knew—until Dr. John Snow proved his theory. Recall that Snow theorized that cholera is a contagious disease caused by a poison that reproduces in the human body and is found in the vomitus and stools of cholera victims. He also believed that the main means of transmission was water contaminated with this poison.

Dr. Snow's theory was correct, of course, as we know today. The question is, how did he prove his theory correct? The answer to which provides us with an account of one of the all time legendary quests for answers in epidemiological research—and an interesting story.

Dr. Snow proved his theory in 1854, during yet another severe cholera epidemic in London. Though ignorant of the concept of bacteria carried in water, Snow traced an outbreak of cholera to a water pump located at an intersection of Cambridge and Broad Street (London).

How did he isolate this source to this particular pump? He accomplished this by mapping the location of deaths from cholera. His map indicated that the majority of the deaths occurred within 250 yards of that water pump. The water pump was used regularly by most of the area residents. Those who did not use the pump remained healthy. Suspecting the Broad Street pump as the plague's source, Snow had the water pump handle removed and ended the cholera epidemic.

Sounds like a rather simple solution, doesn't it? For us, it is simple, but remember, in that era, aspirin had not yet been formulated—to say nothing of other medical miracles we take for granted—antibiotics, for example. Dr. John Snow, by the methodical process of elimination and linkage (Sherlock Holmes would have been impressed—and he was), proved his point, his theory. Specifically, through painstaking documentation of cholera cases and correlation of the comparative incidence of cholera among subscribers to the city's two water companies, Snow showed that cholera occurred much more frequently in customers of the water company that drew its water from the lower Thames, where the river had become contaminated with London sewage. The other company obtained water from the upper Thames. Snow tracked and pinpointed the Broad Street pump's water source. You guessed it: the contaminated lower Thames, of course.

Dr. Snow the obstetrician became the first effective practitioner of scientific epidemiology. His creative use of logic, common sense and scientific information enabled him to solve a major medical mystery—to discern the means by which cholera was transmitted.

Pump Handle Removal—To Water Treatment (Disinfection)

Dr. John Snow's major contribution to the medical profession, to society, and to humanity in general can be summarized rather succinctly: He determined and proved that the deadly disease cholera is a waterborne disease (Dr. John Snow's second medical accomplishment was that he was the first person to administer anesthesia during childbirth).

What does all of this have to do with water treatment (disinfection)? Actually, Dr. Snow's discovery—his stripping of a mystery to its barest bones—has quite a lot to do with water treatment. Combating any disease is rather difficult without a determination on how the disease is transmitted—how it travels from vector or carrier to receiver. Dr. Snow established this connection, and from his work, and the work of others, progress was made in understanding and combating many different waterborne diseases.

Today, sanitation problems in developed countries (those with the luxury of adequate financial and technical resources) deal more with the consequences that arise from inadequate commercial food preparation, and the results of bacteria becoming resistant to disinfection techniques and antibiotics. We simply flush our toilets to rid ourselves of unwanted wastes, and turn on our taps to take in high quality drinking water supplies, from which we've all but eliminated cholera and epidemic diarrheal diseases. This is generally the case in most developed countries today—but it certainly wasn't true in Dr. Snow's time.

The progress in water treatment from that notable day in 1854 [when Snow made the "connection" (actually the "disconnection" of handle from pump) between deadly cholera and its means of transmission] to the present reads like a chronology of discovery leading to our modern water treatment practices. This makes sense, of course, because with the passage of time, pivotal events and discoveries occur—events that have a profound affect on how we live today. Let's take a look at a few elements of the important chronological progression that evolved from the simple removal of a pump handle to the advanced water treatment (disinfection) methods we employ today to treat our water supplies.

After Snow's discovery (that cholera is a waterborne disease emanating primarily from human waste), events began to drive the water/wastewater treatment process. In 1859, four years after Snow's discovery, the British Parliament was suspended during the summer because the stench coming from the Thames was unbearable. According to one account, the river began to "seethe and ferment under a burning sun." As was the case in many cities at this time, storm sewers carried a combination of storm water, sewage, street debris, and other wastes to the nearest body of water. In the 1890s, Hamburg, Germany, suffered a cholera epidemic. Detailed studies by Koch tied the outbreak to the contaminated water supply. In response to the epidemic, Hamburg was among the first cities to use chlorine as part of a wastewater treatment regimen. About the same time, the town of Brewster, New York became the first U.S. city to disinfect its treated wastewater. Chlorination of drinking water was used on a temporary basis in 1896, and its first known continuous use for water supply disinfection occurred in Lincoln, England and Chicago in 1905. Jersey City, New Jersey, became one of the first routine users of chlorine in 1908.

Time marched on, and with it came an increased realization of the need to treat and disinfect both water supplies and wastewater. Between 1910 and 1915, technological improvements in gaseous and then solution feed of chlorine made the process more practical and efficient. Disinfection of water supplies and chlorination of treated wastewater for odor control increased over the next several decades. In the United States, disinfection, in one form or another, is now being used by more than 15,000 out of approximately 16,000 Publicly Owned Treatment Works (POTWs). The significance of this number becomes apparent when you consider that fewer than 25 of the 600+ POTWs in the United States in 1910 were using disinfectants.

Social Engineering: A euphemism for non-technical or low-technology means, including lies, impersonation, tricks, bribes, blackmail, and threats, used to attack information systems. Typically carried out by telephoning users or operators pretending to be an authorized user, to attempt to gain illicit access to systems.

Sodicity: Degree to which a soil is affected by exchangeable sodium. Sodicity is expressed as a sodium adsorption ratio (SAR) of a saturation extract.

Sodium Hypochlorite: The active ingredient in household liquid chlorine bleach. It is ordinarily about 5 percent strength in a water-based solution of bleach.

Soft Detergents: Cleaning agents that break down in nature.

Soft Water: Any water that does not contain a significant amount of dissolved minerals such as salts or calcium or magnesium.

Soil: A dynamic natural body in which plants grow, composed of mineral and organic materials and living forms.

Soil Adsorption Field: A sub-surface area containing a trench or bed with clean stones an a system of piping through which treated sewage may seep into the surrounding soil for further treatment and disposal.

Soil Amendment: Any material, such as lime, gypsum, sawdust, or synthetic conditioner that is worked into the soil to make it more amendable to plant growth. Amendments may contain important fertilizer elements, but the term commonly refers to added materials other than fertilizer.

Soil and Water Conservation Practices (SWCPs): Manipulation of such variables as crops, rotation, tillage, management, and structures to reduce the loss of soil and water.

Soil Boring: Using a boring tool (such as an auger) to take soil samples for analysis.

Soil Column: An in situ volume of soil down through which liquid wastes percolate from ponds, cribs, seepage basins, or trenches.

Soil Conditioner: An organic material like humus or compost that helps soil absorb water, build a bacterial community, and take up mineral nutrients.

Soil Erodibility: An indicator of a soil's susceptibility to raindrop impact, runoff, and other erosive processes.

Soil Factor: In in-situ soil remediation, soil factors include water content, porosity/permeability, clay content, and adsorption site density.

Soil Fertility: The quality of a soil that enables it to provide essential chemical elements in quantities and proportions for the growth of specified plants.

Soil Forming Process: The mode of origin of the soil, with special reference to the processes or soil-forming factors responsible for the development of the solum, or true soil, from the unconsolidated parent material.

Soil Gas: Gaseous elements and compounds in the small spaces between particles of the earth and soil. Such gases can be moved or driven out under pressure.

Soil Guideline Values (SGVs): A series of measurements and values used to measure contamination of the soil.

Soil Horizon: A layer of soil, approximately parallel to the soil surface, differing in properties and characteristics from adjacent layers below or above it.

Soil Map: A map showing the distribution of soil types or other soil mapping units in relation to the prominent physical and cultural features of the earth's surface.

Soil Mechanics: When dealing with nature's nature building material, soil, the engineer should keep the following statement in mind:

"Observe always that everything is the result of change, and get used to thinking that there is nothing Nature loves so well as to change existing forms and to make new ones like them."

Meditations, Marcus Aurelius

By the time a student reaches the third or fourth year of elementary school, he or she is familiar with the Leaning Tower of Pisa. Many are also familiar with Galileo's experiments with gravity and the speed of falling objects dropped from the top of the tower. This twelfth century bell tower has been a curiosity for literally millions of people from the time it was first built to the present. Eight stories high and 180 feet tall, with a base diameter of 52 feet, the tower began to lean by the time the third story was completed, and leans about 1/25 inches more each year.

How many people know why the tower is leaning in the first place—and who would be more than ordinarily curious about why the Leaning Tower leans? If you are a soil scientist or an engineer, this question has real significance—the question requires an answer. And, in fact, the Leaning Tower of Pisa should never have acquired the distinction of being a "leaning" tower in the first place.

So, why does the Leaning Tower of Pisa lean? — Because it rests on a non-uniform consolidation of clay beneath the structure. This ongoing process may eventually lead to failure of the tower.

As you might have guessed, the mechanics of why the Leaning Tower of Pisa leans is what this section is all about. More specifically, it is about the mechanics and physics of the soil—important factors in making the determination as to whether a particular building site is viable for building. Simply put, these two factors are essential in answering the question "Will the soils present support buildings?"

When we refer to the characteristics of soils, we are referring to its mechanical characteristics, physical factors important to safety engineers. Safety engineers focus on the characteristics of the soil related to its suitability as a construction material, and as a substance to be excavated (can the soil in question be safely excavated without caving in on workers?). Simply put, the safety engineer must understand the response of a particular volume of soil to internal and external mechanical forces. Obviously, to be able to determine the soil's ability to withstand the load applied by structures of various types, and its ability to remain stable when excavated is important.

From a purely engineering point of view, soil is any surficial material of the earth that is unconsolidated enough to be excavated with tools (from bulldozers to shovels). The engineer takes into consideration both the advantages and disadvantages of using soil for engineering purposes. The obvious key advantage of using soil for engineering is that there is (in many places) no shortage of it—it may already be on the construction site, thus avoiding the expense of hauling it from afar. Another advantage of using soil for construction is its ease of manipulation; it may be easily shaped into almost any desired form. Soil also allows for the passage of moisture, or, as needed, it can be made impermeable.

We said that the engineer looks at both the advantages and disadvantages of using soil for construction projects. The most obvious disadvantage of using soil is its variability from place to place and from time to time. Soil is not a uniform material for which reliable data related to strength can be compiled or computed. Cycles of wetting and drying, and freezing and thawing affect the engineering properties of soil. A particular soil may be suitable for one purpose, but not for another. Stamford clay in Texas, for example, is rated as "very good" for sealing of farm ponds—and "very poor" for use as base for roads and buildings (Buol et al, 1980).

How does the engineer know if a particular soil is suitable for use as a base for roads or buildings?

The engineer determines the suitability of a particular soil (for whatever purpose) by studying soil survey maps and reports. The engineer also checks with soil scientists and other engineers familiar with the region and the soil types of that region. Any good engineer will also want to conduct field sampling—to ensure that the soil product he or she will be working with possesses the soil characteristics required for its intended purpose.

What are the soil characteristics (the kinds of information) that the engineer is interested in? Important characteristics of soils for engineering purposes include:

- Soil texture
- Kinds of clay present
- Depth to bedrock
- Soil density
- Erodibility
- Corrosivity
- Surface geology
- Plasticity
- Content of organic matter
- Salinity
- Depth to seasonal water table

The engineer will also want to know the soil's density, space and volume or weight-volume relationships, stress-strain, slope stability, and compaction. Because these concepts are of paramount importance to the engineer (and others), these concepts are presented in the following sections.

All natural soil consists of at least three primary components or phases, solid (mineral) particles, water and/or air (within void spaces between the solid particles). The physical relationships (for soils in particular) between these phases must be examined. The volume of the soil mass is the sum of the volumes of the three components, or

$$V_T = V_a + V_w + V_s$$

The volume of the voids is the sum of V_a and V_W. However, regarding weight (because the weighing of air in the soil voids would be done within the earth's atmosphere as with other weighings), the weight of the solids is determined on a different basis. We consider the weight of air in the soil to be zero and the total weight is expressed as the sum of the weights of the soil solids and the water:

$$Wt = W_s + W_w$$

The relationship between weight and volume can be expressed as

$$Wm = V_m G_{m-w}$$

where

W_m = weight of the material (solid, liquid, or gas)
V_m = volume of the material
G_m = specific gravity of the material (dimensionless)
-w = unit weight of water

With the relationships described above, a few useful problems can be solved. When an engineer determines that within a given soil, the proportions of the three major components need to be mechanically adjusted, this can be accomplished by reorienting the mineral grains by compaction or tilling. The engineer, probably for a specific purpose, may want to blend soil types to alter the proportions, such as increasing or decreasing the percentage of void space. How do we go about doing this?

Relationships between volumes of soil and voids are described by the void ratio (e) and porosity (η). To accomplish this, we must first determine the void ratio (the ratio of the void volume to the volume of solids):

$$e = \frac{Vv}{Vs}$$

We must also determine the ratio of the volume of void spaces to the total volume. This can be accomplished by determining the Porosity (η) of the soil, which is the ratio of void volume to total volume. Porosity is usually expressed as a percentage.

$$\eta = Vv/Vt \times 100\%$$

Two additional relationships can be developed. These terms, known as the moisture content, (w) and degree of saturation, (S), relate the water content of the soil and the volume of the water in the void space to the total void volume:

$$w = \frac{Ww}{Ws} \times 100\%$$

and

$$S = \frac{Vw}{Vv} \times 100\% \quad \mathbf{VV}$$

The size and shape of particles in the soil, as well as density and other characteristics, relate to sheer strength, compressibility and other aspects of soil behavior. Engineers use these index properties to form engineering classifications of soil. Simple classification tests are used to measure index properties (see the Table) in the lab or the field.

Index Property of Soils

SOIL TYPE	*INDEX PROPERTY*
Cohesive (fine-grained)	Water content Sensitivity Type and amount of clay Consistency Atterberg limits
Incohesive (coarse-grained)	Relative density In-place density Particle-size distribution Clay content Shape of particles

Source: Adaptation from A. E. Kehew, *Geology for Engineers and Environmental Scientists*, 2nd ed., p. 284, 1995.

From the Table we see that an important division of soils (from the engineering point of view) is the separation of the cohesive (fine-grained) from the incohesive (coarse-grained) soils. Let's take a closer look at these two important terms.

Cohesion indicates the tendency of soil particles to stick together. Cohesive soils contain silt and clay. The clay and water content makes these soils cohesive, through the attractive forces between individual clay and water particles. The influence of the clay particles makes the index properties of cohesive soils somewhat more complicated than the index properties of cohesionless soils. The resistance of a soil at various moisture contents to mechanical stresses or manipulations is called the soil's consistency—the arrangement of clay particles, and is the most important characteristic of cohesive soils.

Another important index property of cohesive soils is its *sensitivity*. Simply defined, sensitivity is the ratio of unconfined compressive strength in the undisturbed state to strength in the remolded state. Soils with high sensitivity are highly unstable.

$$St = \frac{\text{Strength in undisturbed condition}}{\text{Strength in remolded condition}}$$

Soil water content (described earlier) is an important factor that influences the behavior of the soil. The water content values of soil are known as the Atterburg limits, a collective designation of so-called limits of consistency of fine-grained soils, which are determined with simple laboratory tests. They are usually presented as the liquid limit (LL) and plastic limit (PL).

Note: Plasticity is exhibited over a range of moisture contents referred to as plasticity limits—and the plasticity index (PI). The plastic limit is the lower water level at which soil begins to be malleable in a semi-solid state, but molded pieces crumble easily when a little pressure is applied. At the point when the volume of the soil becomes nearly constant, with further decreases in water content, the soil reaches the shrinkage state.

The upper plasticity limit (or liquid limit) is the water content at which the soil-water mixture changes from a liquid to a semi-fluid (or plastic) state and tends to flow when jolted. Obviously, an engineer charged with building a highway or building would not want to choose a soil for the foundation that tends to flow when wet.

The difference between the liquid limit and the plastic limit is the range of water content over which the soil is plastic, and is called the plasticity index. Soils with the highest plasticity indices are unstable in bearing loads.

Several systems for classifying the stability of soil materials have been devised, but the best known (and probably the most useful) system is called the Unified System of Classification. This classification gives each soil type (14 classes) a two-letter designation, which are primarily defined on the basis of particle-size distribution, liquid limit, and plasticity index.

Cohesionless coarse-grained soils behave much differently than cohesive soils and are based on (from index properties) the size and distribution of particles in the soil. Other index properties (particle shape, in-place density, and relative density, for example) are important in describing cohesionless soils, because they relate to how closely particles can be packed together.

If you are familiar with water pressure and its effect as you go deeper into the water (as when diving deep into a lake), that the same concept applies to soil and pressure should not surprise you. Like water, the pressure within the soil increases as the depth increases. A soil, for example, that has a unit weight of 75 pounds per cubic feet exerts a pressure of 75 psi at one-foot depth and 225 psi at three feet, etc. As you might expect, as the pressure on a soil unit increases, the soil particles reorient themselves structurally to support the cumulative load. This consideration is important, because the elasticity of the soil sample retrieved from beneath the load may not be truly representative, once it is delivered to the surface. In sampling, the importance of taking representative samples can not be overstated.

The response of a soil to pressure (stress) is similar to what occurs when a load is applied to a solid object; the stress is transmitted throughout the material. The load subjects the material to pressure, which equals the amount of load, divided by the surface area of the external face of the object over which it is applied. The response to this pressure or stress is called displacement or strain. Stress (like pressure), at any point within the object, can be defined as force per unit area.

When a vertical load such as a building or material stockpile is placed above a soil layer, some settlement can be expected. Settlement is the vertical subsidence of the building (or load) as the soil is compressed.

Compressibility refers to the tendency of soil to decrease in volume under load. This compressibility is most significant in clay soils because of the inherent high porosity. Although the mechanics of compressibility and settlement are quite complex and beyond the scope of this text, you should know something about the actual evaluation process for these properties, which is accomplished in the consolidation test. This test subjects a soil sample to an increasing load. The change in thickness is measured after the application of each load increment.

The goal of compaction is to reduce void ratio and thus increase the soil density, which, in turn, increases the shear strength. This is accomplished by working the soil to reorient the soil grains into a more compact state. If water content is within a limited range (sufficient enough to lubricate particle movement), efficient compaction can be obtained.

The most effective compaction occurs when the soil placement layer (commonly called lift) is approximately 8 inches. At this depth, the most energy is transmitted throughout the lift. Note that more energy must be dispersed, and the effort required to accomplish maximum density is greatly increased when the lift is greater than 10 inches in thickness.

For cohesive soils, compaction is best accomplished by blending or kneading the soil using sheepsfoot rollers and pneumatic tire rollers. These devices work to turn the soil into a denser state.

To check the effectiveness of the compactive effort, the in-place dry density of the soil (weight of solids per unit volume) is tested, by comparing the dry density of field-compacted soil to a standard prepared in an environmental laboratory. Such a test allows a percent compaction comparison to be made.

The construction and safety engineer must be concerned with soil structural implications involved with natural processes (such as frost heave, which could damage a septic system) and changes applied to soils during remediation efforts (e.g. when excavating to mitigate a hazardous materials spill in soil). Soil failure occurs whenever it cannot support a load. Failure of an overloaded foundation, collapse of the sides of an excavation, or slope failure on the sides of a dike, hill, or similar feature is termed structural failure.

The type of soil structural failure that probably occurs more frequently than any other is slope failure (commonly known in practice as cave-in). In a review of the Bureau of Labor Statistics annual report of on-the-job mishaps, including from 80–100 fatalities every year—we see that cave-ins occurring in excavations accomplished in construction are more frequent occurrences than you might think, considering the obvious dangers inherent in excavation.

What is an excavation? How deep does an excavation have to be to be considered dangerous?

Two good questions—and the answers could save your life, or help you protect others when you become a safety engineer.

An excavation is any man-made cut, cavity, trench, or depression in the earth's surface formed by earth removal. This can include excavations for anything from a remediation dig to sewer line installation.

No excavation activity should be accomplished without keeping personnel safety in mind. Any time soil is excavated, care and caution is advised. As a rule of thumb (and as law under 29 CFR 1926.650-. 652), the Occupational Safety and Health Administration (OSHA) requires trench protection in any excavation five feet or more in depth.

Before digging begins, proper precautions must be taken. The responsible party in charge (the competent person, according to OSHA) must:

- Contact utility companies to ensure underground installations are identified and located.
- Ensure underground installations are protected, supported, or removed as necessary to safeguard workers.
- Remove or secure any surface obstacles (trees, rocks, and sidewalks, for example) that may create a hazard for workers.
- Classify the type of soil and rock deposits at the site as either stable rock, type A, type B, or type C soil. One visual and at least one manual analysis must make the soil classification.

Let's take a closer look at the requirement to classify the type of soil to be excavated. Before an excavation can be accomplished, the soil type must be determined. The soil must be classified as: stable rock, type A, type B, or type C soil. Remember, commonly you will find a combination of soil types at an excavation site. Soil classification (used in this manner) is used to determine the need for a protective system.

Exactly what do the soil classifications of stable rock, type A, type B, and type C soil mean?

- **Stable rock**: a natural solid mineral material that can be excavated with vertical sides. Stable rock will remain intact while exposed, but keep in mind that even though solid rock is generally stable, it may become very unstable when excavated (in practice you never work in this kind of rock).
- **Type A soil**: the most stable soil, and includes clay, silty clay, sandy clay, clay loam, and sometimes silty clay loam and sandy clay loam.
- **Type B soil**: moderately stable, and includes silt, silt loam, sandy loam and sometimes silty clay loam and sand clay loam.
- **Type C soil**: the least stable, and includes granular soils like gravel, sand, loamy sand, submerged soil, soil from which water is freely seeping, and submerged rock that is not stable.

How is soil tested?
To test and classify soil for excavation, the environmental specialist conducts both visual and manual tests.

In visual soil testing, you should look at soil particle size and type. You'll see a mixture of soils, of course. You should check to see if the soil clumps when dug—if so it could be clay or silt. Type B or C soil can sometimes be identified by the presence of cracks in walls and spalling (breaks up in chips or fragments). If you notice layered systems with adjacent hazardous areas—buildings, roads and vibrating machinery—you may require a professional engineer for classification. Standing water or water seeping through trench walls automatically classifies the soil as type C.

Manual soil testing is required before a protective system (e.g., shoring or shoring box) is selected. A sample taken from soil dug out into a spoil pile should be tested as soon as possible, to preserve its natural moisture. Soil can be tested either on-site or off-site. Manual soil tests include a sedimentation test, wet shaking test, thread test, and ribbon test.

A sedimentation test determines how much silt and clay are in sandy soil. Saturated sandy soil is placed in a straight-side jar with about five inches of water. After the sample is thoroughly mixed (by shaking it) and allowed to settle, the percentage of sand is visible. A sample containing 80 percent sand, for example, will be classified as Type C.

The wet shaking test is another way to determine the amount of sand versus clay and silt in a soil sample. This test is accomplished by shaking a saturated sample by hand to gauge soil permeability based on the following facts: (1) shaken clay resists water movement through it; and (2) water flows freely through sand and less freely through silt.

The thread test is used to determine cohesion (remember, cohesion relates to stability—how well the grains hold together). After a representative soil sample is taken, it is rolled between the palms of the hands to about 1/8" diameter and several inches in length (any child who has played in dirt has accomplished this at one time or another—nobody said soil science had to be boring). The rolled piece is placed on a flat surface, then picked up. If a sample holds together for two inches, it is considered cohesive.

The ribbon test is used as a backup for the Thread Test. It also determines cohesion. A representative soil sample is rolled out (using the palms of your hands) to 3/4" in diameter, and several inches in length. The sample is then squeezed between thumb and forefinger into a flat unbroken ribbon 1/8" to 1/4" thick, which is allowed to fall freely over the fingers. If the ribbon does not break off before several inches are squeezed out, the soil is considered cohesive.

Once soil has been properly classified, the correct protective system can be chosen (if necessary). This choice is based on both soil classification and site restrictions. There are two main types of protective systems: (1) sloping or benching and (2) shoring or shielding.

Sloping or benching are excavation protective measures that cut the walls of an excavation back at an angle to its floor.

The angle used for sloping or benching is a ratio based on soil classification and site restrictions. In both systems, the flatter the angle, the greater the protection for workers. Reasonably safe side slopes for each of these soil types are presented in the Table.

Maximum Safe Side Slopes in Excavations

Maximum Safe Side Slopes in Excavations

Soil Type	*Side Slope (Vertical to Horizontal)*	*Side Slope (Degrees from Horizontal)*
A	75:1	53°
B	1:1	45°
C	1.5:1	34°

Source: OSHA Excavation Standard 29 CFR 1926.650-652.

Shoring and shielding are two protective measures that add support structure to an existing excavation (generally used in excavations with vertical sides, but can be used with sloped or benched soil).

Shoring is a system designed to prevent cave-ins by supporting walls with vertical shores called uprights or sheeting. Wales are horizontal members along the sides of a shoring structure. Cross braces are supports placed horizontally between trench walls.

Shielding is a system that employs a trench box or trench shield. They can be pre-manufactured or job-build under the specification of a licensed engineer. Shields are usually portable steel structures placed in the trench by heavy equipment. For deep excavations, trench boxes can be stacked and attached to each other with stacking lugs.

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Soil Moisture: The water contained in the pore space of the unsaturated zone.

Soil Morphology: The physical constitution, particularly the structural properties, of a soil profile as exhibited by the kinds, thickness, and arrangement of the horizons in the profile and by the texture, structure, consistence, and porosity of each horizon.

Soil Organic Matter: Organic fraction of the soil that includes plant an animal residue at various stages of decomposition, exclusive of undecayed plant and animal residue. Often used synonymously with humus.

Soil Physics: Soil is a dynamic, heterogeneous body that is non-isotropic (does not have the same properties in all directions). As you might expect, because of these properties, various physical processes are active in soil at all times. This important point is made clear by Windgardner (1996) in the following: *"all of the factors acting on a particular soil, in an established environment, at a specified time, are working from some state of imbalance to achieve a balance"* (63).

Most soil specialists (and many other people) have little difficulty in understanding why soils are very important to the existence of life on earth. They know, for example, not only that soil is necessary (in a very direct sense) to sustain plant life (and thus other lifeforms that depend on plants), they also know that soil functions to store and conduct water, serves a critical purpose in soil engineering involved with construction, and acts as a sink and purifying medium for waste disposal systems.

The soil practitioner must be well versed in the physical properties of soil. Specifically, he or she must have an understanding of those physical processes that are active in soil. These factors include physical interactions related to soil water, soil grains, organic matter, soil gases, and soil temperature. To gain this knowledge, the safety engineer must have training in basic geology, soil science, and/or engineering construction.

Soil Pollution: Contamination of the soil and subsurface by the addition of contaminants or pollutants.

Soil Profile: Section of the soil viewed on a vertical plane extending through all its horizons and into the parent material.

Soil Remediation: The use of various techniques and/or technologies to decontaminate or dispose of contaminated soil.

Soil Sampling: Conducted to determine through analysis the type, texture, and structure of a soil; used to collect samples of contaminated soil to determine degree and extent of contamination and for analysis.

Soil Solution: Liquid phase of the soil including dissolved organic and inorganic materials.

Soil Sterilant: A chemical that temporarily or permanently prevents the growth of all plants and animals.

Soil Structure: The combination or arrangement of primary soil particles into secondary particles, units, or peds. These secondary units may be, but usually are not, arranged in the profile in such a manner as to give a distinctive characteristic, pattern. The secondary units are characterized and classified on the basis of size, shape, and degree of distinctness into classes, types, and grades, respectively.

Soil Structure (**Tilth**): Soil structure, or tilth, should not be confused with soil texture—they are different. In fact, in the field, the properties determined by soil texture may be considerably modified by soil structure. Soil structure refers to the way various soil particles clump together. The size, shape, and arrangement of clusters of soil particles called *aggregates* form larger clumps called *peds*. Sand particles do not clump—sandy soils lack structure. Clay soils tend to stick together in large clumps. Good soil develops small *friable* (crumble easily) clumps. Soil develops a unique, fairly stable structure in undisturbed landscapes, but agricultural practices break down the aggregates and peds, lessening erosion resistance.

The presence of decomposed or decomposing remains of plants and animals (*organic matter*) in soil helps not only fertility, but also soil structure, and especially the soil's ability to store water. Live organisms—protozoa, nematodes, earthworms, insects, fungi, and bacteria are typical inhabitants of soil. These organisms work to either control the population of organisms in the soil or to aid in the recycling of dead organic matter. All soil organisms, in one way or another, work to release nutrients from the organic matter, changing complex organic materials into products that can be used by plants.

Soil Survey: The systematic examination, description, classification, and mapping of soils in an area.

Soil Texture: The relative proportions of the various soil separates in a soil.

Soil Washing and Extraction: In pollution control technology used for USTs, used to leach contaminants from the soil into a leaching medium, after which the extracted contaminants are removed by conventional methods.

Soil Water: A general term emphasizing the physical rather than the chemical properties and behavior of the soil solution.

Solar Energy: 1. The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity. 2. The sun is star that symbolizes life, power, strength, force, clarity, and, yes, energy. The sun nourishes our planet. Solar energy is a renewable resource because it is continuously supplied to the earth by the sun. When we consider the sun and solar energy first, we quickly realize that there is nothing new about renewable energy. The sun was the first energy source; it has been around for 4.5 billion years, as long as anything else we are familiar with. On earth without the sun there is nothing—absolutely nothing. The old 5-5-5-thumb rule that guides the essence of life on Earth, that is, that one cannot survive with to breathe after 5 minutes; that water must be available to drink in 5 or less days; and we need food to eat in 5 weeks or less to stay alive is true but without the sun the 5-5-5-rule has no validity—without the sun there is nothing: no air, no water, no food, and no life.

The sun, the ultimate energy source, provided light and heat to the first humans. During daylight, the people searched for food. They hunted and gathered and probably stayed together for safety. When nightfall arrived and in the dark, we can only imagine that they huddled together for warmth and reassurance in light of the stars and moon, waiting for the sun and its lifegiving and sustaining light to return.

Solar energy (a term used interchangeably with solar power) uses the power of the sun, using various technologies, "directly and/or indirectly" to produce energy. Solar energy is one of the best renewable energy sources available because it is one the cleanest sources of energy. Direct solar radiation absorbed in solar collectors can provide space heating and hot water. Passive solar can be used to enhance the solar energy use in buildings for space heating and lighting requirements. Solar energy can also be used to produce electricity, and this is the renewable energy area that is the focus attention in this section.

The Table highlights solar energy's quadrillion Btu ranking in current renewable energy source use. As pointed out in the table, the energy consumption by energy source computations are from the year 2007. Thus, the 0.080 solar/PV quadrillion Btu figure is expected to steadily increase to an increasingly higher level and this should be reflected in the 2008–2010 figures when they are released.

U.S. Energy Consumption by Energy Source, 2007 (Quadrillion Btu)

Energy Source	*2007*
Total	*101.605*
Renewable	*6.830*
Biomass (biofuels, waste, wood and wood-derived)	3.615
Biofuels	1.018
Waste	0.431
Wood derived Fuels	2.165
Geothermal	0.353
Hydroelectric Conventional	2.463
Solar/PV	**0.080**
Wind	0.319

Source: EIA 2007. *U.S. Energy consumption by Energy Source*. Accessed 06/12/09 @http://www.eia.doe.gov/enaf/alternate/page/renew_energy_conump/table 1.html.

In its Solar Energy Technology Program, USDOE (2009) points out that not only do solar technologies diversify the energy supply but they also reduce the country's dependence on imported fuel. Moreover, solar energy technologies provide a beneficial environmental impact by helping to improve air quality and offset greenhouse gas emissions. An additional (and significant) benefit of a growing solar technology industry is that it stimulates our economy by creating jobs in solar manufacturing and installation. According to DOE (2009), the two solar electric technologies with the greatest potential (based on cost-effectiveness) are concentrating solar power (CSP) and photovoltaics (PV).

Solar Hot Water: Just as the sun heats the surface layers of exposed bodies of water—ponds, lakes, streams, and oceans—it can also heat water used in buildings and swimming pools. To harness the sun's ability to heat water, two main parts are added to the process: a solar collector and a storage tank. The most common collector is called a *flat-plate collector*. The flat-plate collector system is the most commonly used collector and is ideal for applications that require water temperatures under 140ºF (60ºC). Mounted on the roof, it consists of a thin, flat, rectangular, insulated box with a transparent-glass cover that faces the sun. Small copper tubes run through the box and carry the fluid—either water or other fluid, such as an antifreeze solution—to be heated. The tubes, typically arranged in series (i.e., water flows in one end and out the other end) are attached to an absorber plate, which, along with the tubes, is painted black to absorb the heat. As heat builds up in the collector, it heats the fluid (water or propylene glycol) passing through the tubes. The motive force for passing fluid through the tubes can be accomplished either by active or passive means. In an active system, the most common type of system, water heaters rely on an electric pump and controller to circulate water, or other heat-transfer fluids through the collectors. Passive solar water-heater systems rely on gravity and the tendency for water to naturally circulate as it is heated. Because passive systems have no "moving parts" they are more reliable, easier to maintain, and often have a longer life than active systems.

The storage tank holds the hot liquid. It is usually a large well-insulated tank, but modified water heaters can also be used to store the hot liquid. When the fluid used is other than water, the water is heated by passing it through a coil of tubing in the tank, which is full of hot fluid. Active solar systems usually include a storage tank along with a conventional water heater. In two-tank systems, the solar water heater preheats water before it enters the conventional water heater.

Solar Heat Gain Coefficient (SHGC): Measures how well a product blocks heat caused by sunlight. The SHGC is expressed as a number between 0 and 1. The lower the SHGC, the less solar heat it transmits.

Solar Process Heat: In addition to conventional domestic water heating systems, commercial and industrial buildings may use the same solar technologies—photovoltaics, passive heating, daylighting, and water heating. These non-residential buildings can also use solar energy technologies that would be impractical for a home. These technologies include ventilation air preheating, solar process heating, and solar space cooling

Space Heating

In order to maintain indoor air quality (IAQ), many large buildings need ventilated air. Although all that fresh air is great for indoor air quality, in cold climates, heating this air can use large amounts of energy and can be very expensive. But an elegantly simple solar ventilation system can preheat the air, saving both energy and money. This type of system typically uses a transpired collector.

Transpired air collector systems essentially consist of a dark-colored, perforated façade installed on a building's south-facing wall. An added fan or the building's existing ventilation system draws ventilation air into the building through the perforated absorber plate on the facade and up the plenum (the air space between the absorber and the south wall). According to USDOE (2006), solar energy absorbed by the dark absorber and transferred to the air flowing through it can preheat the intake air by as much as 40ºF (22ºC). Reduced heating costs will pay for the systems in three to twelve years.

In addition to meeting a portion of a building's heating load with clean free solar energy, the transpired collector helps save energy and money in other ways. It recaptures heat loss through a building's south-facing wall; heat that escapes through the south wall is captured in the air space between the structural wall and the transpired collector and returned to the interior. Also, by introducing make-up air though ceiling-mounted ducts, the system eliminates the wasteful air stratification that often plagues high-ceiling buildings (USDOE 2006).

To illustrate an active, real-world example of transpired collectors (used as solar pre-heaters for outdoor ventilation air) it is probably best to use an actual example of a working system in an industrial application. The following case study is such an example; it has been monitored extensively by experts.

Case Study—General Motors Battery Plant[2]

The General Motors battery Plant in Oshawa, Canada, is a 100,000-ft^2 facility in which automotive batteries are manufacture. The plant was built in the 1970s and consists of an open shop floor and a 298-foot-high ceiling. GM operates two full-time production shifts within the plant and conducts maintenance activities at night and on weekends, so the building is continuously occupied.

Until the early 1990s, GM relied solely on a team-operated fan coil system for space heating, but the system was incapable of providing the necessary quantities of heated outdoor air. As a result, the plant was not being adequately ventilated.

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[2] Case study is found in USDOE's Federal Technology Alert on Transpired Collectors. Accessed 02/10/10 @ www.eren.doe.gov/solarbuildings.

In 1991, plant management installed transpired collector to correct the ventilation problems. During the following two years the transpired collector system was modified slightly to improve airflow; the original fans and motors were replaced with ane axial fans and high-efficiency motors, and the original ducting was replaced with the upgraded fabric ducting.

The GM plant collector comprises 4520 ft^2 of absorber sheeting. The lower 21 feet of the transpired collector is black, perforated, aluminum wall cladding with 1.6-mm holes totaling 2 percent porosity. The average depth of the plenum between the transpired collector and the plant's structural wall is 6 inches. The canopy at the top of the wall acts as both a manifold for the air-flow and a solar heat collection device. The canopy face is made of perforated plate with 1 percent porosity. The transpired collector covers about 50 percent of the total area of the plant's south-facing wall; the remainder of the south facade has shipping doors and other obstructions that make it unsuitable for mounting collector cladding.

The GM transpired collector hast to fan/distribution systems, each consisting of a constant-speed fan, a recirculation damper system, and a fabric distribution duct. The total airflow delivered by the system's fans is 40,000 cfm. Both recirculated air and air drawn through the solar collectors make up this flow; the percentages of each depend on the temperature of the air coming from the collector.

The GM Battery Plant's transpired collector has been monitored extensively since it was installed. The data in this case study reflect the performance of the system during the 1993/94 heating season. An in-depth report on the monitoring program is available (Enermodal Engineering Ltd. 1995).

The data shows that the annual energy savings for the 4520-ft^2 collector was 940 million Btu/year: 678 MBtu resulted from the thermal energy gained directly from the outside air as it passed through the absorber; and 262 MBtu resulted from heat loss recaptured by the wall from inside the building. Other possible energy-saving mechanisms—such as destratification and heat recapture—likely contributed to improved system performance; however, these effects are highly structure-specific and have not been incorporated into the savings reported here.

The cost of the transpired collector system at the GM plant was \$66,530, or \$14.72/ft^2 of installed collector. The cost per square foot is higher than typical installations for two reasons: 1) this system was installed soon after the technology was introduced, before design and installation procedures had been streamlined, and 2) the cost includes the fan and ducting modifications that were implemented during the first 2 years of operation.

It is important to point out that the GM transpired collector had a number of operational problems. After the system was initially installed, employees complained about fan noise and cold drafts, and they occasionally disabled the system. The fan and duct upgrades described previously eliminated the problems on one of the fan systems; the other fan continues to generate noise, and employees still disable it when working in the immediate vicinity. The manufacturer (Conserval) has addressed these complaints by specifying smaller, but more numerous, fans in subsequent installations.

Also, both bypass dampers and a recirculation damper required additional maintenance. The recirculation damper became stuck in the full recirculation mode, and anew modulating motor was installed to fix the problem. The bypass dampers occasionally because bound, which led to unacceptably high leakage rates. These dampers were kept closed manually through the 1993–1994 heating season.

Water Heating

Solar water-heating systems are designed to provide large quantities of hot water for nonresidential buildings. A typical system includes solar collectors that work along with a pump, heat exchanger, and/or one or more large storage tanks. The two main types of solar collectors used for nonresidential buildings—and evacuated-tube collector and linear concentrator—can operate at high temperatures with high efficiency. An evacuated-tube collector is a set of many double-walled, glass tubes and reflectors to heat the fluid inside the tubes. A vacuum between the two walls insulates the inner tube, retaining the heat. Linear concentrators use long, rectangular, curved (U-shaped) mirrors tilted to focus sunlight on tubes that run along the length of the mirrors. The concentrated sunlight heats the fluid within the tubes.

Space Cooling

Space cooling can be accomplished using thermally activated cooling systems (TACS) driven by solar energy. Because of a high initial cost, TACS are not widespread. The two system currently in operation are solar absorption systems ad solar desiccant systems. Solar absorption system use thermal energy to evaporate a refrigerant fluid to cool the air. In contrast, solar desiccant systems use thermal energy to regenerate desiccants that dry the air, thereby cooling the air. These systems also work well with evaporative coolers in more humid climates.

Lighting Technologies: Lighting technologies include:

- Lamps—lighting sources, like fluorescent and incandescent light bulbs, and solid-state lighting.
- Ballasts—used with electric discharge lamps such as fluorescent lamps, ballasts transform and control electrical power to the light.
- Luminaries (Fixtures)—complete lighting units that contain the bulbs and, if necessary, the ballasts.

- Lighting Controls—devices such as timers and sensors that can save energy by turning lights off when not needed.
- Daylighting—the use of natural light in a building.
- Solid-state lighting—no other technology offers as much potential to save energy and enhance the quality of building environments, contributing to energy and climate change solutions.

Lamps
Commonly called light bulbs, lamps produce light. When comparing lamps, it is important to understand the following performance characteristics:

- Color Rendering Index (CRI)—a measurement of a light source's accuracy in rendering different colors when compared to a reference light source with the same correlated color temperature. The highest attainable CRI is 100. Lamps with CRIs above 70 are typically used in office and living environments.
- Correlated Color Temperature (CCT)—a measurement on the Kelvin (K) scale that indicates the warmth or coolness of a lamp's color appearance. The higher the color temperature, the cooler the color appearance. Typically, a CT rating below 3200 K is considered warm, which a rating above 4000K is considered cool.
- Efficacy—the ratio of the light output to the power, measured in lumens per watt (lm/w). The higher the efficacy, the more efficient the lamp.

Lamp types include:

Incandescent Lamps—a standard incandescent lamp consists of a fairly large, thin, frosted glass envelope. Inside the glass is an inert gas such as argon and/or nitrogen. At the center of the lamp is a tungsten filament. Electricity heats the filament. The heated tungsten emits visible light in a process called incandescence. Most standard light bulbs are incandescent lamps. They have CRI of 100 and CCTs between 2600-3000, making them attractive lighting sources of many applications. However, these bulbs are typically inefficient (10-15 lm/w), converting only about 10 percent of the energy into light while transforming the rest into heat. Another type of incandescent lamp is the halogen lamp. Halogen lamps also have a CRI of 100. But they are slightly more energy efficient, and they maintain their light output over time. A halogen lamp also uses a tungsten filament. However the filament is encased inside a much smaller quartz envelope. And the gas inside the envelope is from the halogen group. If the temperature is high enough, the halogen gas will combine with tungsten atoms as they evaporate and redeposit them on the filament. This recycling process lets the filament last much longer. In addition, it is now possible to run the filament hotter. This means more light per unit of energy is obtained. Because the quartz envelope is so close to the filament, it becomes about four times hotter than a standard incandescent lamp. As a result of this wasted heat energy, halogen lamps—popular in torchieres (i.e., portable electric lamp with a reflector bowl that directs light upward to given indirect illumination)—are not very energy efficient. The exposed heat from halogen torchieres can also pose a serious fire risk, especially near flammable objects. Because of this inefficiency and risk, manufacturers have developed torchieres that can use other lamps, such as compact fluorescent lamps.

Fluorescent Lamps—(70-100 lm/w) consist of a sealed glass tube. The tube contains a small amount of mercury and an inert gas, like argon, kept under very low pressure. In these electric-discharge lamps, a fluorescing coating on the glass, called phosphor powder—transform some of the ultraviolet energy generated into light. Fluorescent lamps also require a ballast to start and maintain their operation. Early fluorescent lamps were sometimes criticized as not producing enough warm colors, making them appear as too white or uncomplimentary to skin tones, and a cool white fluorescent lame had a CRI of 62. But today, there are lamps available with CRIs of 80 and above that simulate natural daylighting and incandescent light. They also are available in a variety of CCTs: 2900 to 7000. The "T" designation for fluorescent lamps stands for tubular—the shape of the lamp. The number after the "T" gives the diameter of the lamp in eighths of an inch. The T8 lamp—available straight or U-shaped—has become the standard for new construction. It is also commonly serves as a retrofit replacement for 40-watt T12 lamps, improving efficacy, CRI, and efficiency. In some cases, T10 lamps offer advantages over both T12 and T8 lamps, including higher efficiency, higher CRI values, a wider selection of CCTs, and compatibility with several ballast types. Another lamp type is the T5FT fluorescent lamp. These lamps produce maximum light output at higher ambient temperatures than those that are linear our U-shaped. Linear fluorescent lamps often are less

Did You Know?

Cold cathode fluorescent lamps are one of the latest technological advances in fluorescent technology. The "cold" in cold cathode means there is no heating filament in the lamp to heat up the gas. This makes them more efficient. Also, since there is no filament to break, they are ideal for use in rough service environments where a regular lamp may fail. They are often used as backlights in LCLD monitors. They are also used in exit signs.

expensive than compact fluorescent lamps. They can also produce more light, are easier to dim, and last longer.

Compact Fluorescent Lamps (CFLs)—are small-diameter fluorescent lamps folded for compactness, with an efficacy of 50-75 lm/w for 27-40 watts. There are several styles of CFLs: two-, four-, and six-tube lamps, as well as circular lamps. Some CFLS have the tubes and ballast permanently connected. Others have separate tubes and ballasts. Some CFLs feature a round adaptor, allowing them to screw into common electrical sockets and making them ideal replacements for incandescent lamps. They last up to 10 times longer than incandescent lamps, and they use about one-fourth the energy, producing 90 percent less heat. However, typical 60-100 watt incandescent lamps are no more than 5.3-inches long, while standard CFLs are longer than 6 inches. Therefore, sub-CFLs have been developed. No more than 4.5 inches long, sub-CFLs fit into most incandescent fixtures.

Did You Know?

Because of their energy efficiency, brightness, and low heat output, CFLS are also good replacements for halogen lamps in torchieres.

High Intensity Discharge Lamps (HID)—compared to fluorescent and incandescent lamps, high-intensity discharge (HID) lamps produce a large quantity of light in a small package. HID lamps produce light by striking an electrical arc across tungsten electrodes housed inside a specially designed inner glass tube. This tube is filled with both gas and metals. The gas aids in the starting of the lamps. Then, the metals produce the light once they are heated to a point of evaporation. Like fluorescent lamps, HID lamps require a ballast to start and maintain their operation. Types of HID lamps include mercury vapor (CRI range 15-55), metal halide (CRI range 65-80), and high-pressure sodium (CRI range 22-75). Mercury vapor lamps (25-45 lm/w), which originally produced a bluish-green light, were the first commercially-available HID lamps. Today, they are also available in a color corrected, whiter light. But they are still often being replaced by the newer, more efficient high-pressure sodium and metal halide lamps. Standard high-pressure sodium lamps have the highest efficacy of all HID lamps, but they produce a yellowish light. High-pressure sodium lamps that produce a whiter light are now available, but efficiency is somewhat sacrificed. Metal halide lamps are less efficient but produce an even whiter, more natural light. Colored metal halide lamps are also available.

Low Pressure Sodium Lamps—have the highest efficacy of all commercially available lighting sources, producing up to 180 lumens/watt. Even though they emit a yellow light, a low-pressure sodium lamp should not be confused with a standard high-pressure sodium lamp—a high-intensity discharge lamp. Low-pressure sodium lamps operate much like a fluorescent lamp and require a ballast. The lamps are also physically large—about 4-feet long for the 180-watt size—so light distribution from fixtures is less controllable. There is a brief warm-up period for the lamp to reach full brightness. With a CRI of 0, low-pressure sodium lamps are used where color rendition is not important but energy efficiency is. They are commonly used for outdoor, roadway, parking lot, and pathway lighting. Low-pressure sodium lamps are preferred around astronomical observatories because the yellow light can be filtered out of the random light surrounding the telescope.

Did You Know?

HID lamps are typically used when high levels of light are required over large areas and when energy efficiency and/or long life are desired. These areas include gymnasiums, large public areas, warehouses, outdoor activity areas, roadways, parking lots, and pathways. More recently, however, HID sources—especially metal halide (45-100 lumens/watt)—have been used in small retail and residential environments.

Solid-State Lighting (SSL)—compared to incandescent and fluorescent lamps, solid-state lighting creates light with less directed heat. A semi-conducting material converts electricity directly into light, which makes the light very energy efficient. Solid-state lighting includes a variety of light producing semiconductor devices including light-emitting diodes (LEDs) and organic light-emitting diodes (OLEDs). Warm white LEDs have an efficacy of 50 lm/w, while cool white LEDs can achieve efficacies up to 100 lm/w. Until recently, LEDs—basically tiny light bulbs that fit easily into an electrical circuit—were used as simple indicator lamps in electronics and toys. But recent research has achieved efficiencies equal to fluorescent lamps. And the cost of semiconductor material, which used to be quite expensive, has lowered, making LEDs a more cost-effective lighting option. On-going research shows that LEDs have great potential as energy-efficient lighting for residential and commercial building use. New uses for LEDs include small area lighting, such as task and under-shelf fixtures, decorative lighting, and pathway and step marking. As while LEDs become more powerful and effective, LEDs will be used in more general illumination applications, perhaps with entire walls and ceilings becoming the lighting system. They are already being used successfully in many general illumination applications including traffic signals and exit signs. OLEDs currently are used in very thin, flat display screens, such as those in portable televisions, some vehicle dashboard readouts, and in postage-stamp-sized data screens built into pilots' helmet visors. Because OLEDs emit their own light and can be incorporated into arrays on very thin, flexible materials, they also could be used to fashion large, extremely thin panels for light sources in buildings.

Did You Know?

RBG designation—red, green, blue. One way to create white light with LEDs is to mix the three primary colors of light.

PC designation—phosphor conversions. White light can be produced by a blue, violet, or near-UV LED coated with yellow or multi-chromatic phosphors. The combined light emission appears white.

Ballasts

Ballasts consume, transform, and control electrical power for electric-discharge lamps, providing the necessary circuit conditions for starting and operating them. Electric-discharge lamps include fluorescent, high-intensity discharge, and low-pressure sodium. When comparing ballasts, it is important to understand the following performance characteristics:

- Ballast Factor (BF)—the ratio of the slight output of a lamp or lamps operated by a specific ballast to the light output of the same lamp(s) operated by a reference ballast. It can be used to calculate the actual light output of that specific lamp-ballast combination. BF is typically different for each lamp type. Ballasts with extremely high BFs could reduce lamp life and accelerate lumen deficiency because of high lamp current. Extremely low BFs also could reduce lam life because they reduce lamp current.
- Ballast Efficacy Factor (BEF)—the ratio of ballast factor (as a percentage) to power (in watts). BEF comparisons should be made only among ballasts operating the same type and number of lamps.
- System Efficacy—the ratio of the light output to the power, measured in lumens per watt (lm/w), for a particular lamp ballast system.

There are three basic types of ballasts: Magnetic, hybrid and electronic ballasts.

Magnetic Ballasts—contain a magnetic core of several laminated steel plates wrapped with copper windings. These ballasts operate lamps at line frequency (60 hertz in North America). Of all ballasts, magnetic ones are the least expensive and also the least efficient. They have greater power losses that electronic ballasts. But magnetic ballasts manufactured today are 10 percent more efficient than the older high-loss magnetic ballasts, which used aluminum windings. Magnetic ballasts are available with dimming capability. However, they cannot be dimmed below 20 percent and still use more electricity than electronic ballasts.

Hybrid Ballasts (Cathode-Disconnect Ballasts)—use a magnetic core-and-coil transformer and an electronic switch for the electrode heating circuit. Like magnetic ballasts, they operate lamps at the frequency (60 hertz in North America). After they start the lamp, these ballasts discount the electrode-heating circuit. Hybrid ballasts cost more than magnetic ballasts, but they are more energy efficient.

Electronic Ballasts—in the early 1980s, manufacturers began to replace the core-and-coil transformer with solid-state, electronic compounds that could operate lamps at 20-50 kilohertz. These electronic ballasts experience half the power loss of magnetic ballasts. Also lamp efficacy increases by approximately 10 to 15 percent compared to 60-hertz operation. Electronic ballasts are the most expensive, but they are also the most efficient. Operating lamps with electronic ballasts reduces electricity use by 10 to 15 percent over magnetic ballasts of the same light output. They are also quieter, lighter, and they virtually eliminate lamp flicker. Electronic ballasts are also available as dimming ballasts. These ballasts allow the light level to be controlled between 1 and 100 percent. There are a variety of electronic ballasts available for use with fluorescent lamps. Electronic ballasts have been successfully used with lower watt high-intensity discharge (HID) lamps (Primarily 35-100 w/MH). These ballasts provide an energy savings over magnetic ballasts of 8 to 20 percent. Their lighter weight also helps in some HID application, such as track lighting.

Luminaires (Lighting Fixtures)

A lamp or lamp-ballast combination may produce light very efficiently, but if it is installed in an inefficient luminaire, the overall system efficiency may still be poor. The best luminaire manufacturers will design their fixtures around specific lamps to optimize the amount of light delivered to the work area. For example, a luminaire designed specifically for a compact fluorescent lamp can deliver almost 10 times as much illumination as an incandescent fixture fitted with the same compact fluorescent lamp.

Luminaire components include reflectors, diffusers—which absorb some of the light from a lamp—and polarizing panels. Reflectors can be used to direct more of the light produced by the lamp out of the luminaire onto the work area. Polarizing panels can sometimes increase the contrast of a visual task.

When comparing luminaires, it is important to understand the flowing performance characteristics:

- Illuminance—the amount of light that reaches a surface. It is measured in footcandles (lumens/square foot) or lux (lumens/square meter).
- Luminaire Efficacy/Efficiency Rating (LER)—the light output (lumens) per watt of electricity use (lm/w).

Before selecting luminaires or lighting fixtures for an office building, factory, warehouse, or even a parking lot, it is a good idea to consult a certified lighting designer. A lighting designer will not only help find the most energy-efficient luminaires, but also provide lighting that makes for a comfortable and more productive work environment.

Today, energy-efficient commercial lighting design includes more than just the ambient or general lighting of a workspace, such as the use of ceiling luminaires. When designing or retrofitting the lighting, the general Illuminance can be reduced if task lighting is implemented properly into the overall design. Task lighting can result in significant energy savings and improved visibility for workers.

Did You Know?

The most efficient light source technology for exit signs is light-emitting diodes (LED). The most popular parking lot luminaires use energy-efficient, high-intensity discharge lamps or low-pressure sodium lamps. But the most efficient light source technology for outdoor use is outdoor photovoltaic lighting.

Lighting Controls

Lighting controls help conserve energy and make a lighting system more flexible. The most common light control is the on/off switch. Other types of light control technologies include: manual dimming, photosensors, occupancy sensors, clock switches or timers, and centralized controls.

Manual dimming—these controls allow occupants of a space to adjust the light output or Illuminance. This can result in energy savings through reductions in input power, as well as reductions in peak power demand, and enhanced lighting flexibility. Slider switches allow the occupant to change the lighting overt the complete output range. They are simplest of the manual controls. Preset scene controls change the dimming setting for various lights all at once with the press of a button. It is possible to have different settings for the morning, afternoon, and evening. Remote control dimming is also available. This type of technology is well suited for retrofit projects, where it is useful to minimize rewiring.

Did You Know?

Fluorescent lighting fixtures require special dimming ballasts and compatible control devices. Some dimming systems for high-intensity discharge lamps also require special dimming ballasts.

Photosensors—these devices automatically adjust the light output of a lighting system based on detected illuminance. The technology behind photosensors is the photocell. A photocell is a light-responding silicon chip that converts incident radiant energy into electrical current. While some photosensors just turn lights off and on, others can also dim lights. Automatic dimming can help with lumen maintenance. Lumen maintenance involves dimming luminaires when they are new, which minimizes the wasteful effects of over-design. The power supplied to them is gradually increased to compensate for light loss over the life of the lamp.

Did You Know?

Nearly all photosensors are used to decrease the electric power for lighting. In addition to lowering the electric power demand, dimming the lights also reduces the heat load on a building's cooling system. Any solar heat gain that occurs in a building during the day must be taken into account for a whole building energy usage analysis.

Occupancy sensors—turn lights on and off base don't their detection of motion within a space. Some sensors can also be used in conjunction with dimming controls to keep the lights from turning completely off when a space is unoccupied. This control scheme may be appropriate when occupancy sensors control separate zones in a large space, such as in a laboratory or in an open office area. In these situations, the lights can be dimmed to a predetermined level when the space is unoccupied. Sensors can also be used to enhance the efficiency of centralized controls by switching off lights in unoccupied areas during normal working hours as well as after hours. There are three basic types of occupancy sensors, these include:

- Passive infrared (PIR)—sensors react to the movement of a heat-emitting body through their field of view. Wall box-type PIR occupancy sensors are best suited of small, enclosed spaces such as private offices, where the sensor replaces the light switch on the wall and no extra wiring is require. They should not be used where walls, partitions, or other objects might block the sensors' ability to detect motion.
- Ultrasonic—these sensors emit an inaudible sound pattern and re-read the reflection. They react to changes in the reflected sound pattern. These sensors detect very minor motion better than most infrared sensors. Therefore, they are good to use in spaces such as restrooms with stalls, which can block the field of view, because the hard surfaces will reflect the sound pattern.
- Dual-technology (hybrid)—occupancy sensors that use both passive infrared and ultrasonic technologies to minimize the risk of false triggering (lights coming on when the space is unoccupied). They also ten dot be more inexpensive.

Clock switches or timers—These control lighting for a preset period of time. They come equipped with an internal mechanical or digital clock, which will automatically adjust for the time of year. The user determines when the light should be turned on and when they should be turned off. Clock switches can be used in conjunction with photosensors.

Centralized controls—these are building controls or building automation systems that can be used to automatically turn on, turn off, or dim electrical lights around a building. In the morning, the centralized control system can be used to turn on the lights before employees arrive. During the day, a central control system can be used to dim the lights during periods of high power demand. And, at the end of the day, the lights can be turned off automatically. A centralized lighting control system can significantly reduce energy use in buildings where lights are left on when not needed.

Daylighting

Daylighting is the practice of placing windows or other openings and reflective surfaces so that during the day natural light provides effective internal lighting. When properly designed and effectively integrated with the electric lighting system, daylighting can offer significant energy savings by offsetting a portion of the electric lighting load. A related benefit is the reduction in cooling capacity and use by lowering a significant component of internal gains. In addition to energy savings, daylighting generally improves occupant satisfaction and comfort. Windows also provide visual relief, a contact with nature, time orientation, the possibility of ventilation, and emergency egress.

The Daylight Zone—high daylight potential is found particularly in those spaces that are predominantly daytime occupied. Site solar analysis should assess the access to daylight by considering what is "seen" from the various potential window orientations. What proportion of the sky is seen from typical task locations in the room? What are the exterior obstructions and glare sources? Is the building design going to shade a neighboring building or landscape feature that is dependent on daylight or solar access? It is important to establish which spaces will most benefit from daylight and which spaces have little or no need for daylight. Within the spaces that can use daylight, place the most critical visual tasks in positions near the window. Try to group tasks by similar lighting requirements and occupancy patterns. Avoid placing the windows to the direct line of sight of the occupant as this can cause extreme contrast and glare. It is best to orient the occupant at 90 degrees from the window. Where privacy is not a major concern, consider interior glazing (known as relights or borrow lights) that allow light from one space to be shared with another. This can be achieved with transom lights, vision glass, or translucent panels if privacy is required. The floor plan configuration should maximize the perimeter daylight zone. This may result in a building with a higher skin-to-volume ratio than a typical compact building design. A standard widow can produce useful illumination to a depth of about 1.5 times the height of the window. With lightshelves or other reflector systems this can be increased to 2.0 times or more. As a general rule-of-thumb, the higher the window is placed on the wall, the deeper the daylight penetration.

Window design considerations—the daylight that arrives at a work surface comes from three sources:

1. The exterior reflected component. This includes ground surfaces, pavement, adjacent buildings, wide windowsills, and objects. Remember that excessive rough reflectance will result in glare.
2. The direct sun/sky component. Typically the direct sun component is blocked from occupied spaces because of heat gain, glare, and UV degradation issues. The sky dome then becomes an important contribution to daylighting the pace.
3. The internal reflected component. Once the daylight enters the room, the surrounding wall, ceiling, and floor surfaces are important light reflectors. Using high reflectance surfaces will better bounce the daylight around the room and it will reduce extreme brightness contrast. Window frame material should

be light-colored to reduce contrast with the view and have a non-specular finish to eliminate glare spots. The window jambs and sills can be beneficial light reflectors. Deep jambs should be splayed (angled toward the interior) to reduce the contrast around the perimeter of the window.

Did You Know?

The most important interior light-reflecting surface is the ceiling. High reflectance paints and ceiling tiles are now available with .90 or higher reflectance values. Titling the ceiling plant toward the daylight source increases the daylight that is reflected from this surface. In small rooms should also be a high reflectance matte finish. The sidewalls followed by the floor have less impact on the reflected daylight in the space.

Major room furnishings such as office cubicles or partitions can have a significant impact on reflected light so select light-colored materials. Suggested reflectance levels for various room surfaces are:

- Ceilings: > 80 percent
- Walls: 50-70 percent
- Floors: 20-40 percent
- Furnishings: 25-45 percent

Because light essentially has no scale for architectural purposes, the proportions of the room are more important than the dimensions. A room that has a higher ceiling compared to the room depth will have deeper penetration of daylight whether from side lighting (windows) or top lighting (skylights and clerestories). Raiding the window head height will also result in deeper penetration and more even illumination in the room. Punched window openings, such as small, square windows separated by wall area, result in uneven illumination and harsh contrast between the window and adjacent wall surfaces. A more even distribution is achieved with horizontal strip windows.

Did You Know?

There is no direct sunlight on the polar-side wall of a structure from the autumnal equinox to the spring equinox in parts of the globe north of the Tropic of Cancer and in parts of the globe south of the Tropic of Capricorn.

Effective Aperture (EA)—One method of assessing the relationship between visible light and the size of the window is the effective aperture method. The *effective aperture* (EA) is defined as the product of the visible transmittance and the window-to-wall ratio (WWR). The window-to-wall ratio is the proportion of window area compared to the total wall area where the window is located. For example, if a window covers 25 square feet in a 100 square-foot wall then the WWR is 25/100 or 0.25. A good starting target for EA is in the range of 0.20 to 0.30. For a given EA number, a higher WWR (larger window) results in a lower visible transmittance.

Example: WWR = .5 (half the wall in glazing)

VT= .6, EA = 0.3

Or WWR = .75, VT = .4 for the same EA of 0.3

Did You Know?

Typically, lowering the visible transmittances will also lower the shading coefficient but you must verify this with glazing manufacturer data since this is not always the case.

Light shelves—are effective horizontal light-reflecting overhangs placed above the eye-level with a transom window placed above it. Light shelves enhance the lighting from windows o the equator-facing side of a building. Exterior shelves are more effective shading devices than interior shelves. A combination of exterior and interior will work best in providing an even illumination gradient.

Toplighting strategies—large single level floor areas and the top floors of multi-story buildings can benefit from toplighting. The general types of toplighting include skylights, clerestories, monitors, and sawtooth roofs.

- Skylights—horizontal skylights can be an energy problem because they tend to receive maximum solar gain at the peak of the day. The daylight contribution also peaks at midday and falls off severely in the morning and afternoon. There are high performance skylight deigns that incorporate reflectors or prismatic lenses that reduce the peak daylight and heat gain while increasing early and late afternoon daylight contributions. Another option is lightpipes where a high reflectance duct channels the light from a skylight down to a diffusing lens in the room. These many be advantageous in deep roof constructions.
- Clerestory window—is a vertical glazing located high on an interior wall. South-facing clerestories can be

effectively shaded from direct sunlight by a properly designed horizontal overhand. In this design the interior north wall can be sloped to better reflect the light down into the room. Use light-colored overhangs and adjacent roof surfaces to improve the reflected component. If exterior shading is not possible, consider interior vertical baffles to better diffuse the light. A south-facing clerestory will produce higher daylight illumination that a northern-facing clerestory. East and west facing clerestories have the same problems as east and west windows: difficult shading and potentially high heat gains.

- Roof monitor—consists of a flat roof section raised above the adjacent roof with vertical glazing on all sides. This design often results in excessive glazing area, which results in higher heat losses and gains than a clerestory design. The multiple orientations of the glazing can also create shading problems
- Sawtooth roof—is an old design often seen in industrial buildings. Typically one sloped surface is opaque and the other is glazed. A contemporary sawtooth roof may have solar collectors or photovoltaic cells on the south-facing slope and daylight glazing on the north-facing slope. Unprotected glazing on the south-facing sawtooth surface may result in high heat gains. In these applications an insulated diffusing panel may be a good choice.

Did You Know?

A building designed for daylighting but without an integrated electrical lighting system will be a net energy loser because of the increased thermal loads. Only when the electric lighting load is reduced will there be more than offsetting savings in electrical and cooling loads. The benefits from daylighting are maximized when both occupancy and lighting sensors are used to control the electric lighting system.

Solar energy has some obvious advantages in that the source is free; however, the initial investment in operating equipment is not free or inexpensive. Solar energy is also environmentally friendly, requires almost no maintenance, and reduces our dependence on foreign energy supplies. Probably the greatest downside of solar energy use is that in areas without direct sunlight during certain times of the year, solar panels cannot capture enough energy to provide heat for home or office. Geographically speaking, the higher latitudes do not receive as much direct sunlight as tropical areas. Because of the position of the sun in the sky, solar panels must be placed in sun-friendly locations such as the U.S. Desert Southwest and the Sahara region of northern Africa. Another downside of solar energy is the efficiency of the system; it may be seriously affected by how well it was installed.

The real bottom line on solar energy is obvious, however, its advantages out number its disadvantages.

Solar Thermal Collector: A device designed to receive solar radiation and convert it into thermal energy. Normally, a solar thermal collector includes a frame, glazing, and an absorber, together with the appropriate insulation. The heat collected by the solar thermal collector may be used immediately or stored for later use.

Solar Thermal Collector, Special: An evacuated tube collector or a concentrating (focusing) collector. Special collectors operate in the temperature (low concentration for pool heating) to several hundred degrees Fahrenheit (high concentration for air condition and specialized industrial processes).

Sole-Source Aquifer: An aquifer that supplies 50-percent or more of the drinking water of an area.

Solid: Matter that has a definite volume and a definite shape.

Solid Manure Storage: Storage unit in which accumulations of bedded manure or solid manure are stacked before subsequent handling and field spreading. The liquid part, including urine and precipitation, may or may not be drained from the unit.

Solid Waste: Any normally solid material that is useless or unwanted that results from human or animal activities.

Solid Waste Disposal: The final placement of refuse that is not salvaged or recycled.

Solid Waste Disposal Act (1965): This 1965 act was the first major step taken by U.S. legislators to promote (among other things) the demonstration, construction, and application of solid waste management and resource recovery systems to preserve and enhance the quality of air, water, and land resources.

Solid Waste Management: Supervised handling of waste materials from their source through recovery processes to disposal.

Solid Waste Stream: A stream of solid waste materials as a whole.

Solids Content: Residue remaining after water is evaporated from a sample at a specified temperature, usually about 215 degrees F (103 degrees C).

Solidification/Stabilization: 1. A stabilization technique used to convert hazardous waste from its original form to a physically and chemically more stable material. Accomplished by reducing the mobility of hazardous compounds in the waste prior to its land disposal. 2. Removal of wastewater from a waste or changing it chemically to make it less permeable and susceptible to transport by water.

Solubility: The ability of a substance to mix with water.

Solute: The substance dissolved in a solution.

Solution: 1. A liquid containing a dissolved substance. 2. A mixture of a solvent and a solute. In some solutions, such as sugar water, the substances mix so thoroughly that the solute cannot be seen. But in other solutions, such as water mixed with dye, the solution is visibly changed.

Solution gas: The dissolved natural gas that bubble out of crude oil on the surface when the pressure drops during production.

Solvent: 1. The substance in excess in a solution. 2. A substance that dissolves other substances, thus forming a solution. Water dissolves more substances than any other, and is known as the “universal solvent.”

Somatic: Pertaining to or characteristic of the body (physical).

Somnolence: A state of abnormal drowsiness.

Soot: Carbon dust formed by incomplete combustion.

Sorbed: Adsorbed or absorbed.

Sorbent: A substance that takes up and holds, e.g., liquids, by absorption or adsorption.

Sorption: Process of adsorption or absorption of a substance on or in another substance.

Source: Spring from which the stream originates, or other point of origin of stream.

Source Area: The location of liquid hydrocarbons or the zone of highest soil or groundwater concentrations, or both, of the chemical of concern.

Source Characterization Measurements: Measurements made to estimate the rate of release of pollutants into the environment from a source such as an incinerator, landfill, etc.

Source of Contamination: The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Source Reduction: Reducing the amount of materials entering the waste steam from a specific source by redesigning products or patterns of production or consumption (e.g., using returnable beverage containers). Synonymous with waste reduction.

Source Separation: Segregating various wastes at the point of generation (e.g., separation of paper, metal, and glass from other wastes to make recycling simpler and more efficient).

Source-Water Protection Area: The area delineated by a state for a Public Water Supply or including numerous such suppliers, whether the source is groundwater or surface water or both.

Spall: A chip or fragment removed from a rock surface by weathering; especially by the process of exfoliation.

Sparge or Sparging: Injection of air below the water table to strip dissolved volatile organic compounds and/or oxygenate groundwater to facilitate aerobic biodegradation of organic compounds.

Spasm: Abnormal and involuntary contraction of a muscle or of a hollow organ (such as an artery).

Spatial: Occupied space relationship between a soil or soil map unit to the landscape or geomorphic surface on which the soil or map unit is located.

Special Local-Needs Registration: Registration of a pesticide product by a state agency for a specific use that is not federally registered. However, the active ingredient must be federally registered for other uses. The special use is specific to that state and is often minor, thus may not warrant the additional cost of a full federal registration process. SLN registration cannot be issued for new active ingredients, food-use active ingredients without tolerances, or for a canceled registration. The products cannot be shipped across state lines.

Special Population: People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Special Review: Formerly known as Rebuttable Presumption Against Registration (RPAR), this is the regulatory process through which existing pesticides suspected of posing unreasonable risks to human health, non-target organism, or the environment are referred for review by EPA. Such review requires an intensive risk/benefit analysis with opportunity for public comment. If risk is found to outweigh social and economic benefits, regulatory actions can be initiated, ranging from label revisions and use-restriction to cancellation or suspended registration.

Special Waste: Items such as household hazardous waste, bulky wastes (refrigerators, pieces of furniture, etc.) tires, and used oil.

Species: A class of plants or animals having common attributes and designated by a common theme. Theoretically, plants or animals of different species cannot interbreed. However, occasionally that does not hold true.

Specific Capacity: *Specific capacity* is one of the most important concepts in well operation and testing. The calculation should be made frequently in the monitoring of well operation. A sudden drop in specific capacity indicates problems such as pump malfunction, screen plugging, or other problems that can be serious. Such problems should be identified and corrected as soon as possible. *Specific capacity* is the pumping rate per foot of drawdown (gpm/ft), or

Specific capacity = Well yield ÷ drawdown

Problem: If the well yield is 300 gpm and the drawdown is measured to be 20 ft, what is the specific capacity?
Solution:

Specific Capacity = 300 ÷ 20
Specific Capacity = 15 gpm per ft of drawdown

Specific Conductance: A measure of the ability of water to conduct an electrical current as measured using 1-cm cell and expressed in units of electrical conductance, i.e., Siemens per centimeter at 25 degrees Celsius. Specific conductance can be used for approximating the total dissolved solids content of water by testing its capacity to carry an electrical current. In water quality, specific conductance is used in ground water monitoring as an indication of the presence of ions of chemical substances that may have been released by a leaking landfill or other waste storage or disposal facility. A higher specific conductance in water drawn from downgradient well when compared to up-gradient wells indicates possible contamination from the facility.

Specific Gravity: Specific gravity is the ratio of the weight of a substance to the weight of an equal volume of water, a number that can be determined by dividing the weight of a body by the weight of an equal volume of water. Since the weight of any body per unit of volume is called density, then:

$$\text{Specific gravity} = \frac{\text{density of body}}{\text{density of water}}$$

Example: The density of a particular material is 0.24 pounds per cubic inch, and the density of water per cubic inch is 0.0361 pounds per cubic inch,

$$\text{Then: Specific gravity of the material} = \frac{0.24}{0.0361} = 6.6$$

The material is 6.6 times as heavy as water. This ratio does not change, regardless of the units that may be used, which is an advantage for two reasons: (1) it will always be the same for the same material, and (2) it is less confusing than the term *density*, which changes as the units change.

Specific Heat: The amount of heat energy in calories necessary to raise the temperature of one gram of the substance one degree Celsius.

$$q = Q/A \qquad (8)$$

where *Q* equals *total discharge* through area *A*. Specific discharge has sometimes been called the bulk velocity or the Darcian velocity. Specific discharge is a precise term (Hubert, 1940, p. 790) and is preferred to terms involving "velocity" because of possible confusion with actual velocity through the pores if a qualifying term is not constantly repeated.

Specific Retention: The ratio of the volume of water retained in a rock after gravity drainage to the volume of the rock.

$$q = Q/A \qquad (8)$$

where *Q* equals *total discharge* through area *A*. Specific discharge has sometimes been called the bulk velocity or the Darcian velocity. Specific discharge is a precise term (Hubert, 1940, p. 790) and is preferred to terms involving "velocity" because of possible confusion with actual velocity through the pores if a qualifying term is not constantly repeated.

Specific Source Wastes: Wastes from specifically identified industries, including wood preserving, petroleum refining, and organic chemical manufacturing. Typically includes sludges, still bottoms, wastewaters, spent catalysts, and residues.

Specific Storage: The volume of water that an aquifer system releases or takes into storage per unit volume per unit change in head. The specific storage is equivalent to the *Storage Coefficient* divided by the thickness of the aquifer system.

Specific Storage, S_s [L^{-1}]: In problems of three-dimensional transient flow in a compressible groundwater body, it is necessary to consider the amount of water released from or taken into storage per unit volume of the porous medium. The specific storage is the volume of water released from or taken into storage per unit volume of the porous medium per unit change in head.

Specific Yield, S_y [Dimensionless]: The specific yield of a rock or soil is the ratio of (1) the volume of water which the rock or soil, after being saturated, will yield by gravity to (2) the volume of the rock or soil (Meinzer 1923, 28). The definition implies that gravity drainage is complete. In the natural environment, specific yield is generally observed as the change that occurs in the amount of water in storage per unit area of unconfined aquifer as the result of a unit change in head. Such a change in storage is produced by the draining or filling of pore space and is therefore dependent upon particle size, rate of change of the water table, time, and other variables. Hence, specific yield is only an approximate measure of the relation between storage and head in unconfined aquifers. It is equal to porosity minus specific retention.

Speed ans Velocity: In routine conversation, the terms speed and velocity are often used interchangeably—they are commonly thought to have the same meaning. In physics, however, they are two distinct quantities. *Speed* is a scalar quantity which refers to how fast an object is moving (i.e., the rate of change of distance with time). Thus, if you travel 16 miles in 2 hours, the average speed is 8 miles per hour (mph). Even though most people are confused about the difference between speed and velocity (defined below) most people do know the difference between two identical objects traveling at different speeds. Many know, for example, that a person moving faster (the one with the greater speed) will go farther than the one moving slower in the same amount of time. If we do not understand this concept, we certainly know that anyone moving faster will get where they are going before anyone who is moving slower. Intuitively, we all know that speed deals with both distance and time. We know that sooner means less time and that faster means greater distance (farther). Thus, it logically follows that we can say to double one's speed means doubling one's distance traveled in a given amount of time. Moreover, doubling one's speed would also mean halving the time required to travel a given distance.

Spent Liquor: The liquid residue left after an industrial process; can be a component of waste materials used as fuel.

Spent Sulfite Liquor: End product of pulp and paper manufacturing processes that contains lignins and has a high moisture content; often re-used in recovery boilers. Similar to black liquor.

Spermatogenesis: Formation and development of spermatozoa.

Spill Prevention, Containment, and Countermeasures Plan (SPCP): Plan covering the release of hazardous substances as defined in the Clean Water Act.

Spinner Survey: The use of a device with a small propeller that spins when fluid passes in order to measure fluid flow in a wellbore. The device is passed up and down the well continuously measuring flow to establish where and how much fluid enters or leaves the wellbore at various depths.

Spinning Reserve: A reserve of generation capacity, where generators are kept only, but at idle, in anticipation of an unexpected increase in demand or decrease in supply.

Spirilla: Bacteria shape characterized as being nonflexible, helical, and curved.

Spirometric Evaluation: A test used to measure pulmonary function. A measurement of FVC and FEV1 of 70 percent or greater is satisfactory. A measurement of less than 70 percent may require further pulmonary function evaluation by a medical doctor.

Spoil: Material removed from an excavation.

Sporangiospore: Spores that form within a sac called a sporangium. The sporangia are attached to stalks called sporangiophores.

Spore: Reproductive stage of fungi.

Sprawl: Unplanned development of open land.

Spray Irrigation: A common irrigation method where water is shot from high-pressure sprayers onto crops. Because water is shot high into the air onto crops, some water is lost to evaporation.

Spray Tower Scrubber: A device that sprays alkaline water into a chamber where acid gases are present to aid in neutralizing the gas.

Spring: Place where any natural discharge of groundwater flows at the ground surface. Point at which a stream emerges from an underground course through unconsolidated sediments or through caves.

Spring Overturn: The lake phenomenon whereby the entire body of water within the lake overturns because of changes in water density.

Spur: A groyne built out from a bank of a river, having a head so armored that it cannot be removed by scour. It diverts the flow from a scoured part and may encouraging silting elsewhere.

Sputum: Matter ejected from the lungs and air passages during a cough.

Square-mile foot: A volume of water 1 foot deep over 1 mile^2.

Stability: Atmospheric turbulence; a function of vertical distribution of atmospheric temperature.

Stability Class: Term used to classify the degree of turbulence in the atmosphere.

Stabilization: Conversion of the active organic matter in sludge into inert, harmless material.

Stabilized: Containing a small amount of another substance included to keep the first material from changing form.

Stable Air: A motionless mass of air that holds, instead of dispersing pollutants.

Stable Atmosphere: Marked by air that is cooler at the ground than aloft, by low wind speeds, and consequently, by a low degree of turbulence.

Stabilizer: A substance that renders or maintains a solution, mixture, suspension, or state resistant to chemical change.

Stack: A device on the end of a ventilation system that disperses exhaust contaminants for dilution by the atmosphere.

Stack Effect: 1. Air, as in a chimney, that moves upward because it is warmer than the ambient atmosphere. 2. Flow of air resulting from warm air rising, creating a positive pressure area at the top of a building and negative pressure area at the bottom. This effect can overpower the mechanical system and disrupt building ventilation and air circulation.

Stage II Controls: Systems placed on service station gasoline pumps to control and capture gasoline vapors during refueling.

Stagnation: Lack of motion in a mass of air or water that holds pollutant in place.

Standard Air, Standard Conditions; Standard Temperature and Pressure (STP): 1. Dry air at 70° F (20° C), 29.92 inches HG (760 mm Hg), 14.7 psi, 407 inches of water. 2. As the density of gases depends on temperature and pressure, defining the pressure and temperature against which the volume of gases are measured is customary. The normal reference point is standard temperature and pressure -0ºC at a standard atmosphere of 760 millimeters of mercury. All gas volumes are referred to these standard conditions.

Standard Industrial Classification Code: Also known as SIC Codes, a method of grouping industries with similar products or services and assigned codes to these groups.

Standard Sample: The part of finished drinking water that is examined for the presence of coliform bacteria.

Standards: Norms that impose limits on the amount of pollutants or emissions produced. EPA establishes minimum standards, but states are allowed to be stricter.

Start of a Response Action: The point in time when there is a guarantee or set-aside of funding by EPA, other federal agencies, states or Principal Responsible parties in order to begin response actions at a Superfund site.

State Air Pollution Regulatory Agency (SAPRA): Administers ambient monitoring programs, issues operating permits, conducts compliance inspection, and compels federally mandated emissions-reduction programs for Nonattainment area. Develops and submits for EPA approval an implementation plan that will bring the nonattainment area into compliance with the National Ambient Air Quality Standards within a reasonable time.

State Emergency Response Commission (SERC): Commission appointed by each state governor according to the requirements of SARA title III. The SERCs designate emergency planning districts, appoint local emergency planning committees, and supervise and coordinate their activities.

State Environmental Goals and Indication Project: Program to assist state environmental agencies by providing technical and financial assistance in the development of environmental goals and indicators.

State Implementation Plan (SIP): State's plan for bringing its federally designated nonattainment areas into compliance with the National Ambient Air Quality Standards.

State Management Plan: Under FIFRA, a state management plan required by EPA to allow states, tribes, and U.S. territories the flexibility to design and implement ways to protect groundwater from the use of certain pesticides.

Static Electricity: Static electricity is a workplace hazard because of its potential to ignite (by arc) certain vapor or dust mixtures in air. Various controls can minimize the effects of static charges, dependent on the individual case.

- Selection of suitable materials (i.e., avoiding the use of materials such as clothing composed of synthetic fabrics that generate static electricity) is often the simplest method.
- Modifying a material by spraying its surface to make it conductive can frequently reduce or eliminate the static electricity problem.
- Bonding and grounding can be used to provide a path by which various surfaces on which charges could accumulate can be neutralized.
- Electrostatic neutralizers can be used to neutralize charges on materials.
- (raising the relative humidity above 65 percent) permits static charges to leak off and dissipate.

Static Pressure (SP): The pressure developed in a duct by a fan; the force in inches of water measured perpendicular to flow at the wall of the duct; the difference in pressure between atmospheric pressure and the absolute pressure inside a duct, cleaner, or other equipment; SP exerts influence in all directions, which tends to burst or collapse the duct. It is expressed in inches of water gauge ("wg). A simple example may help you grasp the concept of static pressure. Consider the balloon that is inflated at a given pressure. The pressure within the balloon is exerted equally on all sides of the balloon. No air velocity exits within the balloon itself. The pressure in the balloon is totally the result of static pressure. Note that static pressure can be both negative and positive with respect to the local atmospheric pressure.

Static Water Depth: The vertical distance from the centerline of the pump discharge down to the surface level of the free pool while no water is being drawn from the pool or water table.

Static Water Level: 1. Elevation or level of the water table in a well when the pump is not operating. 2. The level or elevation to which water would rise in a tube connected to an artesian aquifer or basin in a conduit under pressure.

Statics: Statics is the branch of mechanics concerned with the behavior of bodies at rest and forces in equilibrium and distinguished from dynamics (concerned with the behavior of bodies in motion). Forces acting on statics do not create motion. Static applications are bolts, welds, rivets, load-carrying components (ropes and chains), and other structural elements. A common example of a static situation is the bolt and plate assembly. The bolt is loaded in tension and holds two elements together. One force acting on it is the load on the lower element (160-lb. load plus 15 lb. suspending elements. Another force is that caused by the tightened nut (25 lb.). The total effective load on the bolt is 200 lb. (160 + 15 + 25). The plate will fail in shear if the head of the bolt pulls through the plate. To determine the safe load capacity of the plate, the correct tables and equations should be used.

Stationary Sources: Source of air pollution emanating from any fixed or stationary point.

Statistics: A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

STCC Identification Numbers: An acronym for Standard Transportation Commodity Code. A seven digit identification number commonly used for materials shipped by rail. Numbers beginning at 49- are hazardous materials.

STEL: Short-Term Exposure Limit.

Sterilization: The removal or destruction of all microorganisms, including pathogenic and other bacteria, vegetative forms, and spores.

Sterilizer: One of three groups of anti-microbials registered by EPA for public health uses. EPA considers an antimicrobial to be a sterilizer when it destroys or eliminates all forms of bacterial, viruses, and fungi and their spores. Because spores are considered the most difficult form of microorganism to destroy, EPA considers the term *sporicide* to be synonymous with sterilizer.

Still Bottoms: What remains after a spent solvent is distilled (for recycling); composed of a concentrated, highly toxic mixture, far reduced in volume.

Stimulation: A treatment performed to restore or enhance the productivity of a well. Stimulation treatments fall into two main groups, hydraulic fracturing treatments and matrix treatments.

Stocking Density: Number of cattle per unit corral area. Increased density may reduce downwind dust concentrations modestly, but it reduces the linear bunk space available to each animal and may result in behavioral changes that increase stress and reduce

Stomatitis: Inflammatory disease of the mouth.

Storage: Temporary holding of waste pending treatment or disposal, as in containers, tanks, waste piles, and surface impoundments. In hydraulics: the capacity of an aquifer, aquitard, or aquifer system to release or accept water into groundwater storage, per unit change in hydraulic head.

Storage Coefficient, *S* [dimensionless]: The storage coefficient is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In a confined water body the water derived from storage with decline in head comes from expansion of the water and compression of the aquifer; similarly, water added to storage with a rise in head is accommodated partly by compression of the water and partly by expansion of the aquifer. In an unconfined water body, the amount of water derived from or added to the aquifer by these processes generally is negligible compared to that involved in gravity drainage or filling of pores; hence, in an unconfined water body the storage coefficient is virtually equal to the *specific yield*.

Storm Sewer: A sewer that carries only surface runoff, street wash, and snow melt from the land. In a separate sewer system, storm sewers are completely separate for those that carry domestic and commercial wastewater (sanitary sewers).

Stormwater: Normal stormwater containing grit and street debris, but no domestic or sanitary wastes.

Strain: 1. Deformation that results from a stress. Expressed in terms of the amount of deformation per inch. 2. A group of organisms within a species or variety.

Stratification: Temperature-density relationship of water in temperate lakes (>25 ft in depth) that leads to stratification and subsequent turnover or overturn.

Stratigraphy: Study of the formation, composition, and sequence of sediments, whether consolidated or not.

Stratosphere: An atmospheric layer extending from 6 to 7 miles to 30 miles above the earth's surface. *Stratospheric ozone depletion* the thinning of the ozone layer in the stratosphere; occurs when certain chemicals (such as chlorofluorocarbons) capable of destroying ozone accumulate in the upper atmosphere.

Stream: A general term for a body of flowing water; natural water course containing water at least part of the year. In hydrology, it is generally applied to the water flowing in a natural cannel as distinct from a canal.

Stream Classification: Identification of specific water uses for watercourses.

Stream Ecosystem: It is important to understand that the dynamic balance of the stream ecosystem is between population growth and population reduction factors.

Factors that cause the population to increase in number are growth factors. Factors that cause the population to decrease in number are called reduction factors.

In a stream ecosystem, growth is enhanced by biotic and abiotic factors. These factors include:

1. ability to produce offspring
2. ability to adapt to new environments
3. ability to migrate to new territories
4. ability to compete with species for food and space to live
5. ability to blend into the environment so as not to be eaten
6. ability to find food
7. ability to defend itself from enemies
8. favorable light
9. favorable temperature
10. favorable dissolved oxygen (DO) content
11. sufficient water level

The biotic and abiotic factors in a stream ecosystem that reduce growth include:

1. predators
2. disease
3. parasites
4. pollution
5. competition for space and food
6. unfavorable stream conditions (i.e., low water levels)
7. lack of food

✔ **Important Point**: When all populations within a stream ecosystem are in balance, the entire stream ecosystem is in balance.

With regard to stability in a stream ecosystem, the higher the species diversity the greater the inertia and resilience of the ecosystem is. At the same time, when the species diversity is high within a stream ecosystem, a population within the stream can be out of control because of an imbalance between growth and reduction factors, with the ecosystem at the same time still remaining stable.

In regards to instability in a stream ecosystem, recall that imbalance occurs when growth and reduction factors are out of balance. For example, when sewage is accidentally dumped into a stream, the stream ecosystem, via the self-purification process (discussed later), responds and returns to normal. This process is described as follows:

1. raw sewage is dumped into the stream, which
2. decreases the oxygen available as the detritus food chain breaks down the sewage
3. some fish die at the pollution site and downstream
4. sewage is broken down and washes out to sea and is finally broken down in the ocean
5. oxygen levels return to normal
6. fish populations that were deleted are restored as fish about the spill reproduce and the young occupy the real estate formerly occupied by the dead fish
7. populations all return to "normal"

A shift in balance in a stream's ecosystem (or in any ecosystem) similar to the one just described is a fairly common occurrence. In this particular case, the stream responded (on its own) to the imbalance the sewage caused and through the self-purification process returned to normal. Recall that we defined succession as being the method by which an ecosystem either forms itself or heals itself. Thus, we can say that a type of succession has occurred in the polluted stream described above, because, in the end, it healed itself. More importantly, it does not take a rocket scientist to determine that this healing process is a good thing; otherwise, long ago there would have been few streams on Earth suitable for much more than the dumping of garbage.

In summary, through research and observation, ecologists have found that the succession patterns in different ecosystems usually display common characteristics. First, succession brings about changes in the plant and animal members present. Second, organic matter increases from stage to stage. Finally, as each stage progresses, there is a tendency toward greater stability or persistence. Earlier it was stated that succession is usually predictable. This is the case unless humans interfere. Moreover, this illustrates Garrett Hardin's First Law of Ecology: We can never do merely one thing. Any intrusion into nature has numerous effects, many of which are unpredictable (Miller 1988).

Stress: 1. The internal resistance a material offers to being deformed. Measured in terms of the applied load over the area. 2. The forces acting on rock. In the subsurface the greatest force or stress is generally vertical caused by the weight of overlying rock.

Stress and Strain: In materials, stress is a measure of the deforming force applied to a body. Strain (which is often erroneously used as a synonym for stress) is really the resulting change in its shape (deformation). For perfectly elastic material, stress is proportional to stain. This relationship is explained by Hooke's Law, which states that the deformation of a body is proportional to the magnitude of the deforming force, provided that the body's elastic limit is not exceeded. If the elastic limit is not reached, the body will return to its original size once the force is removed. For example, if a spring is stretched by 2 cm by a weight of 1 N, it will be stretched by 4 cm by a weight of 2 N, and so on; however, once the load exceeds the elastic limit for the spring, Hooke's law will no longer be obeyed, and each successive increase in weight will result in a greater extension until the spring finally breaks.

Stress forces are categorized in three ways:

1. Tension (or tensile stress), in which equal and opposite forces that act away from each other are applied to a body; tends to elongate a body.
2. Compression stress, in which equal and opposite forces that act toward each other are applied to a body; tends to shorten it.
3. Shear stress, in which equal and opposite forces that do not act along the same line of action or plane are applied to a body; tends to change its shape without changing its volume.

Stress, Geostatic (Lithostatic): The total weight (per unit area) of sediments and water above some plane of reference. Geostatic stress normal to any horizontal plane of reference in a saturated deposit may also be defined as the sum of the effective stress and the fluid pressure at that depth.

Stress, Preconsolidation: The maximum antecedent effective stress to which a deposit has been subjected and which it can with stand without undergoing additional permanent deformation. Stress changes in the range less than the preconsolidation stress produce elastic deformations of small magnitude. In fine-grained materials, stress increase beyond the preconsolidation stress produced much larger deformations that are principally inelastic (nonrecoverable). Synonymous with "virgin stress." Commonly used in discussion related to land subsidence.

Stress, seepage: Force (per unit area) transferred from the water to the medium by viscous friction when water flows through a porous medium. The forced transferred to the medium is equal to the loss of hydraulic head and is termed the seepage force exerted in the friction of flow.

Stressors: Physical, chemical, or biological entities that can induce adverse effects on ecosystems or human health.

Strip-Cropping: Growing crops in a systematic arrangement of strips or bands that serve as barriers to wind and water erosion.

Strip-Mining: A process that uses machines to scrape soil rock away from mineral deposits just under the earth's surface.

Stripping: A waste control technology whereby volatile compounds are separated from less volatile ones in a liquid mixture by partitioning the more volatile materials to a gas phase of air or steam.

Structural Deformation: Distortion in walls of a tank after liquid has been added or removed.

Structural Discontinuity: A discontinuity of the rock fabric that can be a fracture, fault, intrusion, or differing adjacent rock type.

Structural Failures: Many types of failures are possible, and failures occur for many reasons. Structural failures are important to the safety engineer because when such failures occur, they typically cause damage and injuries (or worse) to workers and others. Structural failures can be caused by any of the following: design errors, faulty material, physical damage, overloading, poor workmanship, and poor maintenance and inspection practices.

- Design errors are not uncommon. They are usually the result of incorrect or poorly made assumptions. For example, the design engineer might assume some load or a maximum load for a design. However, the actual load may be much different in varying conditions. The 1981 Hyatt Regency Skywalk disaster (114 dead, over 200 injured) was caused by underestimating load, a badly designed and altered structural element design, and the failure to properly calculate and check the numbers (see below).
- Faulty materials cause structural failures for two main reasons: lack of uniformity of material, and changes in properties (material strength, ductility, brittleness, and toughness) over time.
- Physical damage caused by usage, abuse, or unplanned events (natural or human-generated) are another cause of structural failure.
- Overloading and inadequate support are common causes of structural failure. A particular structure might have originally been designed to house an office complex, then later reconfigured for use as a machine shop. The added weight of machines and ancillaries is a change in the use environment, which may overload the original structure and eventually lead to failure because of inadequate structural support.
- Poor and faulty workmanship is a factor that must always be considered when studying structural failures. Improper assembly and maintenance of devices, machines, and structures have certainly caused their share of failures and/or collapses. In fact, one of the major reasons many companies have employed quality control procedures in their manufacturing and construction activities is to guard against poor and faulty workmanship.
- Poor maintenance, use, and inspection play an important role in structural failures. Obviously, exposures to various conditions during their use changes structures. Improper maintenance can affect a structure's useful life. Improper use can have the same affect. Inspection is important to ensure that maintenance and use are providing effective care, and to guard against unexpected failure.

On July 17, 1981, at 7:05 PM, the Kansas City, Missouri Hyatt Regency Hotel Atrium held over 1600 people. At that moment, two suspended structurally connected skywalks (bridges that connected two towers on the second and fourth floor levels) failed and fell, crushing the heavily occupied restaurant bar beneath them.

The death toll for this structural failure (the worst in U.S. history) was 114. Over 200 more people were injured, many permanently disabled. Plaintiff's claims amounted to over three billion dollars. (The hotel owner, Donald Hall [of Hallmark Cards], with an admirable sense of duty and decency, settled more than 90 percent of the claims.)

Immediate theories on what caused this structural failure ranged from continued resonance to faulty materials to poor workmanship. A National Bureau of Standards investigation finally discovered the most probable cause—and their findings laid the blame squarely at the feet of the structural engineers.

The cause? A design change submitted by the contractor, and approved by the design engineers and architect. In the original designs, both skywalks were supported by nuts at both second and fourth floor levels, threaded onto single continuous hanger rods, spaced at regular intervals. Because of the single-rod design, while the roof trusses held the load of both, the welded box beams that supported the load of each skywalk were independent of the other.

The change? The contractor's design change shortened the hanger rods, added an extra hole to the fourth floor beams, and hung the second floor walkway by an independent second set of hanger rods from those box beam connections, thus putting the entire load of both walkways on the fourth floor walkway.

This was not the only factor involved, however. In determining the dead load of the structure, the investigators discovered an 8 percent higher load than originally computed, because of changes and additions to decking and flooring materials. The live load, however, was well within the limits. The obviously weak element in the design was the fourth floor box beams, so the investigators tested both new duplicates, and undamaged beams and hanger rods from the Hyatt Regency Atrium.

The National Bureau of Standards report stated that the Skywalks were under-designed, and that the design lacked redundancy. Six important points summarize the report:

- The collapse occurred under loads substantially less than those specified by the Kansas City Building Code.
- All the fourth-floor box beam-hanger connections were candidates for the initiation of walkway collapse.
- The box beam-hanger rod connections, the fourth-floor to ceiling hanger rods and the third-floor-walkway hanger rods did not satisfy the design provisions of the Kansas City Building Code.
- The box beam-hanger to rod connections under the original hanger rod detail (continuous rod) would not have satisfied the Kansas City Building Code.
- Neither the quality of the workmanship nor the materials used in the walkway system played a significant role in initiating the collapse. (Levy and Salvadori 229–230)

The Bureau's findings also made clear that, although the original design would not have met the Kansas City Building Code either, the original design might not have failed under the minor load present that day. In the inevitable court case that followed, the licenses of the principal and the project manager of the firm responsible for the design were revoked. The attorney for the Missouri State licensing board said, "It wasn't a matter of doing something wrong, they just never did it at all. Nobody ever did any calculations to figure out whether or not the particular connection that held the skywalks up would work. It got built without anybody ever figuring out if it would be strong enough." (Levy and Salvadori 230).

Struvite: Colorless to yellow or pale-brown mineral that can build up as crystals on pump impellers and in pipes conveying wastewater.

Stupor: A state of diminished responsiveness and impaired consciousness.

Subacute: Less marked that acute in character; falling between acute and chronic in nature.

Subadiabatic: The ambient lapse rate when it is less than the dry adiabatic lapse rate.

Subchronic: Of intermediate duration, usually used to describe studies or periods of exposure lasting between 5 and 90 days.

Subchronic Exposure: Multiple or continuous exposures lasting for approximately 10 percent of an experimental species lifetime, usually over a three-month period.

Sublethal: Slightly less than lethal; e.g., less than the amount o an agent required to cause death.

Sublime: To pass directly from the solid to the vapor state and condense back to solid form.

Submersible Sump: Pump with both the pumping mechanism and a driving electric motor suspended together at depth in the well.

Subsidence: A dropping of the land surface as a result of ground water being pumped. Cracks and fissures can appear in the land. Some state that subsidence is virtually an irreversible process. Others, like the author of this book, state the jury is still out on the validity of this statement.

Subsidence Inversion: A type of inversion usually associated with a high pressure system, known as anticyclones, which may significantly affect the dispersion of pollutants over large regions.

Subsoil: That part of the soil below the plow layer.

Substance-Specific Applied Research: A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR's toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

Substrate: The material or substance upon which an enzyme acts.

Subsurface Runoff: Water that infiltrates the soil and then moves laterally/vertically below the surface; includes Baseflow and interflow.

Subsurface Wastewater Infiltration System (SWIS): An underground system for dispersing and further treating pretreated wastewater. The SWIS includes the distribution piping/units, any media installed around or below the distribution components, the biomat at the wastewater-soil interface, and the unsaturated soil below.

Subtitle C Landfill: A landfill that accepts hazardous waste (including treated hazardous waste).

Subtitle D Landfill: A landfill that accepts nonhazardous waste.

Subwatershed: Topographic perimeter of the catchment area of a stream tributary.

Suffocation: Sensation of inability to get enough air.

Suggested levels: Nonenforceable guidelines for secondary drinking water standards regarding public welfare.

Sulfur Cycle: The natural circulation of sulfur through the environment.

Sulfur Dioxide: A primary pollutant originating chiefly from the combustion of high-sulfur coals.

Sulfurous Smog: The haze that develops in the atmosphere when molecules of sulfuric acid accumulate, growing in size as droplets until they become sufficiently large to serve as light scatterers.

Sump: A pit or tank that catches liquid runoff for drainage or disposal.

Sunburn: While getting sunburned isn't good for anyone, certain skin-types are particularly susceptible to damage from the sun. High-level protection sunscreen (20 spf), lightweight long sleeved protective clothing, and a hat are indicated for outdoor safety for these individuals. Workers should be reminded that the effects of overexposure to the sun take time to develop. Often the real problem doesn't show up until the workday is over. Though the short term is painful, safety measures should take long-term consequences of sun-exposure (skin problems that can include cancer) into consideration, while focusing on the sun and heat-related problems that cause symptoms that must be addressed immediately.

Superadiabatic: The lapse rate when a parcel of air starting at 1000m at 20ºC, for example, starts moving downward and becomes cooler and denser than its surroundings. Because the ambient air is unstable, it continues to sink.

Superchlorination: Chlorination with does that are deliberately selected to produce water free of combined residuals so large as to require dechlorination.

Supercritical Water: A type of thermal treatment using moderate temperatures and high pressures to enhance the ability of water to break down large organic molecules into smaller, less toxic ones. Oxygen injected during this process combines with simple organic compounds to form carbon dioxide and water.

Superfund: See *CERCLA and SARA*.

Superfund Innovative Technology Evaluation (SITE) Program: EPA program to promote development and use of innovative and site characterization technologies in Superfund site cleanups.

Supernatant: Liquid fraction in a lagoon.

Supplemental Registration: An arrangement whereby a registrant licenses another company to market its pesticide product under the second company's registration.

Supplier of Water: Any person who owns or operates a public water supply.

Surface Condenser: In air pollution control technology, a type of condensation equipment, normally a shell-and-tube heat exchanger. It uses a cooling medium of air or water where the vapor to be condensed is separated from the cooling medium by a metal wall. Coolant flows through the tubes, while the vapor is passed over and condenses on the outside of the tubes, and drains off to storage.

Surface Impoundment: (1) Another name for a garbage dump. (2) Diked or excavated areas used to store liquid hazardous wastes.

Surface Origins: The surface origins of soil contaminants that include gaseous and airborne particulates; infiltration of contaminated surface water; land disposal of solid and liquid waste materials; stockpile, tailings, and spoil; dumps; salt spreading on roads; animal feedlots; fertilizers and pesticides; accidental spills; and composting of leaves and other wastes.

Surface Runoff: The water flow which occurs when soil is infiltrated to full capacity and excess water, from rain, snowmelt, or other sources flows over the land.

Surface Tension: The attraction of molecules to each other on a liquid's surface. Thus, a barrier is created between the air and the liquid.

Surface Uranium Mines: Strip mining operations for removal of uranium-bearing ore.

Surface Water: 1. Water on the earth's surface, exposed to the atmosphere, and mostly the product of precipitation. 2. Where this text says "surface water," it means "waters of the United States."

Surface-Water Treatment Rule: Rule that specifies maximum contaminant level goals for Giardia lamblia, viruses, and Legionella and promulgates filtration and disinfection requirements for public water systems using surface-water or groundwater sources under the direct influence of surface water. The regulations also specify water quality, treatment, and watershed protection criteria under which filtration may be avoided.

Surfacing ACM: Asbestos-containing material that is sprayed or troweled on otherwise applied to surfaces, such as acoustical plaster on ceilings and fireproofing materials on structural members.

Surfacing Material: Material sprayed or troweled onto structural members (beams, columns, or decking) for fire protection; or on ceilings or walls for fireproofing acoustical or decorative purpose includes textured plaster, and other textured wall and ceiling surfaces.

Surfactant: A surface-active substance (soap).

Surrogate Data: Data from studies of test organisms or a test substance that are used to estimate the characteristics or effects on another organism or substance.

Surveillance System: A series of monitoring devices designed to check on environmental conditions.

Survey: A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people.

Susceptibility Analysis: An analysis to determine whether a public water Supply is subject to significant pollution from known potential sources.

Suspect Material: Building material suspected of containing asbestos; e.g., surfacing material, floor tile, ceiling tile, thermal system insulation.

Suspended Loads: Specific sediment particles maintained in the water column by turbulence and carried with the flow of water.

Suspended Sediments: Very fine soil particles that remain in suspension in water for a considerable period of time without contact with the bottom. Such material remains in suspension due to the upward components of turbulence and currents and/or by suspension.

Suspended-Sediment Concentration: The ratio of the mass of dry sediment in a water-sediment mixture to the mass of the water-sediment mixture. Typically expressed in milligrams of dry sediment per liter of water-sediment mixture.

Suspended-Sediment Discharge: The quantity of suspended sediment passing a point in a stream over a specified period of time. When expressed in tons per day, it is computed by multiplying water discharge (in cubic feet per second) by the suspended-sediment concentration (in milligrams per liter) and by the factor 0.0027.

Suspended Solids: (1) Undissolved solids that are in water, wastewater, or other liquids, and are largely removable by filtering or centrifuging. (2) The quantity of material filtered from wastewater in a lab test, as prescribed in APHA Standard Methods for the Examination of Water and Wastewater or similar reference.

Suspension: Suspending the use of a pesticide when EPA deems it necessary to prevent an imminent hazard resulting from its continued use. An emergency suspension takes effect immediately immediate hazard resulting from its continued use. An emergency suspension takes effect immediately, under an ordinary suspension a registrant can request a hearing before the suspension goes into effect. Such a hearing process might take six months.

Suspension Culture: Cells growing in a liquid nutrient medium.

Swamp: A type of wetland dominated by woody vegetation but without appreciable peat deposits. Swamps may be fresh or slat water and tidal or non-tidal.

Switching Devices: Certain switching devices can reduce or eliminate electrical hazards. These include interlocks, lockouts, and thermal or overspeed switches. Interlocks are switches that prevent access to an energized or dangerous location. Often attached to access doors, panels and gates, interlocks act to shut off power to the equipment whenever these devices are opened. Probably the most commonly used and most familiar interlock device is the one installed in most washing machine lids, which shuts down the machine when the lid is opened.

Lockouts: Recall that a lockout procedure involves placing a lock on a switch, circuit breaker, or other device to prevent the switch, circuit breaker, or equipment from being turned on or energized.

Thermal and overspeed cutout devices are commonly used to protect electrical equipment (and thus the operator). A thermal cutout is simply a temperature-sensitive switch with a preset limit designed to interrupt power when the temperature exceeds a certain value. As its name implies, an overspeed switch operates when it senses that a motor or other device operates too fast. Obviously, excessive speed may create dangerous conditions and/or indicate failure of equipment. The overspeed switch operates to shut down an overspeeding device by interrupting power to it.

Symbiotic: A close relationship between two organisms of different species; one where both partners benefit from the association.

Syncope: A brief loss of consciousness caused by a temporary deficiency of oxygen in the brain; a blackout; fainting.

Synergism: An interaction of two or more chemicals that results in an effect greater than the sum of their separate effects.

Synesthesias: Mixed sensory perceptions (e.g., seeing sounds or felling colors).

Syngas: A synthesis gas produced through gasification of biomass. Syngas is similar to natural gas and can be cleaned and conditioned to form a feedstock for production of methanol.

Synoptic: Of or relating to data obtained nearly simultaneously over a large area of the atmosphere.

Synthesis: The formation of a substance or compound from more elementary compounds.

Synthetic: Produced artificially; not of natural origin.

Synthetic Organic Chemicals: Man-made (anthropogenic) organic chemicals. Some SOCs are volatile; others tend to stay dissolved in water instead of evaporating.

Synthetic Organic Compounds: Organic compounds created by industry either inadvertently as a part of a chemical process or for use in a wide array of applications for modern day life. Some that have been created are persistent in the environment (slow to decompose) because oxidizers, such as soil microbes, may not be readily able to use them as an energy source.

System-Specific Policy: A policy written for a specific system or device.

System with a Single Service Connection: A system that supplies drinking water to consumers via a single service line.

Systemic: Affecting the body generally; not localized.

Systemic Agent: A substance with whole-body (systemic) or multi-organ-system effects. This category includes so-called "Blood Agents," as well as other agents with systemic effects.

Systemic Pesticide: A chemical absorbed by an organism that interacts with the organism and makes the organism toxic to pests.

Systemic Toxicity: Whole-body toxicity.

T

T-Wave: The third and last common wave in an electrocardiogram. It reflects the electrical activity produced when the ventricles are recharging for the next contraction (repolarizing).

Tachycardia: A rapid heart rate, especially one above 100 beats per minute in an adult.

Tachypnea: Rapid breathing.

Tagout: The placement of a tagout device on an energy isolating device, in accordance with an established procedure, to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed.

Tagout Device: A prominent warning device, such as a tag and a means of attachment that can be securely fastened to an energy isolating device in accordance with an established procedure, to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed.

Tail Water: The runoff of irrigation water from the lower end of an irrigated field.

Tailings: The residual fine-grained waste rejected after mining and processing of ore, usually after washing.

Tailpipe Standards: Emissions limitations applicable to mobile sources engine exhaust.

Tall Oil: The oily mixture of rosin acids, fatty acids, and other materials obtained by acid treatment of the alkaline liquors from the digesting (pulping) of pine wood.

Tamper: To deliberately alter a system's logic, data, or control information to cause the system to perform unauthorized functions or services.

Tampering: Adjusting, negating, or removing pollution control equipment on a motor vehicle.

Taste and Odor: A water quality parameter.

Tcf: Trillion cubic feet; a unit typically used to define gas production volumes in the coalbed methane industry; one Tcf is roughly equivalent to the volume of gas required to heat approximately twelve million households for one year (based on the Department of Energy's average household energy consumption statistic, 2001).

TCLP (Toxicity Characteristics Leaching Procedure): Replaced the EP Toxicity Test; it is designed to identify wastes likely to leach hazardous concentrations of particular toxic constituents into the surrounding soils or groundwater.

TCP/IP: A synonym for "Internet Protocol Suite," of which the Transmission Control Protocol and the Internet Protocol are important parts. The basic communication language or protocol of the Internet, TCP/IP is often used as a communications protocol in a private network (either an Intranet or an Extranet).

TDS: Total dissolved solids. Used to describe the amount of solid materials in water.

Technical Assistance Grant (TAG): As part of the Superfund Program, Technical Assistances Grants of up to $50,000 are provided to citizens' groups to obtain assistance in interpreting information related to clean-ups at Superfund sites or those proposed for the National Priorities List. Grants are sued by such groups to hire technical advisers to help them understand the site-related technical information for the education of response activities.

Technical-Grade Active Ingredient (TGA): A pesticide chemical in pure from as it is manufactured prior to being formulated into an end-use product (e.g., wettable powders, granules, emulsifiable concentrates). Registered manufactured products composed of such chemicals are know as Technical Grade Products.

Technology-Based Limitations: Industry-specific effluent limitations based on best available preventive technology applied to a discharge when it will not cause a violation of water quality standards at low stream flows. Usually applied to discharges into large rivers.

Technology-Based Standards: Industry-specific effluent limitations applicable to direct and indirect sources which are developed on a category-by-category basis using statutory factors, not including water-quality effects.

TEEL: Department of Energy Temporary Emergency Exposure Limit.

TEEL-0: The threshold concentration below which most people will experience no appreciable risk of health effects.

TEEL-1: The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

TEEL-2: The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

TEEL-3: The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

Temperature: A measure of the average kinetic energy of the molecules.

Temperature Inversion: A condition characterized by an inverted lapse rate.

Tensile Strength: The property that resists forces acting to pull the metal apart—a very important factor in the evaluation of a metal.

Tepid: Lukewarm (referring to liquids)

Teratogen: A substance capable of causing birth defects.

Teratogenesis: The introduction of nonhereditary birth defects in a developing fetus by exogenous factors such as physical or chemical agents acting in the womb to interfere with normal embryonic development.

Terrorism: When someone mentions terrorism today most of us instantly picture fully loaded and deliberately guided airplanes crashing into tall buildings, military installations, or a farm field somewhere, anywhere. Collateral to and almost always mentioned in the same breath as 'terrorism' are the words Homeland Security. According to Governor Tom Ridge, "You may say Homeland Security is a Y2K problem that doesn't end Jan. 1 of any given year" (Henry 2002).

Governor Tom Ridge, a U.S. political figure who served as a member of the United States House of Representatives (1983-1995), governor of Pennsylvania (1995-2001), assistant to the president for Homeland Security (2001-2003), and the first United States Secretary of Homeland Security (2003-2005), got it right, Homeland Security is an on-going problem that must be dealt with 24/7. Simply, there is no magic on-off switch that we can use to turn off the threat of terrorism in the United States or elsewhere.

The threat to our security is not only on-going but is also universal, including potential and real threats from within—from our own citizens. Consider the American Timothy McVeigh, for example, who blew up the government building in Oklahoma City in 1995 killing almost 200 people, including several children. McVeigh, who bombed the building in revenge for the FBI's Waco, Texas, raid, thought the army (he was a former decorated U.S. Army veteran) had implanted chip in his butt to track his movements, according to reports.

It is interesting to note that McVeigh, who was no doubt suffering from some type of severe disturbance, acted primarily alone. Actually, McVeigh is the exception that proves the rule—most terrorist acts on America are mostly planned by a group beforehand.

Again, notwithstanding the fact that most terrorist acts on America are mostly planned by a group (usually a group of foreigners) beforehand, as with the McVeigh case, this is not always the case. For example, consider the scenario that follows. Note that the following incident occurred in 1991, before McVeigh, before the first attack on the World Trade Center, before 9/11, and prior to the anthrax attacks.

Case Study—Revenge Is Mine, Sayeth Daniel (Spellman, 1997)

Daniel, tall, lean, mean, and evil, stood on the rail tracks outside the water treatment plant's western fence line, peering through the 8' chain-link fence surrounding the plant site at the 55-ton rail tank car inside the plant. When not checking on the tank car, his gaze flashed from right to left, left to right, and back to the rail car. He was being careful, watchful, and deliberate. He was well aware of the plant operator's schedule, her hourly rounds; he had worked the same plant, same sampling route, and same job for five years before his "unlawful" termination (he had been terminated for several reasons but primarily because he failed to treat processed water with chlorine for disinfection. "Adding poisonous chlorine to good ol' drinking water is a commie plot," he always said).

He thought, "Those frog-faced managers said I was greedy, heartless, predatory, unethical, lazy, buffoonish, dysfunctional, and totally incompetent—a real basket-case, one of them said. Well, I will show them."

As the last rays of sunshine struck his back (he did not feel those warming rays; his body was cold, dry, and ready; warming had no effect), he glanced down at the cardboard box at his feet. Then, having heard something, he crouched down a bit and glanced inside the plant again—nothing stirred, not even his breath, just lengthening shadows. Upright again, he glanced at the box, filled with twelve bottles of yellow-gold liquid. The sight of the bottles warmed his coldness a bit. As he stood there waiting for the right moment, for the sun to meet the horizon, his long, sharp-looking face almost grimaced into smile as he thought about those twelve bottles of death at his feet.

Just a week earlier, when he was convinced his master plan would work (failure was not an option), he had fashioned his crude incendiary weapons. The Molotov cocktails (Daniel liked to call them homemade frag) were carefully put together using tall, glass bottles partly filled with gasoline with a touch of sugar to help the gasoline cling to the target. The mouth of each bottle was stopped up with a cork, and a cloth rag was fixed securely around each mouth.

The target of these cocktails? The 55-ton railcar, fully loaded, of course, with deadly chlorine gas. In Daniel's mind, this was the perfect scenario. He could already foresee that yellow-green mushroom cloud of death crossing the plant site, aided by the wind, which seemed to be freshening as the sun touched the horizon.

Looking all around to ensure he was alone, that no one was near the rail car, no one was behind him, and his path of escape was clear, he pulled the small whiskey flask filled with gasoline and the disposable lighter from his coat pocket. Quickly, he poured gas on each of the 12 bottle wicks and put the closed flask back into his pocket. He picked up the first bottle, lit the rag, looked around, and threw the lighted bottle over the fence toward the railroad car. He missed. The first bottle landed in the tall grass, next to a stack of word and junk; it just sat there, though he could see the lighted wick in the darkening plant. He lit another wick and threw. He repeated this procedure several times until the box was empty. He took one last glimpse at his work and noticed that two or three of the bottles had actually struck the metal of the tank car, bursting and flaming instantly. His work was done. It was time to haul ass; he did.

Meanwhile . . . during the same time period . . .
The last rays of the setting sun touched the running waters of the large river that coursed its way through the downtown region of a large metropolitan area. A plant operator at the 100 mgd water treatment plant, located in the city along the same river bank, was walking the plant site making her rounds. Stopping at a sample point, she pulled a sample, then deposited the sample and its bottle into the carrying tray. Grabbing the tray, she proceeded down the long winding stairway from #3 rapid-sand-filter. At the foot of the stairs she stepped onto the gravel path and proceeded toward the final effluent sampling point.

She walked along the path and then turned to her right. Straight ahead, just behind the 55-ton chlorine rail tank car, she noticed an orange glow.

Recognizing the orange glow for the brush fire that it was, the operator dropped the sample tray and ran the 250 feet to the plant's main control center to alert the shift lead operator about the brush fire near the chlorine tank car. While she dialed 9-1-1, the lead operator activated the site emergency alarm and then used his portable radio to direct a plant assistant operator to meet him at the tank car.

With the plant's emergency alarm siren wailed falsetto throughout the plant site and the neighborhood, the lead operator and assistant were standing together approximately 100 feet from the chlorine tank car. They could see the brush fire was growing in strength; it was being fed by a brisk wind.

The lead operator wondered what to do next—hell, what to do *first*—his mind was blank. Quickly it cleared and a series of instantaneous thoughts entered his mind. First, he understood the gravity of the situation: a growing fire was about to engulf 55 tons of chlorine. Second, he realized there was no way he and the assistant operator could move the tank car out of harm's way, though it appeared to him that the tank was already engulfed in flame. Third, he realized the spur line the tank car was positioned on was heavily overgrown with brush (just a few weeks earlier he had directed a former employee, Daniel, to cut the overgrowth and remove the pile of wood near the railcar). As the lead operator and assistant advanced a few yards closer to the tank car, the lead operator noticed another problem. A plant maintenance crew had stacked a pile of wooden cement forms next to the spur line, within a few feet of the tank car; these forms were on the same side of the car where fire was quickly approaching from the end not already aflame. The lead operator knew he would have to act fast to prevent an extremely dangerous situation, the total engulfment of the tank car.

He had to do something.

He did.

The lead operator directed the assistant to go over to the nearest building, the non-potable water pump house, and bring a fully charged fire hose back to the fire with him. Then the lead operator darted off in the opposite direction, toward the chemical handling building, to get another fire hose.

About five minutes later both the operators, manning two fully charged 1.5-inch fire hoses, approached the tank car from the side opposite where the brush fire had already reached the spur and had ignited the wood cement forms; the fire was beginning to grow, to burn with purpose.

Standing to one side with his fire hose directed at the midsection of the chorine tank car body while, at the same time, the assistant, at the other end of the tank car, began directing a steady stream of non-potable water (NPW) in the same general area, the operator could feel the heat from the growing fire.

A few minutes later the fire was burning the entire stack of wood cement forms, generating such intense heat that both operators had to move back a few feet from the car. At that same moment, the tank car emergency relief vale, having reached its design activation pressure, lifted, releasing a controlled stream of deadly chlorine gas to the atmosphere.

Along with the plant alarm siren, the operators could hear the sirens of emergency response vehicles approaching the plant site as the tank care emergency relief valve failed completely. A bad situation just got worse. Now, instead of releasing a controlled amount of chlorine gas, the entire contents of the tank car were escaping full force a steady stream of yellow-green death, all 55 tons.

About six-tenths of a mile away from the water treatment plant, the fire, and the escaping gas, at about the time the emergency relief valve on the 55-ton chlorine tank car had failed, several evening classes at the university were in progress. The 400 college students had heard the plant site emergency alarm siren and then the other sirens as emergency vehicles raced by the university campus toward the water treatment plant, but they paid them no mind. They had heard these alarms several times before; emergencies in the central city were a common occurrence.

Meanwhile, back at the plant, the operators were now fully engulfed by the chlorine's yellow-green cloud of death; they were about to take their last breaths. In the plant control room, the operator who had discovered the fire and sounded the alarm had been busy. Not only had she notified the authorities about the emergency at the plant, she had also called the plant manager and chief operator and filled them in about the fire.

When she heard the emergency responder's sirens, she ran outside just in time to see the fire department and local hazardous materials (hazmat) team enter the plant site through the front gates. However, because darkness had set in, she did not see the dense yellow-green cloud of chorine gas that she walked right into. Instantly overcome by the choking chlorine gas, she fell to her knees, coughing and gasping for air. Instead of air, she filled her lungs with deadly chlorine gas; she died five minutes later.

The emergency responders were not familiar with the plant site they had entered; they had not been invited to tour the plant to learn the layout of the site. However, from information provided to the 911 operator, the emergency responders did know about the fire and the 55-ton tank car of chlorine. From knowledge they had gained through their training, they understood the danger involved with chlorine gas and fire. What they did not know, however, was that the fire had already reached the chlorine tank car and that the tank car emergency relief valve had already activated and released its entire load into the atmosphere.

However, these firefighters and hazmat responders knew their jobs. They had been properly trained in hazardous materials emergency response procedures; therefore, as they entered the plant site they were cautious. They were also alert enough to recognize, with the help of their spot lights, that the yellowish-green cloud of death was moving directly toward them.

It didn't take long before the Fire Captain in charge of this emergency situation gave the order for his responders to retreat to safer ground; they did.

Meanwhile, at the university, two blocks from the treatment plant—less than 600 feet away—class had ended and students poured out of their classrooms. Several students left the building to go home. Others stepped outside for a few minutes to smoke cigarettes before the start of their next class.

About the time the emergency responders were exiting the plant site to set up a command post in a safe zone (approximately 1.6 miles from the plant), the same brisk wind that had steered the fire toward the tank car and stoked the fire there was pushing the ground-hovering poisonous gas toward the front entrance of the college buildings where students were joking and smoking.

Within a few minutes the chlorine cloud came face-to-face with the college students.

Several of the students survived the chlorine gas with only minor respiratory irritation. A few were more seriously affected; they were rushed to a local hospital. An even smaller number of students, those in the parking lot fronting the school, were more profoundly affected; later, three of these students died.

During daylight the next day, after the chlorine had dissipated and no longer was an issue, and for several days after this incident, investigators and other interested viewers had little trouble following the path the deadly chlorine cloud had taken. Its 1.5-mile path was clearly marked by dead grass, flowers, insects, bushes, trees, cats, dogs, raccoons, squirrels, and ducks.

After an extensive criminal investigation, Daniel was charged, tried, and fried in the electric chair—obviously, he had forgotten or never had been privy to that old Chinese saying: "He who seeks revenge should dig two graves." Local newspapers reported the incident as "Daniel's Revenge: The Actions of a Deranged Eco-Terrorist." One news source called Daniel's actions "environmental terrorism." Daniel's entire legal process, including execution, was complete one day prior to September 11, 2001 (9/11).

What Is Terrorism?

If we were to ask 100 different individuals to define terrorism, it might be surprising to many and not to some that we would likely receive 100 different definitions. As a case in point, consider the following: if we were to ask 100 different individuals to describe the actions of Daniel in the railroad tank car incident, how would they describe him and his actions? You might be surprised. In 2000 and again in 2002, pre- and post-9/11, 100 randomly selected Old Dominion University environmental health juniors and seniors ("Generation Why" students ranging in age from 20 to 46 years old) were asked to read about Daniel's chlorine tank car incident and reply to a non-scientific survey questionnaire. The three questions and the students' responses to this unscientific survey are listed in the Table.

From the Old Dominion University survey, it is clear that the students' perceptions of Daniel's actions in the chlorine tank car incident shifted dramatically from pre 9/11 to post 9/11. For example, before 9/11, when asked to select the best pre-9/11 descriptor to characterize Daniel, "crazy" and "insane" ranked high; however, after 9/11, the student's perception shifted away from crazy and insane to "terrorist." Likewise, "madness" and "workplace violence" ranked high in the students' pre-9/11 descriptions of Daniel's actions; however, his actions post 9/11 overwhelmingly were described as "terrorism."

It is interesting to note that even though the 2000 year group reported prior to September/October 2001 anthrax attacks and pre 9/11 events that this student group's response were provided after such events as the World Trade Center attack of 1993 and Timothy McVeigh's 1995 mass murder of the occupants of the Government building in Oklahoma City, Oklahoma. This may help to explain why the year 2000 students' were somewhat reluctant to describe Daniels's actions as terrorism and/or to label him as a terrorist.

After studying this apparent anomaly (in the author's view) for several years, it has become obvious that terrorism, like environmental pollution, is a personal judgment call. Consider, for example, two neighbors living next door to a foul-smelling chemical plant. One of the neighbors works fulltime at the plant, while the other neighbor works elsewhere. Each morning when the neighbor who does not work at the plant steps outside his house to go to work, she has learned to hold her nose against the horrendous odor emanating from the plant site. There is absolutely no doubt in her mind that she lives next door to a pollution source. On the other hand, the other neighbor, the fulltime employee of the plant, steps outside his home to go to the plant to work his shift, he smells the same odor his neighbor does. However, when the plant employee smells the odor, he does not smell pollution;

Student Perceptions of Daniel's Actions

Question 1: In your opinion, Daniel was . . .

	Number of Responses	
*Students' Responses Descriptors**	*Pre 9/11 (2000)*	*Post 9/11 (2002)*
crazy	22	12
a disgruntled former employee	10	2
insane	32	4
misguided	1	0
a cold-blooded murderer	3	5
a misfit	1	0
deranged	6	4
a lunatic	5	6
a bully	17	10
a terrorist	3	57
not sure	0	0
Totals	100	100

Question 2: In your opinion, Daniel's actions are best described as ...

	Number of Responses	
*Students' Response Descriptors**	*Pre 9/11 (2000)*	*Post 9/11 (2002)*
madness	45	5
frustration	9	2
desperation	4	0
dysfunctional thinking	2	0
legitimate concern	1	0
threatening	6	1
terrorism	5	79
workplace violence	20	0
not sure	8	13
Totals	100	100

Question 3: If you described Daniel's actions as terrorism, are they best described as generic terrorism, eco-terrorism or environmental terrorism?

Generic Terrorism	*Eco-Terrorism*	*Environmental Terrorism*
29	10	40

* Student response descriptors were provided to the students by the instructor.

instead, he detects the sweet smell of money in the bank and job security. Thus, terrorism, like pollution, may be a judgment call. That is, unless you happen to be a victim of terrorism.

Terrorism by any other name is …

From the preceding discussion we might want to sum up terrorism as being relative, a personal judgment. But is it really relative? Is it a personal judgment? What is terrorism?

Take your choice. Seemingly, there is an endless list of definitions. Let's review a few of these definitions.

Standard Dictionary Definition of *Terrorism*

After reviewing several dictionaries, a fairly standard definition of *terrorism* is the unlawful use or threatened use of force or violence by a person or an organized group against people or property with the intention of intimidating or coercing societies or governments, often for ideological or political reasons.

America's *National Strategy for Homeland Security* defines *terrorism* as "Any premeditated, unlawful act dangerous to human life or public welfare that is intended to intimidate or coerce civilian populations or governments" (NSHS, 2006).

U.S. State Department defines *terrorism* as "Premeditated, politically motivated violence perpetrated against noncombatant targets by subnational groups or clandestine agents" (USC, 2005).

The FBI defines *terrorism* as "The unlawful use of force or violence against persons or property to intimidate or coerce a Government, the civilian population, or any segment thereof, in furtherance of political or social objectives" (FBI, 2006).

Note that the FBI divides terrorism into two categories: domestic (homegrown), involving groups operating in and targeting the United States without foreign direction; and international, involving groups that operate across international borders and/or have foreign connections.

Well, at this point the obvious question is do you now know what terrorism is? That is, can you definitely define it? If you can't define it, you are not alone—not even the U.S. government can definitively define it. Maybe we need to look at other sources—views from the real experts on terrorism.

Osama bin Ladin's View on Terrorism: "Wherever we look, we find the U.S. as the leader of terrorism and crime in the world. The U.S. does not consider it a terrorist act to throw atomic bombs at nations thousands of miles away [Japan during World War II], when those bombs would hit more than just military targets. Those bombs rather were thrown at entire nations, including women, children, and elderly people. . . ." (Bergen, 2002).

Another View (court testimony) on Terrorism from Ramzi Ahmed Yousef (He helped organize the first terrorist attack on the World Trade Center): "You keep talking also about collective punishment and killing innocent people to force governments to change their policies; you call this terrorism when someone would kill innocent people or civilians in order to force the government to change its policies. Well, when you were the first one who invented this. . . .

"You were the first one who killed innocent people, and you are the first one who introduced this type of terrorism to the history of mankind when you dropped an atomic bomb which killed tens of thousands of women and children in Japan and when you killed over a hundred thousand people, most of them civilians, in Tokyo with fire bombings.

"You killed them by burning them to death. And you killed civilians in Vietnam with chemicals as with the so-called Orange agent. You killed civilians and innocent people, not soldiers, innocent people every single war you went. You went to wars more than any other country in this century, and then you have the nerve to talk about killing innocent people.

"And now you have invented new ways to kill innocent people. You have so-called economic embargo which kills nobody other than children and elderly people, and which other than Iraq you have been placing the economic embargo on Cuba and other countries for over 35 years…

"The government in its summations and opening said that I was a terrorist. Yes, I am a terrorist and I am proud of it. And I support terrorism so long as it was against the United States Government and Israel, because you are more than terrorists; you are the one who invented terrorism and using it every day. You are butchers, liars and hypocrites [sic]" (NY Times, 1998).

An Old Cliché on a Terrorist:

"One man's terrorist is another man's freedom fighter."

In question #3 of the Old Dominion University survey (see the Table) students who had characterized Daniel's actions as terrorism were asked to select the type of terrorism: generic terrorism, eco-terrorism or environmental terrorism. As shown in the Table the 79 students' selections varied. What the table does not show is why the students made the choice they did. In this regard, when asked specifically why they answered as they did none of them gave specific answers. Indeed, some of the students said they made their selections based on what they perceived to be the best selection, the best descriptor. None of the students queried were able to definitively distinguish between the three descriptor terms used.

So, what is the difference between the *terms terrorism*, *eco-terrorism*, and *environmental terrorism*? To this point we have already defined *terrorism* in several different ways. In defining *eco-terrorism* and *environmental terrorism* we turn to Chalecki's (2001) definitions. She notes that *environmental terrorism* can be defined "as the unlawful use of force against in situ environmental resources so as to deprive populations of the benefit(s) and/or destroy other property." In contrast, eco-terrorism is the violent destruction of property in the interest of saving the environment from human encroachment and destruction. More concisely, environmental terror involves targeting natural resources. Eco-terrorism involves targeting the build environment such as roads, buildings, and trucks, ostensibly in defense of nature resources.

Again, from the preceding points of view, it can be seen that defining terrorism or the terrorist is not straightforward and never easy. Even the standard dictionary definition leaves us with the vagaries and ambiguities of other words typically associated with terrorism such as in the definitions of *unlawful* and *public welfare* (Sauter and Carafano 2005).

At this point, the reader may wonder, "Why should we care; that is, what difference does it make what the definition of *terrorist* or *terrorism* is?" Definitions are important because in order to prepare for the terrorism contingency, domestic or international, we must have some feel, as with any other problem, for what it is we are dealing with. We are fighting a war of ideas. We must attempt to understand both sides of the argument, even though the terrorist's side makes no sense to an American or other freedom loving occupant of the globe.

Finally, while it is difficult to pinpoint an exact definition of *terrorism*, we certainly have little difficulty in identifying it when we see it, when we feel it, when suffer from it. Consider, for example, in the earlier account of Daniel's actions and the chlorine disaster. Put yourself in the place of those college students who were simply leaving campus buildings to cross the parking lot to their cars to make the journey home. In particular, put yourself in the place of one of those female students who was pregnant and who, as she approached her parked car, looked up and saw that yellow-green cloud of death racing with the wind toward her, eventually surrounding her, and then killing her. She could not have known that an American terrorist had caused an act of terrorism on U.S. soil that killed her. No, she did not know that. There is one thing she knew for certain; she knew that crushing feeling of terror as she struggled to breathe. Thus, by any other name terrorism is best summed up as an absolute feeling of Terror—nothing judgmental about that—just Terror with a capital T.

In addition to the preceding information on terror and terrorism the authors feel it is important to define many of the terms that are currently used in discussions related to the two words. Accordingly, we have included the following terms in order to gain better understanding of this complex topic.

Abu Sayyaf—Meaning "bearer of the Sword"; the smaller of the two Islamist groups whose goal is to establish an Iranian-style Islamic state in Mindanao in the Southern Philippines. In 1991, the group split from the Maro National Liberation Front with ties to numerous Islamic fundamentalist groups, they finance their operations through kidnapping for ransom, extortion, piracy, and other criminal acts. It is also thought that they receive funding from al Qaeda. It is estimated that there are between 200 and 500 Abu Sayyaf terrorists, mostly recruited from high schools and colleges.

acid bomb—A crude bomb made by combining muriatic acid with aluminum strips in a two-liter soda bottle.

aerosol—A fine mist or spray, which contains minute particles.

Afghanistan—At the time of 9/11, Afghanistan was governed by the Taliban and Osama bin Laden called it home. Amid U.S. air strikes, which began on October 7, 2001, the United States sent in more than $300 million in humanitarian aide. In December, 2001, Afghanistan reopened their embassy for the first time in more than twenty years.

aflatoxin—A toxin created by bacteria that grow on stored foods, especially on rice, peanuts, and cotton seeds.

Agency—A division of government with a specific function, or a non-governmental organization (e.g., private contractor, business, etc.) that offers a particular kid of assistance. In the incident command system, agencies are defined as jurisdictional (having statutory responsibility for incident mitigation) or assisting and/or cooperating (providing resources and/or assistance).

air marshal—A federal marshal whose purpose is to ride commercial flights dressed in plain clothes and armed to prevent hijackings. Israel's use of air marshals on El Al is credited as the reason Israel has had a single hijacking in thirty-one years. The United States started using air marshals after September 11. Despite President Bush's urging there are not enough air marshals to go around, so many flights do not have them.

airborne—Carried by or through the air.

al-Gama'a al-Islamiyya (The Islamic Group, IG)—Islamic terrorist group that emerged spontaneously during the 1970's in Egyptian jails and later in Egyptian universities. After President Sadat released most of the Islamic prisoners from prisons in 1971, groups of militants organized themselves in groups and cells, and al-Gama'a al-Islamiyya was one of them.

al Jazeera—Satellite television station based in Qatar and broadcast throughout the Middle East al Jazeera has often been called the "CNN" of the Arab world.

al Qaeda—Meaning "the Base"; an international terrorist group founded in approximately 1989 and dedicated to opposing non-Islamic governments with force and violence. One of the principal goals of al Qaeda was to drive the U.S armed forces out of the Saudi Arabian peninsula and Somalia by violence. Currently wanted for several terrorist attacks, including those on the U.S. embassy in Kenya and Tanzania as well as the first and second World Trade Center bombings, and the attack on the Pentagon.

al Tahwid—A Palestinian group based in London which professes a desire to destroy both Israel and the Jewish people throughout Europe. Eleven al Tahwid were arrested in Germany allegedly as they were about to begin attacking that country.

alpha radiation—The least penetrating type of nuclear radiation. Not considered dangerous unless particles enter the body.

American Airlines Flight 11—The Boeing 767 carrying eighty-one passengers, nine flight attendants, and two pilots, which was highjacked and crashed into the north tower of the World Trade Center at 8:45 a.m. eastern Time on September 11, 2001. Flight 11 was en route to Los Angeles from Boston.

American Airlines Flight 77—The Boeing 757 carrying fifty-eight passengers, four flight attendants, and two pilots, which was highjacked and crashed into the Pentagon at 9:40 a.m. Eastern Time on September 11, 2001. Flight was en route to Los Angeles from Dulles International Airport in Virginia.

ammonium nitrate-fuel oil (ANFO)—A powerful explosive made by mixing fertilizer and fuel oil. The type of bomb used in the first World Trade Center attack as well as Oklahoma City bombing.

analyte—The name assigned to a substance or feature that describes it in terms of its molecular composition, taxonomic nomenclature, or other characteristic.

anthrax—An often fatal infectious disease contracted from animals. Anthrax spores have such a long survival period; the incubation period is short; disability is severe, making anthrax a bioweapon of choice by several nations.

antidote—A remedy to counteract the effects of poison.

antigen—A substance which stimulates an immune response by the body immune system recognizes such substances as foreign and produces antibodies to fight them.

antitoxin—An antibody which neutralizes a biological toxin.

Armed Islamic Group (GIA)—An Algerian Islamic extremist group which aims to overthrow the secular regime in Algeria and replace it with an Islamic state. The GIA began its violent activities in early 1992 after Algiers voided the victory of the largest Islamic party, Islamic Salvation Front (FIS), in the December 1991 elections.

asymmetric threat—The use of crude or low-tech methods to attack a superior or more high-tech enemy.

Axis of Evil—Iran, Iraq, and North Korea as mentioned by President G.W. Bush during his State of the Union speech in 2002 as nations which were a threat to U.S security due to harboring terrorism.

Baath Party—The official political party in Iraq until the United States debaathified Iraq in May 2003, after a war which lasted a little over a month. Saddam Hussein, the former ruler of the Baath party, was targeted by American-led coalition forces and fled. Baath party members have been officially banned from participating in any new government in Iraq.

Beltway Sniper—For nearly a month in October 2002, the Washington D.C., Maryland, and Virginia area was the hunting grounds for 41-year old John Allen Muhammad and 17-year old Lee Boyd Malvo. Dubbed "the Beltway Sniper" by the media, they shot people at seemingly random places such as schools, restaurants, and gas stations.

Bioaccumulative—Substances that concentrate in living organisms as the breather contaminated air drink or live in contaminated water or eat contaminated food rather than being eliminated through natural processes.

biochemical warfare—Collective term for use of both chemical warfare and biological warfare weapons.

biochemterroism—Terrorism using as weapons biological or chemical agents.

biological ammunition—Ammunition designed specifically to release a biological agent used as the warhead for biological weapons. Biological ammunition may take many forms, such as a missile warhead or bomb.

biological attacks—The deliberate release of germs or other biological substances that cause illness.

Biosafety Level 1—Suitable for work involving well-characterized biological agents not known to consistently cause disease in healthy adult humans, and of minimal potential hazard to lab personnel and the environment. Work is generally conducted on open bench tops using standard microbiological practices.

Biosafety Level 2—Suitable for work involving biological agents of moderate potential hazard to personnel and the environment. Lab personnel should have specific training in handling pathogenic agents and be directed by competent scientists. Access to the lab should be limited when work is being conducted, extreme precautions should be taken with contaminated sharp items, and certain procedures should be conducted in biological safety cabinets or other physical containment equipment if there is a risk of creating infectious aerosols or splashes.

Biosafety Level 3—Suitable for work done with indigenous or exotic biological agents that may cause serious or potentially lethal disease as a result of exposure by inhalation. Lab personnel must have specific training in handling pathogenic and potentially lethal agents and be supervised by competent scientists who are experienced in working with these agents. All procedures involving the manipulation of infectious material are conducted within biological safety cabinets or other physical containment devices, or by personnel wearing appropriate personal protective clothing and equipment. The lab must have special engineering and design features.

Biosafety Level 4—Suitable for work with the most infectious biological agents. Access to the two Biosafety Level 4 labs in the United States are highly restricted.

bioterrorism—The use of biological agents in a terrorist operation. Biological toxin would include anthrax, Ricin, botulism, the plague, smallpox, and tularemia.

Bioterrorism Act—The Public Health Security and Bioterrorism Preparedness and Response Act of 2002.

biowarfare—The use of biological agents to cause harm to targeted people either directly, by bringing the people into contact with the agents or indirectly, by infecting other animals and plants, which would in turn cause harm to the people.

blister agents—Agents which cause pain and incapacitation instead of death and might be used to injure many people at once, thereby overloading medical facilities and causing fear in the population. Mustard gas is the best known blister agent.

blood agents—Agents based on cyanide compounds. More likely to be used for assassination than for terrorism.

botulism—An illness caused by the botulinum toxin, which is exceedingly lethal and quite simple to produce. It takes just a small amount of the toxin to destroy the central nervous system. Botulism may be contracted by the ingestion of contaminated food or through breaks or cuts in the skin. Food supply contamination or aerosol dissemination of the botulinum toxin are the two ways most likely to be used by terrorists.

Bush Doctrine—The policy that holds responsible nations which harbor or support terrorist organizations and says that such countries are considered hostile to the United States From President Bush's speech: "A country that harbors terrorists will either deliver the terrorist or share in their fate. . . . People have to choose sides. They are either with the terrorists, or they're with us."

BWC—Officially known as the "Convention on the Prohibition of Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and Destruction." The BWC works toward general and complete disarmament, including the prohibition and elimination of all types of weapons of mass destruction.

Camp X-Ray—The Guantanamo Bay, Cuba, camp which houses al-Qaeda and Taliban prisoners.

carrier—A person or animal that is potentially a source of infection by carrying on infectious agent without visible symptoms of the disease.

cascading event—The occurrence of one event that causes another event.

causative agent—The pathogen, chemical, or other substance that is the cause of disease or death in an individual.

cell—The smallest unit within a guerrilla or terrorist group. A cell generally consists of two to five people dedicated to a terrorist cause. The formation of cells is born of the concept that an apparent "leaderless resistance" makes it hard for counterterrorists to penetrate.

chain of custody—The tracking and documentation of physical control of evidence.

chemical agent—A toxic substance intended to be used for operations to debilitate, immobilize, or kill military or civilian personnel.

chemical ammunition—A munition, commonly a missile, bomb, rocket, or artillery shell, designed to deliver chemical agents.

chemical attack—The intentional release of toxic liquid, gas or solid in order to poison the environment or people.

chemical warfare—The use of toxic chemicals as weapons, not including herbicide used to defoliate battlegrounds or riot control agents such as gas or mace.

chemical weapons—Weapons that produce effects on living targets via toxic chemical properties. Examples would be sarin, VX nerve gas, or mustard gas.

chemterrorism—The use of chemical agents in a terrorist operation. Well-known chemical agents include sarin and VX nerve gas.

choking agent—Compounds that injure primarily in the respiratory tract (i.e., nose, throat, and lungs). In extreme cases membranes swell up, lungs become filled with liquid, and death results from lack of oxygen.

Cipro—A Bayer antibiotic that combats inhalation anthrax.

'confirmed'—In the context of the threat evaluation process, a water contamination incident is definitive evidence that the water has been contaminated.

counterterrorism—Measures used to prevent preempt, or retaliate against terrorist attacks.

'credible'—In the context of the threat evaluation process, a water contamination threat is characterized as 'credible' if information collected during the threat evaluation process corroborates information from the threat warning.

cutaneous—Related to or entering through the skin.

cutaneous anthrax—Anthrax that is contracted via broken skin. The infection spreads through the bloodstream causing cyanosis, shock, sweating, and finally death.

cyanide agent—Used by Iraq in the Iran war against the Kurds in the 1980s, and also by the Nazis in the gas chambers of concentration camps, cyanide agents are colorless liquid which is inhaled in its gaseous form while liquid cyanide and cyanide salts are absorbed by the skin. Symptoms are headache, palpitations, dizziness, and respiratory problems followed later by vomiting, convulsions, respiratory failure, and unconsciousness and eventually by death.

cyberterrorism—Attacks on computer networks or systems, generally by hackers working with or for terrorist groups. Some forms of cyberterrorism include denial of service attacks, inserting viruses or stealing data.

dirty bomb—A makeshift nuclear device which is created from radioactive nuclear waste material. While not a nuclear blast, an explosion of a dirty bomb causes localized radioactive contamination as the nuclear waste material is carried into the atmosphere where it is dispersed by the wind.

ebola—Ebola hemorrhagic fever (Ebola EF) is a severe, often-fatal disease in nonhuman primates such as monkeys, chimpanzees, gorillas and in humans. Ebola has appeared sporadically since 1976 when it was first recognized.

eBomb (for e-bomb)—Electromagnetic bomb which produces a brief pulse of energy which affects electronic circuitry. At low levels, the pulse temporarily disables electronics systems, including computers, radios, and transportation systems. High levels completely destroy circuitry, causing mass disruption of infrastructure while sparing life and property.

Ecotage—Is the portmanteau of the "eco-" prefix and "sabotage". It is used to describe illegal acts of vandalism and violence, committed in the name of environmental protection.

Ecoterrorism—A neologism for terrorism that includes sabotage intended to hinder activities that are considered damaging to the environment.

Euroterrorism—Associated with left wing terrorism of the 1960s, 1970s, and 1980s involving the Red Brigade, Red Army Faction, and November 17th Group, among other groups which targeted American interests in Europe and NATO. Other groups include Orange Volunteers, Red Hand Defenders, Continuity IRA, Loyalist Volunteer Force, Ulster Defense Association, and First of October Anti-Fascist Resistance Group.

fallout—The descent to the earth's surface of particles contaminated with radioactive material from a radioactive cloud. The term can also be applied to the contaminated particulate matter itself.

Fatah—Meaning "conquest by means of jihad"; a political organization created in the 1960's and led by Yasser Arafat. With both a military and intelligence wing, it has carried out terrorist attacks on Israel since 1965. It joined the PLO in 1968. Since 9/11, the Fatah was blamed for attempting to smuggle 50 tons of weapons into Israel.

fatwa—A legal ruling regarding Islamic Law.

Fedayeen Saddam—Iraq's paramilitary organization said to be an equivalent to the Nazi's "SS". The militia is loyal to Saddam Hussein and is responsible for using brutality on civilians who are not loyal to the policies of Saddam. They do not dress in uniform.

filtrate—In ultrafiltration, the water that passes through the membrane and which contains particles smaller than the molecular weight cutoff of the membrane.

frustration-aggression hypothesis—A hypothesis that every frustration leads to some form of aggression and every aggressive act results from some prior frustration. As defined by Gurr: "The Necessary precondition for violent civil conflict is relative deprivation, defined as actors' perception of discrepancy between their value expectations and their environment's apparent value capabilities. This deprivation may be individual or collective."

fundamentalism—Conservative religious authoritarianism. Fundamentalism is not specific to Islam; it exists in all faiths. Characteristics include literal interpretation of scriptures and a strict adherence to traditional doctrines and practices.

Geneva Protocol 1925—The first treaty to prohibit the use of biological weapons. The 1925 Geneva Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases and Bacteriological Methods of Warfare.

germ warfare—The use of biological agents to cause harm to targeted people either directly, by bringing the people into contact with the agents or indirectly, by infecting other animals and plants, which would in turn cause harm to the people.

glanders—An infectious bacterial disease known to cause inflammation in horses, donkeys, mules, goats, dogs and cats. Human infection has not been seen since 1945, but because so few organisms are required to cause disease, it is considered a potential agent for biological warfare.

grab sample—A single sample collected at a particular time and place that represents the composition of the water, air, or soil only at that time and location.

ground zero—From 1946 until 9/11, ground zero was the point directly above, below, or at which a nuclear explosion occurs or the center or origin of rapid, intense, or violent activity or change. After 9/11, the term, when used with initial capital letters, refers to the ground at the epicenter of the World Trade Center attacks.

guerrilla warfare—The term was invented to describe the tactics Spain used to resist Napoleon, though the tactic itself has been around much longer. Literally, it means "little war." Guerilla warfare features cells and utilizes no front line. The oldest form of asymmetric warfare, guerilla warfare is based on sabotage and ambush with the objective of destabilizing the government through lengthy and low-intensity confrontation.

Hamas—A radical Islamic organization which operates primarily in the West Bank and Gaza Strip whose goal is to establish an Islamic Palestinian state in place of Israel. On the one hand, Hamas operates overtly in their capacity as social services deliverers, but its activists have also conducted many attacks, including suicide bombings, against Israeli civilians and military targets.

hazard—An inherent physical or chemical characteristic that has the potential for causing harm to people, the environment, or property.

hazard assessment—The process of evaluating available information about the site to identify potential hazards that might pose a risk to the site characterization team. The hazard assessment results in assigning one of four levels to risk: lower hazard, radiological hazard, high chemical hazard, or high biological hazard.

hemorrhagic fevers—In general, the term viral hemorrhagic fever is used to describe severe multisystem syndrome wherein the overall vascular system is damaged, and the body becomes unable to regulate itself. These symptoms are often accompanied by hemorrhage; however, the bleeding itself is not usually life-threatening. While some types of hemorrhagic fever viruses can cause relatively mild illnesses.

Hizbollah (Hezbollah)—Meaning "The Party of God." One of many terrorist organizations which seek the destruction of Israel and of the United States. They have taken credit for numerous bombings against civilians, and have declared that civilian targets are warranted. Hezbollah claims it sees no legitimacy for the existence of Israel, and that their conflict becomes one of legitimacy that is based on religious ideals.

Homeland Security Office—An agency organized after 9/11, with former Pennsylvania Governor Tom Ridge heading it up. The Office of Homeland Security is at the top of approximately forty federal agencies charged with protecting the United States against terrorism.

homicide bombings—A term the White House coined the term to replace the old "suicide bombings."

incident—A confirmed occurrence that requires response actions to prevent or minimize loss of life or damage to property and/or natural resources. A drinking water contamination incident occurs when the presence of a harmful contaminant has been confirmed.

inhalation anthrax—A form of anthrax that is contracted by inhaling anthrax spores. This results in pneumonia, sometimes meningitis, and finally death.

intifada (intifadah)—(alternatively Intifadah, from Arabic "shaking off") The two intifadas are similar in that both were originally characterized by civil disobedience by the Palestinians which escalated into the use of terror. In 1987, following the killing of several Arabs in the Gaza Strip, the first intifada began and went on until 1993. The second intifada began in September 2000, following Ariel Sharon's visit to the Temple Mount.

Islam—Meaning "submit." The faith practiced by followers of Muhammad. Islam claims more than a billion believers worldwide.

jihad—Meaning "struggle." The definition is a subject of vast debate. There are two definitions generally accepted. The first is a struggle against oppression, whether political or religious. The second is the struggle within oneself, or a spiritual struggle.

kneecapping—A malicious wounding by firearm to damage the knee joint; a common punishment used by Northern Ireland's IRA involves collaborating with the British.

Koran—The holy book of Islam, considered by Muslims to contain the revelations of God to Mohammed. Also called Qu'ran.

LD50—The dose of a substance which kills 50 percent of those infected.

Laboratory Response Network (LRN)—A network of labs developed by the CDC, APHL, and FBI for the express purpose of dealing with bioterrorism threats, including pathogens and some biotoxins.

lassa fever—An acute, often fatal, viral disease characterized by high fever, ulcers of the mucous membranes, headaches, and disturbances of the gastrointestinal system.

links—The means (road, rail, barge, or pipeline) by which a chemical is transported from one node to another.

mindset—According to *American Heritage Dictionary*: "1. A fixed mental attitude or disposition that predetermines a person's response to and interpretation of situations; 2. and inclination or a habit." *Merriam Webster's Collegiate Dictionary* (10th ed.) defines it as 1. A mental attitude or inclination; 2. a fixed state of mind. The term dates from 1926 but apparently is not included in dictionaries of psychology.

Molotov cocktail—A crude incendiary bomb made of a bottle filled with flammable liquid and fitted with a rag wick.

monkeypox—The Russian bioweapon program worked with this virus, which is in the same family as smallpox. In June 2003, a spate of human monkeypox cases was reported in the U.S. Midwest. This was the first time that monkeypox was seen in North America, and it was the first time that monkeypox was transferred from animal to human. There was some speculation that it was a bioattack.

mullah—A Muslim, usually holding an official post, who is trained in traditional religious doctrine and law and doctrine.

Muslim (also Moslem)—Followers of the teachings of Mohammed, or Islam.

mustard gas—Blistering agents which cause severe damage to the eyes, internal organs, and respiratory system. Produced for the first time in 1822, mustard gas was not used until World War I. Victims suffered the effects of mustard gas thirty to forty years after exposure.

narcoterrorism—The view of many counterterrorist experts that there exists an alliance between drug traffickers and political terrorists.

National Pharmaceutical Stockpile—A stock of vaccines and antidotes which are stored at Centers for Disease control in Atlanta, to be used against biological warfare.

nerve agent—The Nazis used the first nerve agents: insecticides developed into chemical weapons. Some of the better known nerve agents include VX, sarin, soman, and tabun. These agents are used because only a small quantity is necessary to inflict a substantial damage. Nerve agents can be inhaled or can absorb through intact skin.

nodes—A facility at which a chemical is produced, store, or consumed.

nuclear blast—An explosion of any nuclear material which is accompanied by a pressure wave, intense light and heat, and widespread radioactive fallout which can contaminate the air, water and ground surface for miles around.

opportunity contaminant—A contaminant that might be readily available in a particular area, even through they may not be highly toxic or infectious or easily dispersed and stable in treated drinking water.

Osama bin Laden (also spelled "Usama")—A native of Saudi Arabia, was born the seventeenth of twenty-four sons of Saudi Arabian builder Mohammed bin Oud bin Laden, a Yemeni immigrant. Early in his career, he helped the mujahedeen fight the Soviet Union by recruiting Arabs and building facilities. He hated the United States and apparently this is because he views the United States as having desecrated holy ground in Saudi Arabia with their presence during the first Gulf War. Expelled from Saudi Arabia in 1991 and from Sudan in 1996, he operated terrorist training camps in Afghanistan. His global network al Qaeda is credited with the attacks on the United States on September 11, 2001, the attack on the USS Cole in 2000, and number other terrorist attacks.

pathogen—Any agent which can cause disease.

pathways—The sequence of nodes and links by which a chemical is produced, transported, and transformed from its initial source to its ultimate consumer.

plague—The pneumonic plague, which is more likely to be used in connection with terrorism, is naturally carried by rodents and fleas but can be aerosolized and sprayed from crop dusters. A 1970 World Health Organization assessment asserted that, in a worst case scenario, a dissemination of 50 kg in an aerosol over a city of 5 million could result in 150,000 cases of pneumonic plague, 80,000 to 100,000 of which would require hospitalization, and 36,000 of which would be expected to die.

political terrorism—Terrorist acts directed at governments and their agents and motivated by political goals (i.e., national liberation).

"possible"—In the context of the threat evaluation process, a water contamination threat is characterized as 'possible' if the circumstances of the threat warning appear to have provided an opportunity for contamination.

potassium iodide—An FDA-approved nonprescription drug for use as a blocking agent to prevent the thyroid gland from absorbing radioactive iodine.

presumptive results—Results of chemical and/or biological field testing that need to be confirmed by further lab analysis. Typically used in reference to the analysis of pathogens.

psychopath—A mentally ill or unstable person, especially one having a psychopathic personality (*q.v.*), according to *Webster's*.

psychopathology—The study of psychological and behavioral dysfunction occurring in mental disorder or in social disorganization, according to *Webster's*.

psychopathy—A mental disorder, especially an extreme mental disorder marked usually by egocentric and antisocial activity, according to *Webster's*.

psychotic—Of, relating to, or affected with psychosis, which is a fundamental mental derangement (as schizophrenia) characterized by defective or lost contact with reality, according to *Webster's*.

rapid field testing—Analysis of water during site characterization uses rapid field water testing technology in an attempt to tentatively identify contaminants or unusual water quality.

red teaming—As used in this text, a group exercise to imagine all possible terrorist attack scenarios against the chemical infrastructure and their consequences.

retentate—In ultrafiltration, the retentate is the solution that contains the particles that do not pass through the membrane filter. The retentate is also called the concentrate.

ricin—A stable toxin easily made from the mash that remains after processed castor beans. At one time, it was used as an oral laxative, castor oil; castor oil causes diarrhea, nausea, vomiting, abdominal cramps, internal bleeding, liver and kidney failure, and circulatory failure. There is no antidote.

salmonella—An infection caused by a gram-negative bacillus, a germ of the Salmonella genus. Infection with this bacteria may involve only intestinal tract or may be spread from the intestines to the bloodstream and then to other sites in the body. Symptoms of salmonella enteritis include diarrhea, nausea, fever, and abdominal cramping. Dehydration resulting from the diarrhea can cause death, and the disease could cause meningitis or septicemia. The incubation period is between eight and forty-eight hours, while the acute period the illness can hang on for one to two weeks.

sarin—A colorless, odorless gas. With a lethal dose of .5 mg (a pinprick-sized droplet), it is 26 times more deadly than cyanide gas. Because the vapor is heavier than air, it hovers close to the ground. Sarin degrades quickly in humid weather, but sarin's life expectancy increases as temperature gets higher, regardless of how humid it is.

Sentinel Laboratory—An LRN lab that reports unusual results that might indicate a possible outbreak, and refers specimens that may contain select biological agents in reference labs within the LRN.

site characterization—The process of collecting information from an investigation site in order to support the evaluation of a drinking water contamination threat. Site characterization activities include the site investigation, field safety screening, rapid field testing of the water, and sample collection.

sleeper cell—A small cell which keeps itself undetected until such time as they can "awaken" and cause havoc.

smallpox—The first biological weapon, used during the eighteenth century, smallpox killed three hundred million people in the nineteenth century. There is no specific treatment for smallpox disease, and the only prevention is vaccination. This currently poses a problem, since the vaccine was discontinued in 1970 and the WHO declared smallpox eradicated. Incubation is 7 to 17 days, during which the carrier is not contagious. 30 percent of people exposed are infected, and it has a 30 percent mortality rate.

sociopath—Basically synonymous with psychopath (q.v.). Sociopathic symptoms in the adult sociopath include an inability to tolerate delay or frustration, a lack of guild feelings, a relative lack of anxiety, a lack of compassion for others, a hypersensitivity to personal ills, and a lack of responsibility. Many authors prefer the term sociopath because this type of person had defective socialization and a deficient childhood.

sociopathic—Of, relating to, or characterized by asocial or antisocial behavior or a psychopathic (q.v.) personality, according to *Webster's*.

spore—An asexual, usually single-celled reproductive body of plants such as fungi, mosses, or ferns; a microorganism, as a bacterium, in a resting or dormant state.

terrorist group—A group which practices or has significant elements which are involved in terrorism.

threat—An indication that a harmful incident, such as contamination of the drinking water supply, may have occurred. The threat may be direct, such as a verbal or written threat, or circumstantial, such as a security breach or unusual water quality.

toxin—A poisonous substance produced by living organisms capable of causing disease when introduced into the body tissues.

transponder—A device on an airliner which sends out signal allowing air traffic controllers to track an airplane. Transponders were disabled in some of the planes highjacked 9/11.

Transportation Security Administration (TSA)—A new agency created by the Patriot Act of 2001 for the purpose of overseeing technology and security in American airports.

tularemia—An infectious disease caused by a hardy bacterium *Francisella tularensis*, found in animals, particularly especially rabbits, hares, and rodents. Symptoms depend upon how the person was exposed to tularemia but can include difficulty breathing, chest pain, bloody sputum, swollen and painful lymph glands, ulcers on the mouth or skin, swollen and painful eyes, and sore throat. Symptoms usually appear from three to five days after exposures but sometimes will take up to two weeks. Tularemia is not spread from person to person, so people who have it need not be isolated.

ultrafiltration—A filtration process for water that uses membranes to preferentially separate very small particles that are larger than the membrane's molecular weight cut-off, typically greater than 10,000 Daltons. (A Dalton is a unit of mass, defined as 1/12 the mass of a carbon-12 nucleus. It's also called the atomic mass unit, abbreviated as either 'amu' or 'u').

vector—An organism which carries germs from one host to another.

vesicle—A blister filled with fluid.

weapons of mass destruction (WMD)—According to the National Defense Authorization Act: Any weapon or device that is intended, or has the capability, to cause death or serious bodily injury to a significant number of people through the release, dissemination, or impact of

- toxic or poisonous chemicals or their precursors
- a disease organism
- radiation or radioactivity

xenophobia—Irrational fear of strangers or those who are different from oneself.

zyklon b—A form of hydrogen cyanide. Symptoms of inhalation include increased respiratory rate, restlessness, headache, and giddiness followed later by convulsions, vomiting, respiratory failure and unconsciousness. Used in the Nazi gas chambers in WWII.

Tertiary Wastewater Treatment (see Advanced Wastewater Treatment): Selected biological, physical, and chemical separation processes to remove organic and inorganic substances that resist conventional treatment practices; the additional treatment of effluent beyond that of primary and secondary treatment methods to obtain a very high quality of effluent. The complete wastewater treatment process typically involves a three-phase process: (1) First, in the primary wastewater treatment process, which incorporates physical aspects, untreated water is passed through a series of screens to remove solids wastes; (2) Second, in the secondary wastewater treatment process, typically involving biological and chemical processes, screened wastewater is then passed through a series of holding and aeration tanks and ponds; and (3) Third, the tertiary wastewater treatment process consists of flocculation basins, clarifiers, filters, and chlorination basins or ozone or ultraviolet radiation processes.

Texture, Soil: Relative proportions of sand, silt, and clay particles in a mass of soil.

Tg Teragrams: 1×10^{12} g

Theoretical Maximum Residue Contribution: The theoretical maximum amount of a pesticide in the daily diet of an average person. It assumes that the diet is composed of all food items for which there are tolerance-level residues of the pesticide. The MRC is expressed as milligrams of pesticide/kilogram of body weight/day.

Therapeutic Index: The ratio of the dose required to produce toxic or lethal effects to the dose required to produce nonadverse or therapeutic response.

Thermal Circulation: The result of the relationship based on a law of physics whereby the pressure and volume of a gas being directly related to its temperature.

Thermal Comfort: Thermal comfort in the workplace is a function of a number of different factors. Temperature, humidity, air distribution, personal preference, and acclimatization are all determinants of comfort in the workplace. However, determining optimum conditions is not a simple process (Alpaugh 1988).

Thermal Drawdown: Decline in formation temperature due to geothermal production.

Thermal Gradient: The rate of increase in temperature as a function of depth into the earth's crust.

Thermal Incinerator (or afterburner): A device used in combustion whereby the contaminant airstream passes around or through a burner and into a refractory-lined residence chamber where oxidation occurs. Flue gas from a thermal incinerator is at high temperature and contains recoverable heat energy.

Thermal Inversion: A layer of cool air trapped under a layer of less dense warm air, thus preventing reversing to the normal situation.

Thermal $\mathbf{No_X}$: Created when nitrogen and oxygen in the combustion air (for example, within an internal combustion engine) are heated to a high enough temperature (above 1000K) to cause nitrogen (N_2) and oxygen (O_2) in the air to combine.

Thermal Pollution: An increase in water temperature with harmful ecological effects on aquatic ecosystems. Thermally polluted water and harm the environment because plants and animals can have a hard time adapting to it.

Thermal Radiation: Heat energy directly radiated into space from the earth's surface and atmosphere.

Thermal Stratification: The formation of layers of different temperatures in a lake or reservoir.

Thermal System Insulation (TSI): Asbestos-containing material applied to pipes, fittings, boilers, breeching, tanks, ducts, or other interior structural components to prevent heat loss or gain or water condensation.

Thermal Treatment: In non-in-situ soil pollution control technology, the complete destruction (by incineration) of petroleum-laden contaminants.

Thermal Treatment Processes: In waste control technology, incineration of wastes.

Thermocline: The fairly thin transition zone in a lake that separates an upper warmer zone from a lower colder zone.

Thermoelectric Power Water Use: Water used in the process of the generation of thermoelectrical power. Power plants that burn coal and oil are examples of thermoelectric-power facilities.

Thermosiphon System: A solar collector system for water heating in which circulation of the collection fluid through storage loop is provided solely by the temperature and density difference between the hot and cold fluids.

Thermosphere: An atmospheric layer that extends from fifty-six miles to outer space.

Thermoluminescent Dosimeter (TLD): A dosimeter worn by radiation workers to measure their radiation dose. The TLD contains crystalline material which stores a fraction of the absorbed ionizing radiation and releases this energy in the form of light photons when heated.

Thin-Film Silicon: A technology in which amorphous or polycrystalline material is used to make photovoltaic (PV) cells.

Thio: Containing a sulfur atom.

Threat: A potential for violation of security that exists when a circumstance, capability, action, or event could breach security and cause harm.

Threat Assessment: The identification of types of threats that an organization might be exposed to.

Threat Model: Used to describe a given threat and the harm it could to do a system if it has a vulnerability.

Threat Vector: The method a threat uses to get to the target.

Threshold: The lowest dose of a chemical at which a specified measurable effect is observed and below which it is not observed.

Threshold Level: Time-weighted average pollutant concentration values, exposure beyond which is likely to adversely affect human health.

Threshold Limit Value (TLV): The same concept as PEL, except that TLVs do not have the force of governmental regulations behind them, but are base on recommended limits established and promoted by the American Conference of Governmental Industrial Hygienists.

Threshold of Effect: In the dose-response relationship, the level of "no effect."

Threshold Planning Quantity: A quantity designated for each chemical on the list of extremely hazardous substances that triggers notification by facilities to the State Emergency Response Commission. That such facilities are subject to emergency planning requirements under SARA Title III.

Threshold Reporting Quantity: Level set by the EPA for extremely hazardous substances that if exceeded during spill or release to environment must be reported to appropriate authorities.

Thrombocyte: A type of blood cell, also called a platelet.

Thrombocytopenia: An abnormal decrease in the number of platelets in circulating blood.

Thrombosis: The formation or presence of blood clots.

Tidal Energy: The tides rise and fall in eternal cycles. Tides are changes in the level of the oceans caused by the gravitational pull of the moon and sun, and the rotation of the earth. The relative motions of these cause several different tidal cycles, including: a semi-diurnal cycle—period 12 hrs, 25 minutes; a semi-monthly cycle—i.e., Spring or neap tides corresponding with the position of the moon; a semi-annual cycle—period about 178 days which is associated with the inclination of the moon's orbit. This causes the highest spring tides to occur in March and September; and other long term cycles—e.g., a nineteen year cycle of the moon. Nearshore water levels can vary up to forty feet, depending on the season and local factors. Only about twenty locations have good inlets and a large enough tidal range—about ten feet—to produce energy economically (DOI 2010).

Did You Know?

The spring tides have a range about twice that of neap tides, while the other cycles can cause further variations of up to 15 percent. The tidal range is amplified in estuaries, and in some situations, the shape of the estuary is such that near resonance occurs.

Tidal Energy Technologies: Some of the oldest ocean energy technologies use tidal power. Tidal power is more predictable than solar power and wind energy. All coastal areas consistently experience two high and two low tides over a period of slightly greater than twenty-four hours. For those tidal differences to be harness into electricity, the difference between high and low tide must be at least five meters, or more than sixteen feet. There only about forty sites on the earth with tidal ranges of this magnitude. Currently, there are no tidal power plants in the United States. However, conditions are good for tidal power generation in both the Pacific Northwest and the Atlantic Northeast regions of the country. Tidal energy technologies include the following:

- Tidal barrages—a barrage or dam is a simple generation system for tidal plants involves a dam, known as a barrage, across an inlet. Sluice gates (gates commonly used to control water levels and flow rates) on the barrage allow the tidal basin to fill on the incoming high tides and to empty through the turbine system on the outgoing tide, also known as the ebb tide. There are two-way systems that generate electricity on both the incoming and outgoing tides. A potential disadvantage of a barrage tidal power system is the effect a tidal station can have on plants and animals in estuaries. Tidal barrages can change the tidal level in the basin and increase the amount of matter in suspension in the water (turbidity). They can also affect navigation and recreation.
- Tidal fences—these look like giant turnstiles. A tidal fence has vertical axis turbines mounted in a fence. All the water that passes is forced through the turbines. Some of these currents run at 5-8 knots (5.6-9 miles per hour) and generate as much energy as winds of much higher velocity. Tidal fences can be used in areas such as channels between two landmasses. Tidal fences are cheaper to install than tidal barrages and have less impact on the environment tidal barrages, although they can disrupt the movement of large marine animals.
- Tidal turbine—are basically wind turbines in the water that can be located anywhere there is a strong tidal flow (function best where coastal currents run at between 3.6 and 4.9 knots—4 to 5.5 mph). Because water is about 800 times denser than air, tidal turbines have to be much sturdier than wind turbines. Tidal turbines are heaver ad more expensive to builds but capture more energy.

Tidal Marsh: Low, flat marshlands traversed by channels and tidal hollows, subject to tidal inundation; normally, the only vegetation present is salt-tolerant bushes and grasses.

Tillage: Plowing, seedbed preparation, and cultivation practices.

Tilth, Soil: The physical condition of the soil as related to tillage, seedbed preparation, seedling emergence, and root penetration.

Tiltmeter: Device able to measure extremely small changes in its rotation from horizontal. The "tilt" measured by an array of tiltmeters emplaced over a stimulation allow delineation of inflation and fracturing caused by the stimulation.

Time-Weighted Average (TWA): A mathematical average [(exposure in ppm × time in hours) 1/4 time in hrs. = time weighted average in ppm] of exposure concentration over a specific time.

Tinnitus: A sound in one ear or both ears, such as buzzing, ringing, or whistling.

Tipping Fee: A fee for disposal of waste.

Tire Processor: Intermediate operating facility where recovered tires are processed in preparation for recycling.

Tires: As used in recycling, passenger care and truck tires (exclude airplane, bus, motorcycle and special service military, agricultural off-the-road and slow speed industrial tires). Car and truck tires are recycled into rubber products such as trash cans, storage containers, rubberized asphalt to use whole for playground and reef construction.

Titan: An abnormal phase of prolonged muscular contractions.

Title 49 CFR: When we need to find general or specific information on something, on anything, several different reference sources are available to find the information, from abstracts to dictionaries to the myriad sources available on the Internet. If we need to define some term ("**transportation**," for example), we could use a standard dictionary. A typical entry for transportation would probably include at least the following sub-definitions: (1) The act of transporting; (2) The state of being transported; (3) A means of transport; conveyance. We might also find that the dictionary suggests certain synonyms for the word transportation: conveyance, hauling, moving, transferal, transmit, and several others, including both nouns and verbs.

Using a standard English language dictionary and other standard references (an encyclopedia, for example) is rather straightforward, a piece of cake; it is something we often do without giving much thought to what we are actually doing.

How is using a dictionary or any other reference germane to what we are discussing in this text?

To find what we are looking for, whatever it might be, we must find the correct reference. For example, to find out information about Hazardous Materials Regulations (HMRs), we first need to know where to look. One thing is certain: We won't find the answers to questions about

Hazardous Materials Regulations in a standard dictionary or encyclopedia.

For HMRs, we need to refer to 49 CFR.

Seems straightforward enough doesn't it? Not so fast . . . have you ever used a CFR—any CFR? If so, then you may not have any difficulty in finding what you are looking for—though understanding what you find might be a completely different matter.

Consider, for example, 49 CFR 172.101 (c)(10). Is this information helpful? Maybe, maybe not. Its helpfulness depends on your familiarity with CFRs . . . and that is the point. In this section, we discuss information to help in understanding—and use—49 CFR.

The key to compliance with Hazardous Materials Regulations is knowing how the regulations are organized so that they may be deciphered and put into effect. The minimum federal safety standards applicable to transportation are contained in the **Code of Federal Regulations** or the **CFR**.

The Code of Federal Regulations is basically an encyclopedia of government regulations, a collection of different numbered volumes. Each numbered issue contains the regulations specific to certain agencies and subjects. For example, 29 CFR is specific to the Department of Labor and Occupational Safety and Health regulations (OSHA). 40 CFR is specific to the United States Environmental Protection Agency (USEPA) and Environmental regulations. A complete listing of CFRs is presented in the Table.

All CFRs are organized into sub-titles, chapters, subchapters, parts, subparts, sections, paragraphs and subparagraphs. For example, DOT's Hazardous Materials Regulations are contained in Subchapter C of Chapter I of Subtitle B of Title 49 CFR.

Subchapter C is organized into parts that run numerically. The overall organization is as follows:

Title 49 - TRANSPORTATION
  Subtitle B–Other Regulations Pertaining to Transportation
    Chapter I–Research and Special Programs Administration
      Parts 171–180

Recall that earlier you were asked you to consider the example: 49 CFR 172.101 (c) (10). You were asked if this particular information was useful to you. Let's take a closer look at 49 CFR 172.101 (c)(10); let's put it in a manageable, more understandable form.

The Table provides an overview of HMR contents.

Tobacco Smoke in Air: OSHA has published a proposed rule for IAQ (including tobacco smoke in the workplace), and this rulemaking is likely to be completed in the near future. Smoking policies should include provisions for

Code of Federal Regulations (CFRs)

Title	*Specific To*
1, 2	General Provisions
3	The President
4	Accounts
5, 6	Administrative Personnel
7	Agriculture
8	Aliens and Nationality
9	Animals and Animal Products
10	Energy
11	Federal Elections
12	Banks and Banking
13	Business Credit and Assistance
14	Aeronautics and Space
15	Commerce and Foreign Trade
16	Commercial Practices
17	Commodity and Securities Exchanges
18	Conservation of Power and Water Resources
19	Customs Duties
20	Employees' Benefits
21	Food and Drugs
22	Foreign Relations
23	Highways
24	Housing and Urban Development
25	Indians
26	Internal Revenue
27	Alcohol, Tobacco Products and Firearms
28	Judicial Administration
29	Labor/OSHA
30	Mineral Resources
31	Money and Finance: Treasury
32	National Defense
33	Navigation & Navigable Waters
34	Education
35	Panama Canal
36	Parks, Forests, and Public Property
37	Patents, Trademarks, and Copyrights
38	Pensions, Bonuses, and Veterans' Benefits
39	Postal Service
40	Environment
41	Public Contracts and Property Management
42	Public Health
43	Public Lands: Interior
44	Emergency Management and Assistance
45	Public Welfare
46	Shipping
47	Telecommunications
48	Federal Acquisitions Regulations System
49	Transportation
50	Wildlife & Fisheries

Title 49 (more commonly known as 49 CFR), part of which contains the Hazardous Materials Regulations of USDOT, is the subject matter of this text. The various parts that make up 49 CFR include:

49 CFR 1-99	Secretary of Transportation
49 CFR 100-185	Hazmat Transportation
49 CFR 186-199	Pipeline Safety
49 CFR 200-399	Federal Highway Administration
49 CFR 400-999	National Highway Traffic Safety Administration
49 CFR 1000-1199	Interstate Commerce Commission
49 CFR 1200-END	Interstate Commerce Commission

49 CFR 172.101 (c) (10)

49	CFR	172	.101	(c)	(10)
Title	**Code of Federal Regulations**	**Part**	**Section**	**Paragraph**	**Subparagraph**

Parts	These are organized into Sections, which run numerically. 172.101 refers to the 101st Section within Part 172.
Sections	The Section starts with the first series of numbers to the right of the period after the Part. A Section reference must include the Part because each Part could have a Section "1" in it. Example: 171.1 = refers to the first Section within Part 171
Paragraphs and Subparagraphs	Sections are organized into Paragraphs, Subparagraphs, etc. The first lower-case letter in parentheses to the right of the Section denotes the start of the Paragraph. The first number in parentheses to the right of the Paragraph is the Subparagraph. Example: 172.101 (c)(10) The (c) refers to a Paragraph reference and the (10) is a Subparagraph reference.
Sub-Subparagraphs	Subparagraphs are organized into Sub-Subparagraphs. These are first in lower case Roman Numeral in parentheses after the Subparagraph and Sub-Sub-Subparagraphs are denoted by a capital letter in parentheses. Example: 172.101 (c)(10)(i)(A) (c)(10)(i)(A) = refers to Sub-Sub-Subparagraph (A) of Sub-Subparagraph (i) of Subparagraph (10) of Paragraph (c).
Subparts	Parts are divided into Subparts containing Sections. These are lettered with a capital letter alphabetically within the Part. Examples: Subpart A, Subpart B, etc.

HMR Contents

Part/Section	*Content*
171.8	Definitions
171.15	Incident Reporting
Part 172	HM Table and Provisions
172.101-102	Table and Special Provisions
172.200-205	Shipping Papers
172.300-338	Marking
172.400-450	Labeling
172.500-560	Placarding and Appendix C Dimensions
172.600-604	Emergency Response
172.700-704	Training Requirements
173.1—173.478	Packaging
174.1—174.840	Shipping by Rail
175.1—175.705	Carriage by Aircraft
176.1—176.906	Carriage by Vessel
177.800-177.861	Carriage by Public Highway
177.816	Driver Training
178	Packaging Specifications: Tanks, Cylinders
180	Packaging Maintenance

dedicated smoking areas. Dedicated smoking areas should be configured so that migration of smoke into nonsmoking areas will not occur. Such areas should:

- have floor-to-ceiling walls of tight construction
- be under negative pressure relative to adjacent areas
- be exhausted outside the building and not recirculated

Tolerance Petition: A formal request to establish a new tolerance or modify an existing one.

Tolerances: Permissible residue levels for pesticides in raw agricultural produce and processed foods. Whenever a pesticide is registered for use on a food or a feed crop, a tolerance (or exemption for the tolerance requirement) must be established. EPA establishes the tolerance levels, which are enforced by the Food and Drug Administration and the Department of Agriculture.

Tonnage: The amount of waste that a landfill accepts, usually expressed in tons per month. The rate at which a landfill accepts waste is limited by the landfill's permit.

Topography: The physical features of a surface area including relative elevations and the position of natural and man-made (anthropogenic) features.

Topsoil: The layer of soil moved in cultivation.

Torsional Strength: The ability of a metal to withstand forces that cause a member to twist.

Total Dissolved Phosphorous: The total phosphorous content of all material that will pass through a filter, which is determined as orthophosphate without prior digestion or hydrolysis.

Total Dissolved Solids (TDS): The solids residue after evaporating a sample of water or effluent expressed in mg/liter.

Total Dust Concentration: Measurement of all of the dust particles that a filter collects in and near animal facilities.

Total Effective Dose Equivalent (TEDE): The sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Total Kjeldahl Nitrogen (TKN): The total concentration of organic and ammonia nitrogen in wastewater.

Total Petroleum Hydrocarbons (TPH): Measure of the concentration or mass of petroleum hydrocarbon constituents present in a given amount of soil or water. The word total is a misnomer—few, if any of the procedures for quantifying hydrocarbons can measure all of them in a given sample. Volatile ones are usually lost in the process and not quantified and non-petroleum hydrocarbons sometimes appear in the analysis.

Total Pressure (TP): The pressure exerted in a duct, i.e., total pressure (TP) is defined as the algebraic sum of the static and velocity pressures or

$$TP = SP + VP$$

The total pressure of a ventilation system can be either positive or negative (i.e., above or below atmospheric pressure). Generally, the total pressure is positive for a supply system, and negative for an exhaust system.

Total Quality Management (TQM) Paradigm

"We want to be the best. What else is there?" —Lee Iacocca

What is Total Quality Management (TQM)? TQM is not a traditional part of American culture. In the old days, if an organization had an abundance of resources, waste was affordable. At present, with increasing competition, and an economy growing at a slower rate, doing it right the first time is more important. Simply, "TQM is an integrated system of principles, methods, and best practices that provide a framework for organizations to strive for excellence in everything they do" (Total Quality Engineering Inc., 2003).

Total Recovered Petroleum Hydrocarbons: A method for measuring petroleum hydrocarbons in samples of soil or water.

Total Solids: Sum of dissolved and undissolved solids in water or wastewater, usually stated in milligrams per liter.

Total Suspended Particles (TSP): A method of monitoring airborne particulate matter by total weight.

Total Suspended Solids (TSS): A measure of the suspended solids in wastewater, effluent, or water bodies, determined by tests for "total suspended non-filterable solids."

Total Waste Analysis: Analytic test method used to measure compliance with most of the organic treatment standards. Carbon disulfide, Cyclohexanone, and methanol treatment standards are measured using toxicity characteristic leaching procedure.

Totally-Encapsulating Chemical Protective (TECP) Suit: A full body garment which is constructed of protective clothing materials; covers the wearer's torso, head, arms, legs and respirator; may cover the wearer's hands and feet with tightly attached gloves an boots; completely encloses the wearer and respirator by itself or in combination with the wearer's gloves and boots.

Toughness: May be considered as strength, together with ductility. A tough material can absorb large amounts of energy without breaking.

Toxaphene: Chemical that causes adverse health effects in domestic water supplies and its toxic to fresh water and marine aquatic life.

Toxic: Poisonous, injurious to health or dangerous to life.

Toxic Chemical: Term used by USEPA for chemicals whose total emissions or releases must be reported annually by owners and operators of certain facilities that manufacture, process, or otherwise use a listed toxic chemical. The list of toxic chemicals is identified in Title III of SARA.

Toxic Chemical Release Form: Information form required of facilities that manufacture, process, or us (in quantities above a specific amount) chemicals listed under SARA Title III.

Toxic Chemical Use Substitution: Replacing toxic chemicals with less harmful chemicals in industrial processes.

Toxic Cloud: Airborne plume of gases, vapors, fumes, or aerosols containing toxic materials.

Toxic Concentration: The concentration at which a substance produces a toxic effect.

Toxic Dose: The dose level at which a substance produces a toxic effect.

Toxic Inhalation Hazard (TIH): Term used in the U.S. Department of Transportation ERG 2000 Guidebook to describe gases and volatile liquids that are toxic when inhaled.

Toxic Metals: Metals, including arsenic, cadmium, lead, mercury, that are all cumulative toxins and particularly hazardous to human health.

Toxic (or Hazardous) Substance: Substances injurious to the health of individual organisms and sometimes fatal.

Toxic Pollutants: Materials that cause death, disease, or birth defects in organisms that ingest or absorb them. The quantities and exposures necessary to cause these effects can vary widely.

Toxic Release Inventory: Database of toxic releases in the United States compiled for SARA Title III Section 313 reports.

Toxic Substances Control Act (TSCA): TSCA was enacted in 1977. Its primary purpose is to require that adequate data be compiled to determine toxic effects of chemicals posing "unreasonable risk." In effect, this includes about 50,000 chemicals currently in use and about 1,000 new chemicals each year. Pesticides, food items or additives, drugs, cosmetics, tobacco, and radioactive chemicals are not included in these numbers because these are regulated under other Acts. For new chemicals, tests must conclude that the chemical poses "no unreasonable risk" based on animal testing. For existing chemicals, either a finding of "no unreasonable risk" is made, or certain restrictions or prohibitions on use are implemented for the chemical. For example, polychlorinated biphenyls (PCBs) were historically used in electrical transformers due to their physical properties. After TSCA was enacted, data indicating that PCBs could cause cancer in rodents at low levels led to prohibition of their use by 1981.

Toxic Waste: A waste that can produce injury if inhaled, swallowed, or absorbed through the skin.

Toxicant: A harmful substance or agent that may injure an exposed organism.

Toxicity: (1) The degree of poisonousness. (2) The degree to which a substance or mixture of substances can harm humans or animals. *Acute toxicity* involves harmful effects in an organism through a single or short-term exposure. *Chronic toxicity* is the ability of a substance or mixture of substances to cause harmful effects over an extended period, usually upon repeated or continuous exposure sometimes lasting for the entire life of the exposed organism. *Subchronic toxicity* is the ability of the substance to cause effects for more than one year but less than the lifetime of the exposed organism.

Toxicity Assessment: Characterization of the toxicological properties and effects of a chemical, with special emphasis on establishment of dose-response characteristics.

Toxicity Characteristic Leaching Procedure (TCLP): Analytic test method used to measure compliance with the metal treatment standards.

Toxicity Testing: Biological testing (usually with an invertebrate, fish, or small mammal) to determine the adverse effect of a compound or effluent.

Toxicokinetics[1]: ***Toxicokinetics*** can be defined as how a chemical acts in the body. Toxicokinetics is a subfield of toxicology and consists of the following four components:

- Absorption
- Distribution
- Metabolism
- Excretion

Toxicokinetics is also described as the *disposition* of a chemical.

Absorption is defined as passage of a chemical across a membrane into the body.

Until a chemical is absorbed, toxic effects are only rarely observed and then only at points of contact with the body (e.g., acid burns on the skin). Once a chemical is absorbed into the body, it is ***distributed*** to certain organs via the circulatory system. How a chemical is distributed in the body in part governs the target organ for that chemical, how easily it is eliminated from the body, how long it may take to act, and how long and where it will persist in the body.

Metabolism is the transformation of a chemical in the body to other chemicals.

This can either increase or decrease the toxicity, but typically increases the water solubility of a chemical, which leads to increased excretion.

Excretion is defined as elimination from the body, either as urine, feces, or through sweat or tears.

These four factors in combination govern the degree of toxicity, if any, from chemical exposure. For example, a chemical may be absorbed but never reach a concentration at the target location above a threshold level. Or the chemical might be absorbed at concentrations

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[1] Much of the information on toxicology and its principles and applications are adapted from the excellent text, *Toxicology for Non-Toxicologists*, 2nd ed. By M. E., Stelljes, PhD, 2007. Also available from Government Institutes Press.

high enough to cause toxicity, but the chemical is not distributed to the organ in which it can cause toxicity. As a result, no toxicity will result even through the amount absorbed was above a threshold level. Alternatively, a chemical might reach a target organ in sufficiently high levels to cause toxicity, but specific activities of cells in that organ change the structure of the chemical so that it is less toxic. Again, in this situation, a dose that is high enough to cause toxicity leads to no effects. Finally, a chemical could be eliminated from the body so fast that it never builds up in tissues enough to cause toxicity. These processes can occur simultaneously, and may either increase, decrease, or not affect the toxicity of a given chemical, depending on the magnitude and direction of each component.

Absorption

A chemical must be dissolved to be absorbed. Lipid (i.e., fat) solubility and size of the molecule govern the rate and overall degree of absorption for a given chemical. To understand how chemicals can be absorbed, an understanding of the anatomy of a cell is needed. Membranes within cells are semipermeable; chemical can enter a cell through the membrane, but they need to diffuse through a sandwich of three layers composed of lipid, water, and lipid again to enter.

Once in the cell, the chemical must then pass out of the cell on the other side. This may lead directly to the bloodstream, or other locations depending on where the chemical is absorbed.

There are three main locations where chemicals can be absorbed. These include the lung, the intestinal tract, and the skin. The first two of these are designed to absorb oxygen and nutrients, respectively, while the third is designed as a barrier to absorption.

Lung Absorption

For absorption from the lungs to occur, a chemical must pass from the alveoli into the bloodstream. The alveoli are extremely thin structures; each is just one cell thick. Similarly, the blood vessels that line the alveoli are capillaries that are themselves only one cell thick. This design maximizes oxygen exchange between the lungs and the blood. However, this design also enables chemicals dissolved in air to pass into the blood, as does oxygen. Smaller, lighter weight chemicals will be absorbed more efficiently because they more closely resemble oxygen than do larger chemicals.

The lining of our alveoli is moist; oxygen exchange could not otherwise occur.

Therefore, some areas on the alveoli produce a surfactant, which is a fatty substance that lines the alveolar surface and keeps the thin structures from collapsing. Because this surfactant is primarily composed of fatty chemicals, fat-soluble (or lipid-soluble) chemicals will pass through the layer and into the cells more readily than water-soluble ones.

Before absorption can occur in the alveoli, the chemical needs to pass a host of defense mechanisms in the upper respiratory tract. These primarily include tiny hairs called cilia, which constantly beat upward towards the mouth, and mucus, which is sticky and is secreted by cells in the bronchioles called goblet cells. Particles stick to the much, and the beating cilia act as an escalator and bring the particles up into the mouth where they are swallowed. These defenses are less effective if the lining of the respiratory tract has been damaged, such as by smoking.

The damage kills cells lining the airways and destroys the cilia and mucus-producing glands.

Therefore, inhalation absorption increases in situations where lung function has been reduced.

Gastrointestinal Absorption

Absorption through the gastrointestinal tract (GIT) includes absorption through the mouth, stomach, and intestines. Chemicals may reach the GIT from either direct ingestion or inhalation of particles and transfer of these particles from the respiratory tract to the mouth, as discussed above. The vast majority of absorption from the GIT is from the intestines, particularly the area of the small intestine known as the duodenum. The wall of the duodenum is highly folded into finger-like projections called villi. These villi are bathed in fluids from the GIT that assist in digestion and absorption. The villi are lined with a layer of epithelial cells that separates the GIT and the blood. The membranes of these cells contain digestive enzymes that help move chemicals into and through cells. These chemicals primarily act to increase the absorption of certain essential chemicals, such as amino acids. These mechanisms do not differentiate between nutrients and other chemicals, so potentially toxic chemicals could also be absorbed.

Once material reaches the bloodstream, the first destination is the liver. The liver serves as a filter for materials absorbed through the GIT. Toxic chemicals can be altered to nontoxic forms, or vice versa. This is referred to as the "first-pass effect"; the liver can alter chemicals before they reach their targets. This anatomical feature allows ingested materials to be screened prior to their release into the rest of the body.

Skin Absorption

Unlike the lungs and the intestines, the skin is not designed for absorption. The outer several layers of skin consist of dead tissue. The first living tissue encountered in the skin lies beneath these dead layers of skin, referred to as the stratum corneum. Therefore, a chemical must pass through several layers of cells to reach a blood vessel and enter the body. Also, blood vessels are spaced far apart in the skin, so even after a chemical reaches the living cell layers, it still might never reach a blood vessel to be transported to a site where it can cause toxic effects.

Overall, absorption is usually most efficient through the lungs and least efficient through the skin. Only 1 to 15 percent of a chemical amount is typically absorbed through the skin, depending on the type of chemical. However, more than 75 percent of an exposed amount is often absorbed from the lungs. The variability of absorption is highest for the GIT; absorption ranges from as low as 0.1 percent (for some metals such as cadmium) to as high as 100 percent (for some essential nutrients like calcium).

Distribution

Defines where a chemical goes in the body once it has been absorbed. For some chemicals, distribution differs depending on how or where it was absorbed (e.g., skin or lung). For other chemicals, distribution is the same regardless of how and where absorption occurred. For example, regardless of how it was absorbed, the majority of lead that is absorbed will end up in our bones. However for cadmium, absorption by the lungs will lead to primary distribution in the lung, while absorption through the GIT will lead to distribution in the kidneys.

In addition to defining where a chemical goes, distribution also tells you what percentage of a chemical dose goes to different locations. For example, we know that lead can cause toxic effects in the nervous system and in the blood cells.

However, the majority of absorbed lead (about 90 percent) eventually goes to the bone tissue.

Not all the lead goes to the bone, however. If it did, no lead would reach the targets of toxicity, and lead would not affect us. Therefore, the amount of a chemical that goes to a specific location is more important than what percent of the dose goes there.

The primary factors that govern where a chemical will be distributed in the body include the blood flow to a particular tissue or organ, and the relative affinity of that tissue or organ for the chemical. Based on different combinations of these factors, there are four major locations in the body that serve as **storage depots** for chemicals. These include:

- liver and kidney
- fat
- bone
- plasma protein

Liver and Kidney Storage Depot

The liver and kidneys receive among the highest blood flows of any organs. For example, about twice as much blood flows to the liver than to the brain. The differences in blood flow are even more striking when the weight of the tissue is factored into the rate of blood flow. The kidneys receive the highest relative blood flow other than the lungs, and bout 8 times as much as the brain. The liver receives the next highest blood flow. This means that chemicals in our bloodstream will more likely reach the liver and kidneys than other tissues or organs because more blood passes through these organs than most other organs. The liver is the primary site of chemical metabolism, so it is not surprising that blood flow is high to this organ.

Similarly, the kidneys serve to filter unwanted items from our blood. To do this efficiently, the blood flow through the kidneys must be high in order to filter a lot of blood very quickly.

As a result of this high blood flow and the types of activities that occur in these organs, the liver and kidneys are primary sites of chemical storage.

Fat Storage Depot

Fat has low blood flow. For example, 80 times more blood flows to the skin than to fat reserves.

However, many chemicals are stored primarily in fatty tissues because they are lipophilic (fat-loving). For example, the distribution of DDT administered to lab mice through the diet was examined by chemically analyzing the organs. The results of this study indicated that roughly similar DDT concentrations were found in the brain and fat tissues, even though the brain receives 20 times higher relative blood flow than fat.

However, because blood flow to the fat is very low, distribution into fat takes time.

Therefore, a chemical like dioxin may first be distributed to the liver, but the amount in the liver will decrease with time as some reenters the blood supply and reaches fat cells.

Some will also be metabolized by and interact with the liver, but the dioxin not affected by the liver will likely reach the fat cells. This phenomenon of a chemical having two different destinations over time is known as redistribution.

Blood flow and fat content are inversely proportional. In other words, as the blood flow to an area increases, the fat content of the area typically goes down. So, we have a situation where most chemicals want to be stored in fatty tissue, but the majority of blood is going elsewhere. Identifying the ultimate destination of chemicals in these circumstances is part of the discipline of toxicokinetics. The ultimate destination will likely change over time; the longer a lipophilic chemical exists in the body, the more likely it is to be present in fatty tissue.

Once a chemical reaches fatty tissue, it can still reenter the general circulation if the fatty tissue is affected. Going back to the DDT example, it has been shown that short-term starvation has led to destruction of fatty tissues that liberated a high enough level of DDT to cause toxic effects.

This demonstrates that fat may be a storage location, but this does not mean the chemical poses no threat in the body just because it is in the fat.

Bone Storage Depot

In addition to fat, bone is another tissue that has a relatively low blood flow yet still is the preferential storage location for some chemicals, most notably lead and fluoride. In general, chemicals that are stored in bone are elements (e.g., lead and strontium) that bind to the structure of the bone. As with fatty tissue, chemicals bound to bone can be redistributed if bone tissue is lost, such as in osteoporosis. Lead is not toxic to bone; however, both fluoride and strontium are.

Plasma Protein Storage Depot

Lastly, there are circulating proteins (e.g., albumin) in our bodies that function to transport other chemicals within our bloodstream. These plasma proteins are too large to be filtered through the kidneys or diffused out of the blood, so they remain circulating in the bloodstream. In essence, these circulating plasma proteins serve as a taxi service for chemicals. Some of the chemicals that use the service include Vitamin C, histamine, thyroxin, iron, and hemoglobin. These chemicals get to where they are going, and unbind from the proteins (i.e., get out of the taxi).

These are the paying customers. Other chemicals go along for the ride, but are not recognized by the plasma protein. Some of these chemicals include drugs such as a sulfonamide or acetaminophen. These chemicals can take the place of paying customers and cause toxic reactions by either directly damaging the body or preventing the correct chemical from reaching its destination. For example, in the case of the sulfonamide, a treatment with a tetracycline and sulfonamide mixture was being used to deal the bacterial infections in premature infants. The mixture led to higher mortality of the infants than use of just the tetracycline alone because the sulfonamide displaced the liver byproduct bilirubin from plasma proteins. The bilirubin, unattached from the large protein, passed through the unformed blood-brain barrier of the infant and caused severe brain damage known as kernicterus. In this situation, and endogenous chemical, bilirubin, exerted the toxicity. However, the toxic agent was the sulfonamide because the action of the sulfonamide triggered the toxic response.

Barriers to Distribution

As referred to earlier, there are some barriers that affect where a chemical will be distributed.

These include the blood-brain barrier and the placental and mammary (breast milk) barriers (in pregnant and nursing women). In mammals, the central nervous system (CNS), which includes the brain and spinal cord, is separated from the rest of the body by a barrier. A layer of special cells that lie between blood vessels and the CNS represents this barrier. These special cells do not allow chemicals or fluid to move between them; movement can only occur through he cells themselves. This greatly slows movement of chemicals from the bloodstream to the CNS, and allows time for intracellular actions to modify or destroy the chemical before it ever enters the CNS. However, many chemicals, especially lightweight gaseous chemicals like chloroform, can easily pass through the barrier because they dissolve in cellular lipids very well. Even chemicals that do not dissolve in fats, like lead, can pass through the barrier, but in a different way than more fat-soluble chemicals. These chemicals need to be modified to make them more lipid-soluble before they can pass through the barrier. For lead, it is methylated in the liver as part of regular metabolic processes. Addition of these methyl groups makes lead act much more like a natural chemical in our body and increases its ability to gain access to the CNS.

The CNS is bathed in a fluid known as the cerebrospinal fluid; this fluid is continuous throughout the CNS. This means that, once a chemical reaches the CNS, it will be distributed throughout the brain and spinal cord. Significantly, the blood-brain barrier is not developed at birth. Therefore, extremely young infants are particularly susceptible to chemicals because there is no barrier to prevent the chemicals from reaching the CNS.

The placenta exists in pregnant women, and separates the maternal and fetal blood supplies. Its main purpose is to pass nutrients and oxygen from the mother to the fetus, and to pass wastes from the fetus to the mother. This is similar to the actions of the lungs and the GIT; therefore, exchange of chemicals across the placenta is designed to be efficient. Unlike the blood-brain barrier, most chemicals can pass across the placenta either by simple diffusion or by mimicking necessary nutrients and using their active transport mechanisms. Cells within the placenta do have the ability to transform some chemicals and prevent them from reaching the fetus. Fat-soluble chemicals will diffuse more rapidly through the placenta than water-soluble chemicals. However, if the level of exposure is high enough, toxic levels of a water-soluble chemical can pass through the placenta and injure the fetus. Two examples of chemicals that do this are ethanol and cocaine.

The mammary barrier is less distinct than the other two discussed. There is no anatomical feature that prevents chemicals from entering breast tissue or breast milk. Instead, the breast is primarily composed of fatty materials and many small blood vessels. Chemicals that are very lipid-soluble and have very low water solubility, like dioxin and some polychlorinated biphenyls (PCBs; chemicals that historically were used in transformers), will be preferentially stored in fatty tissues like the breasts. If a woman is breast-feeding, the chemicals stored in the breasts could be transferred to the infant in the breast milk.

Species Differences

As we have seen from the discussion of toxicokinetics, the anatomy and physiology of an organism play key roles in defining the toxicity of a chemical to that organism. Birds have feathers rather than hair; this impacts absorption. Aquatic mammals like muskrats have an insulating layer of fur that prevents water from reaching the skin. This will also affect absorption. Cattle have four stomachs and have a large amount of various bacteria in their stomachs. This impacts both absorption across the gut and metabolism of the chemical by bacteria, even before it is absorbed. Chocolate is toxic to dogs because they lack an enzyme that metabolizes it so that it can be excreted. Differences in metabolic processes across species play a primary role in impacting the sensitivity of various species to chemicals.

Finally, physiological and anatomical differences can impact excretion. For example, the kangaroo rat lives in the desert yet requires no water to survive because its kidneys are extremely efficient at reabsorbing chemicals. However, this could also lead to increased retention of toxic chemicals, which could increase the toxicity of a chemical relative to other species.

Toxicological Evaluation: Part of risk assessment that should answer the question: "Does the chemical have an adverse effect?"

Toxicological Profile: An examination, summary, and interpretation of a hazardous substance to determine levels of exposure and associated health effects.

Toxicology: The study of poisons, which are substances that can cause harmful effects to living things.

Toxin: A poison produced by a plant or animal.

Tracer: A chemical injected into the flow stream of a production or injection well to determine fluid path and velocity.

Tracking System: In hazardous waste management, a manifest document that accompanies any waste transported from one location to another.

Transboundary Pollutants: Air pollution that travel from one jurisdiction to another, often crossing state or international boundaries.

Transdermal: Through or by way of the skin, such as a skin patch.

Transfer Facilities: Any transportation-related facility such as loading docks, parking areas, storage areas, or other similar areas where shipments of hazardous waste are temporarily held during the normal course of transportation.

Transfer Station: Facility where solid waste is transferred from collection vehicles to larger trucks or rail cars for longer distance transport.

Transformation: Chemical transformations that takes place in the atmosphere; for example, the conversion of the original pollutant to a secondary pollutant such as ozone.

Transformers: Transformers allow the transmission of electrical energy at high voltages, which is cheaper than transmitting at low voltages because of the smaller loss of power in the line at high voltages. They are used to step up or step down AC voltage or AC current.

Transfusion: The transfer of whole blood or blood products from one individual to another.

Transient: Existing temporarily; passing away in time.

Transient Water System: A non-community water system that does not serve twenty-five of the same nonresidents per day for more than six months per year.

Transmission Lines: Pipelines that transport raw water from its soruce to a water treatment plant, then to the distribution grid system.

Transmission System (Electric): An interconnected group of electric transmission lines and associated equipment of moving or transferring electric energy in bulk between points of supply and points tat which it is transformed for delivery over the distribution system lines to consumers, or is delivered to other electrical systems.

Transmissivity (Groundwater): The capacity of a rock to transmit water under pressure. The coefficient of transmissibility is the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer one foot wide, extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent. A hydraulic gradient of 100 percent means a one foot drop in head in one foot of flow distance.

Transpiration: Process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores.

Transportation Control Measures (TCMs): Steps taken by a locality to reduce vehicular emission and improve air quality by reducing or changing the flow of traffic; e.g., bus and HOV lanes, carpooling and other forms of ride-sharing, public transit, bicycle lanes.

Transportation Sector: An energy-consuming sector that consists o all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. Included are automobiles; trucks; busses; motorcycles; trains, subways, and other rail vehicles; aircraft; and ships, barges, and other waterborne vehicles. Vehicles whose primary purpose is not transportation (e.g., construction cranes and bulldozes, farming vehicles, and warehouse tractors and forklifts) are classified in the sector of their primary use.

Transporter: Any person engaged in the off-site transportation of hazardous waste by air, rail, highway, or water.

Trash: Highly combustible waste paper, wood, cardboard cartons, including up to 10 percent treated papers, plastic or rubber scraps.

Trash-to-Energy Plan: Burning trash to produce energy.

Treatability Studies: Tests of potential cleanup technologies conducted in a laboratory.

Treated Regulated Medical Waste: Medical waste treated to substantially reduce or eliminate its pathogenicity, but that has not yet been destroyed.

Treated Wastewater: Wastewater that has been subjected to one or more physical, chemical, and biological processes to reduce its potential of being a health hazard.

Treatability Group: A grouping of hazardous wastes that can be treated to similar concentrations using identical technologies.

Treatment: (1) Any method, technique, or process designed to remove solids and/or pollutants from solid waste, waste-streams, effluents, and air emissions. (2) Methods used to change the biological character or composition of any regulated medical waste so as to substantially reduce or eliminate its potential for causing disease.

Treatment Plant: A structure built to treat wastewater before discharging it into the environment.

Treatment, Storage, and Disposal Facility: Site where a hazardous substance is treated, stored, or disposed of. TSD facilities are regulated by EPA and states under RCRA.

Treatment Plant Site Sources of MSW: Wastes generated in water, wastewater, and other industrial treatment processes (for example, incineration ash, sludges or biosolids and general plant wastes).

Treatment System: Any technology or combination of technologies (treatment trains or unit processes) that discharges treated wastewater to surface waters, ground water, or the atmosphere.

Tremie: Device used to place concrete or grout under water.

Trench Method: In pollution control technology for USTs, a method used to capture the entire leading edge of the contaminant plume.

Triage: A process for sorting inured people into groups based on their need for or likely benefit from immediate medical treatment. Triage is used in hospital emergency rooms, or battlefields, and at disaster sites when limited medical resources must be allocated.

Trial Burn: An incinerator test in which emissions are monitored for the presence of specific organic compounds, particulates, and hydrogen chloride.

Tributary: A smaller river or stream that flows into a larger river or stream. Usually, a number of smaller tributaries merge to form a river.

Trichloroethylene (TCE): A stable, low-boiling-point colorless liquid, toxic if inhaled. Used as a solvent or metal degreasing agent, an in other industrial applications.

Trickle Irrigation: Method in which water drips to the soil from perforated tubes or emitters.

Trickling Filter: A coarse treatment system in which wastewater is trickled over a bed of stones or other material covered with bacteria that break down the organic waste and produce clean water.

Trihalomethane (THM): One of a family of organic compounds named as derivative of methane. THMs are generally by-products of chlorination of drinking water that contains organic material.

Trismus: Muscle spasm which causes the jaw to be rigidly clamped, such as during convulsions or seizures.

Trophic Level: The feeding position occupied by a given organism in a food chain, measured by the number of steps removed from the producers.

Tropic Levels: A functional classification of species that is based on feeding relationships (e.g., generally aquatic an terrestrial green plants comprise the first trophic level, and herbivores comprise the second.)

Troposphere: A region of the atmosphere based on temperature difference between the earth's surface and ten miles in altitude.

Trust Fund: A fund set up under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) to help pay for cleanup of hazardous waste sites and for legal action to force those responsible for the sites to clean them up.

TSP: Total suspended particulates.

Tube Settler: Device using bundles of tubes to let solids in water settle to the bottom for removal by conventional sludge collection means; sometimes used in sedimentation basins and clarifiers to improve particle removal.

Tuberculation: Development of formation of small mounds of carrions products on the inside of iron pipe. These tubercules roughen the inside of the pipe, increasing its resistance to water flow.

Tumor: An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Tundra: A type of treeless ecosystem dominated by lichens, mosses, grasses, and woody plants. Tundra is found at high latitudes (artic tundra). Artic tundra is underlain by permafrost and is usually water saturated.

Turbidimeter: A device that measures the cloudiness of suspended solids in a liquid; a measure of the quantity of suspended solids.

Turbidity: Reduced transparency of the atmosphere caused by absorption and scattering of radiation by solid or liquid particles other than clouds, and held in suspension.

Turbulence: (1) Uncoordinated movements and a state of continuous change in liquids and gases; (2) one of the three Ts of combustion.

Turbulent Flow: 1. Air flow characterized by transverse velocity components as well as velocity in the primary direction of flow in a duct; mixing velocities. 2. In a stream where complex mixing is the result.

Turnover: The mixing of the upper and lower levels of a lake that most often occurs during the spring and fall, caused by dramatic changes in surface water temperature.

U

U-Factor: Measure the rate of heat loss or how well a product prevents heat from escaping. It includes the thermal properties of the frame as well as the glazing. The insulating value is indicated by the R-value, which is the inverse o the U-factor. U-factor ratings generally fall between 0.20 and 1.20. The lower the U-factor, the grater a product's resistance to heat flow and the better its insulating value.

Ulcer: A break in skin or mucous membrane with loss of surface tissue, disintegration and death of tissue, and often pus.

Ulceration: Tissue damage (e.g., of the cornea, airway lignin, stomach or intestine lining).

Ultimate Stress: The greatest stress that can be produced in a body before rupture occurs.

Ultra Clean Coal (UCC): Coal that is washed, ground into fine particles, then chemically treated to remove sulfur, ash, silicone, and other substances; usually briquetted and coated with a sealant made from coal.

Ultra Low Head: Head of ten feet or less.

Ultraviolet Rays: Radiation from the sun that can be useful or potentially harmful. UV rays from one part of the spectrum (UV-A) enhance plant life. UV rays from other parts of the spectrum (UV-B) can cause skin cancer or other tissue damage. The ozone layer in the atmosphere partly shields us from ultraviolet rays reaching the earth's surface.

Uncertainty: Degree of confidence that can be assigned to a numerical measurement in terms of both in accuracy and its precision.

Uncertainty Factor: One of several factors used in calculating the reference dose from experimental data. UFs are intended to account for (1) the variation in sensitivity among humans; (2) the uncertainty in extrapolating animal data to humans; (3) the uncertainty in extrapolating data obtained in a study that covers less than the full life of the exposed animal or humans; and (4) the uncertainty in using LOAEL data rather than NOAEL data.

Unconfined Aquifer: An aquifer where the water table is exposed to the atmosphere through openings in the overlying materials.

Under Reamer: A drilling device that can enlarge a drill hoe. The device is placed about the drill bit and can be opened to drill and then closed to be brought back up through smaller diameter hole or casing.

Underground Injection Control (UIC): The program under the Safe Drinking Water Act that regulates the use of wells to pump fluids into the ground. Injection wells are known as Class V wells. There are twenty-two types of Class V injection wells. The types of wells are shown in the Table.

Underground Injection Wells: Steel- and concrete-encased shafts into which hazardous waste is deposited by force and under pressure.

Underground Sources of Drinking Water: Aquifers currently begin used as a source of drinking water or those capable of supplying a public water system. They have a total dissolved solids content of 10,000 milligrams per liter or less, and are not "exempted aquifers."

Underground Storage Tanks (USTs): The biggest problem associated with USTs is that no one knows the exact number of underground storage tank (UST) systems

Class V Underground Injection Wells

Type of Injection Well	*Purpose*
Agricultural Drainage Wells	Receive agricultural runoff
Stormwater Drainage Wells	Dispose of rain water and melted snow
Carwashes Without Undercarriage Washing or Engine Cleaning	Dispose of wash water from car exteriors
Large-Capacity Septic Systems	Dispose of sanitary waste through a septic system
Food Processing Disposal Wells	Dispose of food preparation wastewater
Sewage Treatment Effluent Wells	Used to inject treated or untreated wastewater
Laundromats Without Dry Cleaning Facilities	Dispose of fluid from laundromats
Spent Brine Return Flow Wells	Dispose of spent brine for mineral extraction
Mine Backfill Wells	Dispose of mining byproducts
Aquaculture Wells	Dispose of water used for aquatic sea life cultivation
Solution Mining Wells	Dispose of leaching solutions (lixiviants)
In-Situ Fossil Fuel Recovery Wells	Inject water, air, oxygen solvents, combustibles, or explosives into underground or oil shale beds to free fossil fuels.
Special Drainage Wells	Potable water overflow wells and swimming pool drainage
Experimental Wells	Used to test new technologies.
Aquifer Remediation Wells	Use to clean up, treat, or prevent contamination of underground sources of drinking water.
Geothermal Electrical Power Wells	Dispose of geothermal fluids.
Geothermal Direct Heat Return Flow Wells	Dispose of spent geothermal fluids.
Heat Pump/Air Conditioning Return Flow Wells	Re-inject groundwater that has passed through a heat exchanger to heat or cool buildings.
Saline Intrusion Barrier Wells	Injected fluids to prevent the intrusion of salt water.
Aquifer Recharge/Recovery Wells	Used to recharge an aquifer.
Noncontact Cooling Water Wells	Used to inject noncontact cooling water.
Subsidence Control Wells	Used to control land subsidence caused by groundwater withdrawal or over pumping of oil and gas.

installed in the United States. All present-day estimates range in the millions. Not being able to find the tanks for which we have no records (especially those where the locations have changed use) is a problem that allows an unknown number of old, unlined tanks to literally disintegrate undetected. We know thousands of these tanks must exist, and their probable condition, but we don't know where. There are also thousands of tanks for which we know the location are currently leaking, including ancillaries such as piping. USTs leak for several reasons.

Corrosion Problems

Corrosion is the most common cause of tank failure. Most older tanks are single shell construction, made of unprotected bare steel. Many leaked in the past (and have been removed, we hope), are leaking at present, or (if not removed or rehabilitated) will certainly leak in the future. Even a small leak, if undetected or ignored, causes large amounts of petroleum product to enter the subsurface. Most unknown USTs are this type.

Faulty Construction

Any material item is only as good as its construction, workmanship and materials. USTs are no different. Poor construction and workmanship will cause failure, though the results of such failure are not simple. Proper monitoring equipment can at least indicate that leakage is occurring. Older tanks with no monitoring equipment could be emitting small quantities from a minor leak, undetected, over the course of years.

Faulty Installation

Without careful handling of the tank itself and any appurtenances during installation, failure can result. Tank beds must be specially prepared to receive the tank for burial, and adequate backfilling ensures that no possible movement of the tank can occur after it is placed in the ground. Underground movement from whatever reason can damage the tank (especially FRP tanks) and can also jar loose pipe connections, or separate pipe joints. Failure to use special care in this installation process results in leaks.

Underground leak detection devices must also be carefully and correctly installed. Quick discovery of a leaking tank is best so that remediation can be initiated quickly, before a minor spill turns into a major environmental contamination incident.

Piping Failures

Piping failure is one of the most common causes of larger UST spills. Metal piping used to connect tanks, or for connecting tanks to delivery pumps, to fill drops, or for whatever reason, presents the danger of corrosion from rust or from electrolytic action. Threaded pipes (or other metal parts made electrically active by threading) have a strong tendency to corrode if not properly coated or otherwise protected, causing electrolytic action. Usually *cathodic protection* is installed to negate electrolytic action.

Another common cause of piping failures is poor workmanship. Improperly fitted piping joints (both threaded and PVC types) and incomplete tightening of joints, construction accidents, and improper installation of cover pads are frequent areas of workmanship problems.

Spills and Overfills

Any UST facility can be the site of environmental pollution as the result of spills and overfills—usually caused by human error. While the USEPA has promulgated tank filling procedures in its 40 CFR 280 regulations, and the National Fire Protection Association (NFPA) has issued its NFPA-385 Tank Filling Guidelines, spills from overfilling occur frequently. UST overfilling is bad enough in itself, but environmental contamination problems are compounded by repeated spills and/or unreported spills. Petroleum products or hazardous wastes can literally saturate the spill area, intensifying soil corrosiveness (Blackman, 2001).

Compatibility of Contents and UST

Placing highly corrosive materials into containers not rated to contain them is asking for trouble. New chemicals (including fuels) are constantly under development and entering the marketplace. Developing such fuels is usually meant to achieve improved air quality, but improving air quality at the expense of water and soil makes no sense.

Many USTs presently in use are FRP (fiberglass- reinforced plastic) tanks, installed to replace unprotected, bare steel tanks. FRPs are rated (or modified by using a different liner) to safely store the fuel products now commonly used. When a new, exotic blend of fuel is developed, and placed in a FRP-type tank that proves incompatible, problems occur.

Incompatibility problems include blistering, internal stress, cracking, and underfilm corrosion. The American Petroleum Institute put together a standard to help prevent FRP-constructed or lined tank problems. The standard should be referred to when existing tanks are used for non-standard fuel products.

Underlying Hazardous Constituent (UHC): Any constituent listed in 40 CFR 268.48, "Table UTS-Universal Treatment Standards", except fluoride, selenium, sulfide, vanadium, and zinc, which can reasonably be expected to be present at the point of generation of the hazardous waste, at a concentration above the constituent-specific universal treatment standard.

UN Identification Number: An international four digit number assigned to all hazardous material regulated by the United Nations.

Uniform Resource Locator (URL): The global address of documents and other resources on the World Wide Web.

United Nations Hazard Class Number System: A system for designating and labeling hazardous materials that uses a dedicated number system.

Universal Soil Loss Equation (USLE): An empirical equation estimating the amount of soil loss; used for the evaluation of a resource management system for water erosion control.

Universal Treatment Standards (UTS): These are the constituent-specific treatment standards found in §268.48.

Unknown: This term is used when information for a section has not been identified for the agent.

Unprotected Share: In Windows terminology, a "share" is a mechanism that allows a user to connect to file systems and printers on other systems. An "unprotected share" is one that allows anyone to connect to it.

Unreasonable Risk: Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), "unreasonable adverse effects" means any unreasonable risk to man or the environment, taking into account the medical, economic, social, and environmental costs and benefits of any pesticide.

Unrestricted Area: An area, access to which is neither limited nor controlled by the licensee.

Unsafe Condition: Any physical state that deviates from that which is acceptable, normal, or correct in terms of past production or potential future production of personal injury and/or damage to property; any physical state that results in a reduction in the degree of safety normally present.

Unsaturated Flow: Movement of water in a soil that is not filled to capacity with water.

Unsaturated Zone: Lies just beneath the soil surface and is characterized by crevices that contain both air and water; water contained therein is not available for use.

Unstable Atmosphere: Characterized by a high degree of turbulence.

Upper Detection Limit: The largest concentration that an instrument can reliably detect.

Upper Explosive Limit (UEL): The maximum concentration of a flammable gas in air required for ignition in the presence of an ignition source.

Upwind Turbine: A turbine that faces into the wind, requires a wind vane and yaw drive in order to maintain proper orientation in relation to the wind.

Uranium: A naturally occurring element found in low levels within all rock, soil, and water. A heavy, naturally radioactive, metallic element (atomic number 92). Its two principally occurring isotopes are ^{235}U and ^{238}U. The isotope ^{235}U is indispensable to the nuclear industry because it is the only isotope existing in nature to any appreciable extent that is fissionable by thermal neutrons. The isotope ^{235}U is also important because it absorbs neutrons to produce a radioactive isotope that subsequently decays to the isotope ^{239}Pu, which also is fissionable by thermal neutrons.

Uranium Concentrate: A yellow or brown powder obtained by the milling of uranium ore, processing of in situ leach mining solutions, or as a byproduct of phosphoric acid production.

Uranium Deposit: A discrete concentration of uranium mineralization that is of possible economic interest.

Uranium Endowment: The uranium that is estimated to occur in rock with a grade of at least 0.01 percent U_3O_8. The estimate of the uranium endowment is made before consideration of economic availability and any associated uranium resources.

Uranium Hexafluoride (UF_6): A white solid obtained by chemical treatment of U_3O_8 and which forms a vapor at temperatures above 56° C. UF_6 is the form of uranium required for the enrichment process.

Uranium Mill Tailing Piles: Former uranium ore processing sites that contain leftover radioactive materials (wastes), including radium and unrecovered uranium.

Uranium Mill-Tailings Waste Piles: Licensed active mills with tailings piles and evaporation periods created by acid or alkaline leaching processes.

Uranium Ore: Rock containing uranium mineralization in concentrations that can be mined economically (typically 1 to 4 pounds of U_3O_8 per ton or 0.05 to 0.20 percent U_3O_8).

Uranium Oxide: Uranium concentrate or yellowcake. Abbreviated as U_3O_8.

Uranium Property: A specific tract of land with known uranium reserves could be developed for mining.

Uranium Reserves: Estimated quantities of uranium in known mineral deposits of such size, grade, and configuration that the uranium could be recovered at or below a specified production cost with currently proven mining and processing technology and under current law and regulations. Reserves are based on direct radiometric and chemical measurements of drill hole and other types of sampling of the deposit. Mineral grades and thickness, spatial relationships, depths below the surface, mining and reclamation methods, distances to milling facilities, and amenability or ores to processing are considered in the evaluation. The amounts of uranium in ore that could be exploited within the chose forward-cost levels are estimated utilizing available sampling, engineering, geologic, and economic data in accordance with conventional engineering practices.

Uranium Resource Categories: Three categories of uranium resources are used to reflect differing levels of confidence in the resources reported. Reasonably assured rescores (RAR), estimated additional resources (EAR), and speculative (SR) are described below.

- **Reasonably assured resources (RAR):** The uranium that occurs in known mineral deposits of such size, grade, and configuration that it could be recovered within the given production cost ranges, with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. RAR correspond to DOE's uranium reserves category.
- **Estimated additional resources (EAR)**: The uranium in addition to RAR that is expected to occur, mostly on the basis of direct geological evidence, in extensions of well-explored deposits, little explored deposits, and undiscovered deposits believed to exist along well-defined geological trends with known deposits, such that the uranium can subsequently be recovered within the given cost ranges. Estimates of tonnage and grade are based on available sampling data and on knowledge of the deposit characteristics, as determined in the best-known parts of the deposit or in similar deposits. EAR correspond to DOE's probable potential resources category.
- **Speculative resources (SR)**: Uranium in addition to EAR that is thought to exist, mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing extrapolation techniques. The locations of deposits in this category can generally be specified only being somewhere within given regions or geological trends. The estimates in this category of SR corresponds to DOE's possible resources plus speculative potential resources categories combined.

Urban Expansion Zone: A boundary or mapped area surrounding a municipality and officially designated by the governing body of the municipality as the area in which future urban development will be allowed to occur as the municipality grows.

Urban Runoff: Storm water from city streets and adjacent domestic or commercial properties that carries pollutants of various kinds into the sewer systems and receiving waters.

Urea-Formaldehyde Foam Insulation: A material once used to conserve energy by sealing crawl spaces, attics, etc.; no longer used because emissions were found to be a health hazard.

Urgent Public Health Hazard: A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result n harmful health effects that require rapid intervention.

Urticant: An agent that causes severe irritation to the skin and mucous membranes, as well as pain; also called nettle agent .

USDA: U.S. Department of Agriculture.

USDOT: The mission of the United States Department of Transportation (DOT)—a cabinet-level executive department of the U.S. government established by an Act of Congress, and signed into law by President Lyndon B. Johnson on October 15, 1966, is to:

> *Serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future.*

The DOT is the primary agency of the federal government with the responsibility for shaping and administering policies and programs to protect and enhance the safety, adequacy, and efficiency of the transportation system and services.

The Department of Transportation contains the Office of the Secretary and eleven individual operating administrations: (1) the Federal Aviation Administration, (2) the Federal Highway Administration, (3) the Federal Motor Carrier Safety Administration, (4) the Federal Railroad Administration, (5) the National Highway Traffic Safety Administration, (6) the Federal Transit Administration, (7) the Maritime Administration, (8) the Saint Lawrence Seaway Development Corporation, (9) the Research and Innovation Technology Administration, and (10) the Pipeline and Hazardous Materials Safety Administration, and (11) the Surface Transportation Board.

1. **The Federal Aviation Administration (FAA)**—oversees the safety of civil aviation. The safety mission of the FAA is first and foremost and includes the issuance and enforcement of regulations and standards related to the manufacture, operation, certification and maintenance of aircraft. The agency is responsible for the rating and certification of airmen and for certification of airports serving air carriers. It also regulates a program to protect the security of civil aviation, and enforces regulations under the Hazardous Materials Transportation Act (HMTA) for shipments by air. The FAA, which operates a network of airport towers, air route traffic control centers, and flight service stations, develops air traffic rules, allocates the use of airspace, and provides for the security control of air traffic to meet national defense requirements. Other responsibilities include the construction of installation of visual and electronic aids to air navigation and promotion of aviation safety internationally. The FAA, which regulates and encourages the U.S. commercial space transportation industry, also licenses commercial space launch facilities and private sector launches.
2. **The Federal Highway Administration (FHWA)**—coordinates highway transportation programs in cooperation with states and other partners to enhance the country's safety, economic vitality, quality of life, and the environment. Major program areas include the Federal-Aid Highway Program, which provides federal financial assistance to the States to construct and improve the National highway System, urban and rural roads, and bridges. This program provides funds for general improvements and development of safe highways and roads. The Federal Lands Highway Program provides access to and within national forests, national parks, Indian reservations and other public lands by preparing plans and contracts, supervising construction facilities, and conducting bridge inspections and surveys. The FHWA also manages a comprehensive research, development, and technology program.
3. **Federal Motor Carrier Safety Administration**—was established within the DOT on January 1, 2000, pursuant to the Motor carrier Safety Improvement Act of 1999 [Public Law No. 106- 159, 113 Stat. 1748 (December 9, 1999)]. Formerly a part of the Federal Highway Administration, the Federal Motor Carrier Safety Administration's primary mission is to prevent commercial motor vehicle-related fatalities and injuries. Administration activities contribute to ensuring safety in motor carrier operations through strong enforcement of safety regulations, targeting higher-risk carriers and commercial motor vehicle drivers; improving safety information systems and commercial motor vehicle technologies;

strengthening commercial motor vehicle equipment and operating standards; and increasing safety awareness. To accomplish these activities, the Administration works with federal, state, and local enforcement agencies, the motor carrier industry, labor safety interest groups, and others.

4. **Federal Railroad Administration (FRA)**—promotes safe and environmentally sound rail transportation. With the responsibility of ensuring railroad safety throughout the nation, the FRA employs safety inspectors to monitor railroad compliance with federally mandated safety standards including track maintenance, inspection standards and operating practices. The FRA conducts research and development tests to evaluate projects in support of its safety mission and to enhance the railroad system as a national transportation resource. Public education campaigns on highway-rail grade crossing safety and the danger of trespassing on rail property are also administered by FRA.
5. **National Highway Traffic Safety Administration (NHTSA)**—is responsible for reducing deaths, injuries and economic losses resulting from motor vehicle crashes. NHTSA sets and enforces safety performance standards for motor vehicles and equipment, and through grants state and local governments enables them to conduct effective local highway safety programs. NHTSA investigates safety defects in motor vehicles, sets and enforces fuel economy standards, helps states and local communities reduce the threat of drunk drivers, promote the use of safety belts, child safety seats and air bags, investigate odometer fraud, establish and enforce vehicle anti-theft regulations and provide consumer information on motor vehicle safety topics. Research on driver behavior and traffic safety is conducted by NHTSA to develop the most efficient and effective means of bringing about safety improvements.
6. **Federal Transit Administration (FTA)**—assists in developing improved mass transportation system for cities and communities nationwide. Through its grant programs, FTA helps plan, build, and operate transit systems with convenience, cost and accessibility in mind. While buses and rail vehicles are the most common type of public transportation, other kinds include commuter ferryboats, trolleys, inclined railways, subways, and people movers. In providing financial, technical and planning assistance, the agency provides leadership and resources for safe and technologically advanced local transit systems while assisting in the development of local and regional traffic reduction. The FTA maintains the National Transit Library (NTL), a repository of reports, documents, and data generated by professionals and others from around the country. The NTL is designed to facilitate document sharing among people interested in transit and transit related topics.
7. **Maritime Administration (MARAD)**—promotes development and maintenance of an adequate, well-balanced, United States merchant marine, sufficient to carry the Nation ‘s domestic waterborne commerce and a substantial portion of its waterborne foreign commerce, and capable of serving as a naval and military auxiliary in time of war or national emergency. MARAD also seeks to ensure that the United States enjoys adequate shipbuilding and repair service, efficient ports, effective intermodal water and land transportation systems, and reserve shipping capacity in time of national emergency.
8. **Saint Lawrence Seaway Development Corporation (SLSDC)**—operates and maintains a safe, reliable and efficient waterway for commercial and noncommercial vessels between the Great Lakes and the Atlantic Ocean. The SLSDC, in tandem with the Saint Lawrence Seaway Authority of Canada, oversees operations safety, vessel inspections, traffic control, and navigation aids o the Great Lakes and the Saint Lawrence Seaway. Important to the economic development of the great Lakes region, SLSDC works to develop trade opportunities to benefit port communities, shippers and receivers and related industries in the area.
9. **Research and Innovative Technology Administration (RITA)**—is an agency whose mission is to identify and facilitate solutions to the challenges and opportunities facing America’s transportation system. RITA’s focus is to promote transportation research that will foster the use of innovative technology. RITA includes the Volpe National Transportation Systems Center, an organization dedicated to enhancing the effectiveness, efficiency, and responsiveness of other Federal organizations with critical transportation-related functions and missions. With responsibility for research policy and technology sharing, the agency partners with national and international organizations and universities. RITA also includes the Bureau of Transportation Statistics, the Transportation Safety Institute and the University Transportation Centers program.
10. **Pipeline and Hazardous Materials Safety Administration (PHMSA)**—oversees the safety of more than 800,000 daily shipments of hazardous materials in the United States and 64 percent of the nation’s energy that is transported by pipelines. PHMSA is dedicated solely to safety by working toward the elimination of transportation-related deaths and injuries in hazardous materials and pipeline transportation and by promoting transportation solutions that enhance communities and protect the natural environment.

11. **Surface Transportation Board (STB)**—is an independent, bipartisan, adjudicatory body organizationally housed within the DOT. It is responsible for the economic regulation of interstate surface transportation, primarily railroads, within the United States. The STB's mission is to ensure that competitive, efficient, and safe transportation services are provided to meet the needs of shippers, receivers, and consumers. The Board is charged with promoting, where appropriate, substantive and procedural regulatory reform in the economic regulation of surface transportation, and with providing an efficient and effective forum for the resolution of disputes. The Board continues to strive to develop, through rulemakings and case disposition, new and better ways to analyze unique and complex problems, to reach fully justified decisions more quickly, to reduce the costs associated with regulatory oversight, and to encourage private-sector negotiations and resolutions to problems where appropriate.

A chronology of significant dates in DOT history is shown in the Table.

Chronology of Significant USDOT Dates

Date	*Event*
August 4, 1790	President George Washington signed into law a bill authorizing the construction of ten 50-foot, two-masted boats—to guard the coast against smugglers.
January 12, 1874	Representative Laurin D. Woodworth (R-OH) introduces the first post-Civil War legislation to establish a federal bureau of transportation.
March 3, 1893	President Benjamin Harrison signed into law the Agriculture Appropriations Act of 1894, $100,000 of which will be used to launch the Office of Road Inquiry, predecessor agency to the Bureau of Public Roads and Federal Highway Administration.
July 11, 1916	President Woodrow Wilson signed the Federal-aid Road Act, launching the Federal-aid highway program, with grants to the states for the construction of roads used to deliver the mail.
February 5, 1949	The First Hoover Commission Report called for coordination activities, under the auspices of the Commerce Department. President Harry S. Truman would respond by putting the office of Under Secretary for Transportation in the Department of Commerce.
November 20, 1950	A Commerce Department Order established the Office of the Under Secretary for Transportation, with supervisory responsibility over transportation functions exercised by various departmental components.
May 13, 1954	President Dwight D. Eisenhower signed into law the Wiley-Dondero Act, which created the Saint Lawrence Seaway Development Corporation, a wholly owned government corporation, to construct, operate and maintain that part of the Saint Lawrence Seaway between Montreal and Lake Erie, within the territorial limits of the U.S.
June 29, 1956	Eisenhower signed into law the Federal-Aid Highway Act of 1956 and the Highway Revenue Act of 1956, authorizing the National System of Interstate and Defense Highways, and creating the Federal Highway Trust Fund.
August 23, 1958	Eisenhower signed into law the Federal Aviation Act of 1958, establishing the Federal Aviation Agency (Administration, after the DOT Act passed), to take effect on January 1, 1959. In addition, the bill freed the Civil Aeronautics Board (CAB) from its administrative connections with the Department of Commerce.
June 26-27, 1959	The Saint Lawrence Seaway formally opened, having opened for business on April 25.
June 26, 1961	The U.S. Senate Committee on Commerce issued a staff report on *National Transportation Policy*, commonly known as the Doyle Report, calling for, among other things, the establishment of a Department of Transportation.
June 30, 1961	President John F. Kennedy signed into law the Housing Act of 1961, which acknowledged, for the first time, a federal role in mass transportation by establishing the Office of Transportation within the Housing and House Finance Agency.
July 9, 1964	President Lyndon B. Johnson signed into law the Urban Mass Transportation Act of 1964, a three-year program of federal matching grants to help the states and localities provide adequate mass transportation for the nation's cities. Responsibility for these functions rested with the Administrator of the Housing and Home Finance Agency, later shifting to the Secretary of Housing and Urban Development, and, in turn, the Administrator of the Urban Mass Transportation Administration.
October 19, 1964	A task force on transportation organization, headed by George W. Hilton and the Bureau of the Budget's Gordon Murray, advised President Johnson to establish a Department of Transportation.
June 30, 1965	The Federal Aviation Agency administrator, Najeeb E. Halaby, recommended the establishment of a Cabinet-level department of transportation, of which the FAA would become a part. Halaby had been frustrated in part over supersonic transport (SST) decision making.

(continued)

Chronology of Significant USDOT Dates

Date	*Event*
July 1, 1965	During the swearing-in of General William F. McKee as Halaby's successor, President Johnson announced that the SST project was moving into the next stage, an 18-month detailed design phase.
August 12, 1965	Presidential Assistant Joseph A. Califano, Jr., asked Commerce Under Secretary Alan S. Boyd to chair a task force to look into combining government responsibilities for transportation problems by reorganizing those agencies that dealt with them.
August 25, 1965	President Johnson ordered across-the-board use of Defense Secretary Robert S. McNamara's Planning, Programming, and Budgeting System throughout the Cabinet-level Departments and other Executive Branch agencies.
September 30, 1965	President Johnson signed into law the High-Speed Ground Transportation Act, marking the first time that the federal government sought to promote high-speed ground transportation.
October 22, 1965	President Johnson signed into law the Highway Beautification Act.
January 12, 1966	In his State of the Union Address, President Johnson announced his intention to seek the establishment of the Department of Transportation.
January 14, 1966	The White House authorized the Zwick Task Force to prepare the Administration bill that would establish a Cabinet-level Department of Transportation to transmit to Congress. They finished ten days later.
March 2, 1966	Proclaiming that "in a nation that spans a continent, transportation is the web of union," President Johnson sent Congress a bill, recommending that the United States reorganize its entire transportation policy making apparatus and created a Department of Transportation. That same day, Representative Chet Holifield (D-CA) and Senator Warren G. Magnuson (D-WA) introduced that measure in the House and Senate.
March 29, 1966	The Senate Committee on Government Operations opened hearings on the DOT Act.
April 13, 1966	President Johnson signed into law the Uniform Time Act. The DOT Enabling Act charged the Secretary of Transportation with the administration of this act. In turn, he delegated this authority to the Department's General Counsel.
October 15, 1966	President Johnson signed into law Public Law 89-670, establishing the Department of Transportation.
January 6, 1967	Secretary of Commerce John T. Connor appointed the first National Motor Vehicle Advisory Council.
January 16, 1967	Alan S. Boyd was administered the oath of office as the nation's first Secretary of Transportation. Simultaneously, the interagency Department of Transportation Task Force adjourned, and many of its members left to take up tasks in the nascent Department of Transportation.
April 1, 1967	The new cabinet-level Department of Transportation was officially open for business.
January 22, 1969	Former Massachusetts governor John A. Volpe took the oath of office as the nation's second Secretary of Transportation.
February 2, 1973	Dr. Claude S. Brinegar took the oath of office as the nation's third Secretary of Transportation.
March 7, 1975	William T. Coleman, Jr., took the oath of office as the nation's fourth Secretary of Transportation.
January 23, 1977	Former congressman Brock Adams (D-WA) was administered the oath of office as the nation's fifth Secretary of Transportation.
September 24, 1979	Neil E. Goldschmidt formally took the oath of office as the nation's sixth Secretary of Transportation.
January 23, 1981	Pennsylvania politician-businessman Andrew L."Drew" Lewis, Jr., took the oath of office as the nation's seventh Secretary of Transportation.
February 7, 1983	Elizabeth Hanford Dole, the former director of the White House Office of Public Liaison, took the oath of office as the nation's eighth Secretary of Transportation.
December 3, 1987	The former Deputy Secretary, and Acting Secretary, James Horace Burnley IV, took the oath of office as the nation's ninth Secretary of Transportation.
February 6, 1989	In ceremonies at the FAA Auditorium, with President George Bush looking on, Samuel Knox Skinner, the former head of the Regional Transportation Authority of Northeastern Illinois, took the oath of office as the nation's tenth Secretary of Transportation.
February 24, 1992	In a private ceremony, former White House deputy chief of staff Andrew Hill Card, Jr., took the oath of office as the nation's eleventh Secretary of Transportation.
January 21, 1993	Former Denver mayor Federico F. Pena took the oath of office as the nation's twelfth Secretary of Transportation.
January 14, 1997	Former Federal Highway Administrator Rodney E. Slater took the oath of office as the nation's thirteenth Secretary of Transportation.
December 9, 1999	President Clinton signed into law the Motor Carrier Safety Improvement Act of 1999.
March 8, 2000	Slater formally inaugurated the new Federal Motor Carrier Safety Administration, whose mission is to significantly improve truck and bus safety on the nation's highways.

✔ **Interesting Point:** The United States Federal Government's involvement in supervising transportation began in the first half of the nineteenth century with the inspection of steamboats.

Use Cluster: A set of competing chemicals, processes, and/or technologies that can substitute for one another in performing a particular function.

Use Constituting Disposal: The direct placement of recycled materials that is wastes or waste derived-products on the land. Note, remediation activities involving replacement of treated soils onto the land is not a type of use constituting disposal, in part, because it is a supervised remediation instead of an unsupervised recycling activity.

Used Oil: Spend motor oil from passenger cars and trucks collected at specified locations for recycling (not included in the category of municipal solid waste).

Useful Heat: Heat stored above room temperature (in a solar heating system).

Useful Thermal Output: The thermal energy made available for use in any industrial or commercial process or used in any heating or cooling application, i.e., total thermal energy made available for processes and applications other than electrical generation.

User: A person, organization entity, or automated process that accesses a system, whether authorized to do so or not.

User Contingency Plan: The alternative methods of continuing business operations if IT systems are unavailable.

User Fee: Fee collected from only those persons who use a particular service, as compared to one collected from the public in general.

Utility Load: The total electricity demand for a utility district.

V

Vaccine: A preparation consisting of antis of a disease-causing organisms, which, when introduced into the body, stimulates the production of specific antibodies or altered cells. This produces an immunity to the disease-causing organism. The antigen in the preparation can be whole disease-causing organisms (killed or weakened) of parts of these organisms.

Vacuole: A small cavity in the protoplasm of a cell.

Vadose Water: Water in the unsaturated zone that is essentially unavailable for use.

Vadose Zone: Zone containing water under less pressure than that of the atmosphere, including soil water, intermediate vadose water, and capillary water. This zone is limited above by the land surface and below the surface of the zone of saturation, that is, the water table.

Valence: The net electric charge of an atom or the number of electrons an atom can give up (or acquire) to achieve a filled out shell.

Valley Winds: At valley floor level, slope winds transform into valley winds that flow down-valley, often with the flow of a river.

Valued Environmental Attributes/Components: Those aspects (components/processes/functions) of ecosystems, human health, and environmental welfare considered to be important and potentially at risk from human activity or natural hazards. Similar to the term "valued environmental components" used in environmental impact assessment.

Vapor: The gaseous state of a substance that is liquid or solid at ordinary temperature and pressure.

Vapor Capture System: Any combination of hoods and ventilation system that captures or contains organic vapors so they may be directed to an abatement or recovery device.

Vapor Density: Weight of a volume of pure vapor or gas (with no air present) compared to the weight of an equal volume of dry air at the same temperature and pressure. A vapor density less that 1 (one) indicates that the vapor is lighter than air and will tend to rise. A vapor density greater than 1 (one) indicates that the vapor is heavier than air and may travel along the ground.

Vapor Dispersion: The movement of vapor clouds in air due to wind, thermal action, gravity spreading, and mixing.

Vapor Dominated: A geothermal reservoir system in which subsurface pressures are controlled by vapor rather than by liquid. Sometimes referred to as a dry-steam reservoir.

Vapor Plume: Flue gases visible because they contain water droplets.

Vapor Pressure: A measure of a substance's propensity to evaporate, vapor pressure is the force per unit area exerted by vapor in an equilibrium state with surroundings at a given pressure. It increases exponentially with an increase in temperature. A relative measure of chemical volatility, vapor pressure is used to calculate water partition coefficients and volatilization rate constants.

Vapor Recovery System: A system by which the volatile gases from gasoline are captured instead of being released into the atmosphere.

Vaporize: To convert into vapor, as by the application of heat, whether naturally or artificially.

Variance: Government permission for a delay or exception in the application of a given law, ordinance, or regulation.

Vasoconstriction: Narrowing of the interior diameter of blood vessel.

Vasodilation: Widening of the interior diameter of blood vessels.

Vasopressor: Of, relating to, or causing constriction of blood vessels, and thereby an increase in blood pressure.

Vector: Bearer or carrier; such as an organism (often an insect), that carries and transmits disease-causing micro-organisms.

Vegetative Controls: Non-point source pollution control practices that involve vegetative cover to reduce erosion and minimize loss of pollutants.

Vegetative Practices: Candidate measure that include vegetation as the principal method of pollution control.

Vehicle Miles Traveled (VMT): A measure of the extent of motor vehicle operation; the total number of vehicle miles traveled within a specific geographic area over a given period to time.

Velocity (V): The time rate of movement of air; usually expressed as feet per minute.

Velocity Pressure (VP): The pressure attributed to the velocity of air. Velocity pressure (VP) is created as air travels at a given velocity through a ventilation system. Velocity pressure is only exerted in the direction of airflow and is *always* positive (i.e., above atmospheric pressure). When you think about it, velocity pressure has to be positive, and obviously the force or pressure that causes it also must be positive.

Note that the velocity of the air moving within a ventilation system is directly related to the velocity pressure of the system. This relationship can be derived into the standard equation for determining velocity (and clearly demonstrates the relationship between velocity of moving air and the velocity pressure):

$$v = 4005\sqrt{VP}$$

Ventilation Fan Laws: Relationships that describe theoretical, mutual performance changes in pressure, flow rate, rpm of the fan, horsepower, density of air, fan size, and sand power.

Ventilation (Industrial): Facts, Concepts and Practice Problems: Ventilation is an important form of emission/exposure control. It also provides for health, comfort, and well-being. All human occupancies require ventilation.

Facts and Concepts

Properties of air MW = 29; weight density = 0.075 lbs/cu ft at STP

STP (ventilation) Standard Temperature and Pressure T = 70°F, BP = 29.92 inches HG, dry air; weight density = 0.075 lbs/cu ft at STP.

Density Correction Factor (d)—a factor derived from the Ideal Gas equations:

In the following equation, BP = absolute barometric pressure

$$d = \frac{T_{TSP}\text{ (absolute)}}{T_{actual}\text{ (absolute)}} \times \frac{BP_{actual}}{BP_{STP}}$$

°R Degrees Rankine, °R = °F + 460; absolute temperature

K Kelvin, K = °C + 273; absolute temperature

Example 1

The temperature is 90°F and the barometric pressure is 27.50” Hg. What is the density correction factor, d?

Solution:

$$d = \frac{460 + 70}{460 + 90°} \times \frac{\text{B.P.}}{29.92\text{ in Hg}}$$

$$d = \frac{530}{550} \times \frac{27.50\text{ in Hg}}{29.92\text{ in Hg}} = 0.886$$

Local exhaust ventilation systems are made up of 5 components: Hood, ductwork, air cleaner, fan, and stack

Pressure

Air moves under the influence of pressure differentials. A fan is commonly used to create the pressure difference. At sea level the standard static (barometric) pressure (SP) is 14.7 psia = 29.92 inches Hg = 407 inch w.g. If a fan is capable of creating one inch of negative static pressure (e.g., 1” w.g., or “one inch water gauge”), then the absolute static pressure in the duct will be reduced to 406 inches w.g.

Manometers Used to measure pressure differences.

Pitot tube A device used to measure TP and SP
“S” = “side” = SP
“TP” = “tip” = “top” = TP
Attach both legs to the manometer to measure VP

Pressures are related as follows: TP = SP + VP

	TP	SP	VP
Upstream	–	–	+
Downstream	+	+	+

Example 2
Determine the velocity pressure, VP.

TP = –0.35” w.g. SP = –0.5 w.g.

Solution:

TP = SP + VP and
VP = TP – SP = –0.35 – (–0.50) = 0.15” w.g.

Role of velocity pressure
The velocity pressure is related to the velocity of air in the duct. The relationship is given by:

$$V = 4005 \sqrt{VP/d}$$

where:
VP = velocity pressure, inch w.g. (measured with a Pitot tube, for example)
V = velocity, feet per minute (fpm)
d = density correction factor

Example 3
The velocity pressure of an airstream in a lab fume hood duct is VP = 0.33 inches w.g. What is the velocity? (d = 1)

Solution:

$$V = 4005\ (VP/d)^{1/2} = 4005\ (0.33/1)^{1/2} = 2300 \text{ fpm}$$

Static Pressure
Static pressure is the potential energy of the ventilation system. It is converted to kinetic energy (VP) and other (less useful) forms of energy (heat, vibration, and noise). These are the “losses” of the system.

Volume flow rate can be described by:

$$Q = VA$$

where
Q = volume flow rate, cubic feet per minute (cfm)
A = cross-sectional area of duct, square feet (sf)
V = velocity, fpm

Example 4
The cross-sectional area of a duct is A = 0.7854 sq ft. The velocity of air flowing in the duct is V = 2250 ft. per minute. What is the flow rate, Q?
Solution:

Q = V × A
= 2250 fpm × 0.7854 sq ft = 1770 scfm

Example 5
The static pressure is measured in a 10-inch square duct at SP = –1.15 inch w.g. The average total pressure is TP = –0.85 inch w.g. Find the velocity and volume flow rate of the air flowing in the duct. (STP; d = 1)

Solution:

Area, A = 10” × 10”/144” per sq ft = 0.6944 sq ft
VP = TP – SP = -0.85” – (-1.15”) = 0.30” w.g.
Velocity, $V = 4005\ (VP/d)^{1/2} = 4005\ (0.30)^{1/2} = 2194$
Volume flow rate, Q = VA = (2194)(0.6944) = 1524 scfm

Losses
As the air moves through a duct, losses are created (i.e., static pressure is converted to heat, vibration, noise.) The loss is usually directly related to velocity pressure:

$$SP_{Loss} = K \times VP \times d$$

where
SP_{Loss} = loss of static pressure, inches w.g.
K = loss factor, unitless
VP = average velocity pressure in duct; d = density correction factor

Loss Types
Losses include hood entry, friction, elbow, branch entry, system effect, air cleaner, and others.

Hoods
The hood captures, contains, or receives contaminants generated at an emission source. The hood converts duct static pressure to velocity pressure and hood entry losses (e.g., slot and duct entry losses).

Hood entry loss (H_e) $He = K \times VP \times d = I\ SP_h\ I - VP$

where
K = loss factor, unitless
VP = velocity pressure in duct, inches w.g.

ISPhI = absolute static pressure about 5 duct diameters down the duct from the hood, inches w.g
d = density correction factor

Coefficient of Entry (Ce)
A hood's ability to convert static pressure to velocity pressure is given by

$$Ce = \frac{Q_{actual}}{Q_{ideal}} = \sqrt{VP/SP_h} = \sqrt{1/(1 + K_h)}$$

Example 6
What is the hood static pressure SP_h when the duct velocity pressure is VP = 0.33 inches w.g., and the hood entry loss is He = 0.44 inches w.g.? What is Ce.

Solution:

$$|SPh| = VP + He = 0.33 + 0.44 = 0.77 \text{ inch w.g.}$$

$$Ce = \frac{Q_{actual}}{Q_{ideal}} = \left[\frac{VP}{|SPh|}\right]^{0.5} = \left[\frac{0.33}{0.77}\right]^{0.5} = 0.65$$

Hood Entry Loss
Hood entry losses normally occur at the hood slots and at the entrance to the duct, due to the vena contracta formed. The most narrowed portion of the vena contracta is usually found about one-half duct diameter inside the duct or plenum.

The hood static pressure, SPh, is the sum total of the acceleration and all losses from the hood face to the point of measurement in the duct.

Head loss is
$He = K \times VP_d \times d$ where K is the hood entry loss factor.

Hood entry loss factors (K) have been estimated over the years and have been reported in the literature for many types of hoods, including lab fume hoods.

Example 7
What is the entry loss He for a laboratory fume hood when the average velocity pressure in the duct is VP_d = 0.30' w.g.? (Assume K = 2.0, d = 1)

Solution:

$$He = K \times VP_d \times d = 2.0 \times 0.30 \times 1 = 0.60' \text{ w.g.}$$

Three hood types
Three types of hoods are the enclosing, capture (active, external), and receiving (passive, often canopy type hood).

Determining Q (flow) for capture hoods
Area approach: Basically, air approaches from all directions toward the source of negative pressure. Imagine a three-dimensional sphere around the end of a small, plain duct hood. Air molecules don't know if they are in the front, to the side, or to the back of the opening. All they know is that they are experiencing a big push to get over to that spot of negative pressure. The velocity of air moving toward the opening is equal at all points on the surface of the sphere. The surface area of a sphere is given by

$$A = 4\pi X^2$$

Knowing the area and the desired capture velocity at X, we can estimate the volume flow rate from Q = VA

Example
Air enters an ideal 4" plain duct hood. What is the required volume flow rate Q for capture 6" in front of the hood if we need V_c = 100 fpm? (Area method)

Solution:

$$\begin{aligned} Q &= V_c \times A \qquad \text{(where area} = A = 4\pi X^2\text{)} \\ &= 100 \times 4\pi (0.5')^2 \qquad \text{(where } 6'' = 0.5\text{)} \\ &= 315 \text{ cfm} \end{aligned}$$

Types of fans
The types of fans include the centrifugal (forward curved, backward inclined, radial) and axial.

Fan curves
Fan characteristic curves plot volume flow rate Q against static pressure, horsepower, noise, and efficiency.

Fan specification
Fans are specified by pressure and flow rate—the "system operating point" (SOP). The pressure is that found across the fan—at the inlet and outlet of the fan in the ductwork.

Fan Total Pressure
The fan total pressure, FTP, represents all energy requirements for moving air through the ventilation system. FTP is calculated by adding the absolute values of the average total pressures found at the fan. If the sign convention is followed, then a formula for FTP is

$$FTP = TP \text{ (outlet)} - TP \text{ (inlet)}$$

Substituting for TP = SP + VP gives

$$FTP = SP_{out} + VP_{out} - SP_{in} - VP_{in}$$

If VP (out) equals VP (in), i.e., if the average inlet and outlet velocities are equal, then the VP terms in the above equation cancel, leaving

$$FTP = SP_{out} - SP_{in}$$

The FTP is often referred to as "the fan total static pressure drop."

Example 9

The inlet and outlet conditions at a fan are $SP_{out} = 0.10$", $SP_{in} = -0.75$".

$$VP_{in} = VP_{out} = 0.25\text{" w.g.}$$

What is FTP?

Solution:

$$FTP = SP_{out} - SP_{in} = 0.10\text{" w.g.} - (-0.75\text{"})\text{ w.g.} = 0.85\text{" w.g.}$$

Ventilation (Medical): It consists of the circulation and exchange of gases in the lungs that is basic for respiration.

Ventilation Rate: The rate at which indoor air enters and leaves a building. Expressed as the number of changes of outdoor air per unit of time [air changes per hour (ACH)], or the rate at which a volume of outdoor air enters in cubic feet per minute (CFM).

Ventilation Standards, Codes, and OSHA Regulations: Foremost amongst OSHA and industry consensus standards are those recommended by the Air Movement and Control Association (AMCA), the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the American National Standards Institute (ANSI), the Sheet Metal and Air Conditioning Contractors National Association (SMACNA), the National Fire Protection Association (NFPA), and the American Conference of Governmental Industrial Hygienists (ACGIH). AMCA is a trade association that has developed standards and testing procedures for fans. ASHRAE is a society of heating and air conditioning engineers that has produced, through consensus, a number of standards related to indoor air quality, filter performance and testing, and HVAC systems. ANSI has produced several important standards on ventilation, including ventilation for paint spray booths, grinding exhaust hoods, and open-surface tanks exhausts. Four ANSI standards were adopted by OSHA in 1971 and are codified in 29 CFR 1910.94; these standards continue to be important as guides to design. ANSI has recently published a new standard for laboratory ventilation (ANSI Z9.5). SMACNA is an association representing sheet metal contractors and suppliers. It sets standards for ducts and duct installation. NFPA has produced a number of recommendations (which become requirements when adopted by local fire agencies), e.g., NFPA 45 lists a number of ventilation requirements for laboratory fume hood use. The ACGIH has published widely used guidelines for industrial ventilation.

Ventilation criteria or standards are included in OSHA regulatory codes for job- or task-specific worker protection. In addition, many OSHA health standards include ventilation requirements. The four standards in 29 CFR 1910.94 deal with local exhaust systems, and OSHA's construction standards (29 CFR 1926) contain ventilation standards for welding. OSHA's compliance policy regarding violation of ventilation standard is set forth in the Field Inspection Reference Manual.

Ventilation/Suction: The act of admitting fresh air into a space in order to replace stale or contaminated air; achieve by blowing air into the space. Similarly, suction represents the admission of fresh air into an interior space by lowering the pressure outside the space, thereby drawing the contaminated air outward.

Venting: In pollution control technology, a method of remediating hydrocarbon (gasoline) spills or leaks from USTs.

Venturi: A short tube with a constricted throat used to determine fluid pressures and velocities by measurement of differential pressures generated at the throat as a fluid traverses the tube.

Venturi Scrubber: Air pollution control devices that use water to remove particulate matter from emissions.

Vermiculite: A lightweight, highly absorbent material made from mica.

Vernal Ponds: Spring ponds, usually of short duration.

Vertigo: A sensation that one's self or one's surroundings are whirling dizzily.

Vesicant: An agent that produces blisters on exposed tissue.

Vesication: Formation of blisters; blistering.

Vesicular: Blister-like.

Viewshed: The scenic characteristics of an area, when referred to as a resource.

Vinyl Chloride: A chemical compound, used in producing some plastics, that is believed to be oncogenic.

Viral Protection: IT personnel should regularly update and share viral protection software, as well as educate employees on the dangers of stranger-generated email. As some folks have to climb a mountain "because it's there," other folks seem to feel obligated to trash computer systems on a widespread basis to prove they can, or for financial gain. Computer server security systems involve solid firewall protection, but various Trojan horses, viruses, parasites, worms, and bugs are being created and spread all the time. A really massive infestation of some of the more wicked bugs can bring an organization to its knees for days, and cost thousands of dollars of wasted work hours and ruined data and applications, as well as hundreds of hours of IT staff time to fix. Make sure viral protection software is on all workstations, and that it is regularly and completely updated. Ensure that anti virus software is configured to identify viruses by all of each computer's means of entry—e-mail, web browsing, floppy disks, CDs, archives etc.).

Virgin Materials: Resources extracted from nature in their raw form, such as timber o metal ore.

Virulent: Highly lethal, causing severe illness or death.

Virus: 1. A hidden, self-replicating section of computer software, usually malicious logic that propagates by infecting—i.e., inserting a copy of itself into and becoming part of—another program. A virus cannot run by itself; it requires that its host program be run to make the virus active. 2. Smallest form of microorganisms capable of causing disease. 3. An infectious agent with a simple acellular organization, a protein coat, a single type of nucleic acid, that reproduce only with living host cells.

Viscosity: The molecular friction within a fluid that produces flow resistance.

Visible Light Transmittance: The amount of visible light that passes through the glazing material of a window, expressed as a percentage.

Visual Pollution: The unattractive or unnatural (human-made) visual elements of a vista, a landscape, or any other thing that a person might not want to look at.

Volatile: When a substance (usually a liquid) evaporates at ordinary temperatures if exposed to the air.

Volatile Compounds: Byproducts of animal manure decomposition that readily become vapors (e.g., ammonia, carbon dioxide, and methane).

Volatile Liquids: Liquids which easily vaporize or evaporate at room temperature.

Volatile Organic Compounds (VOCs): Organic molecules, usually arising from the decomposition of manure that tend to move from liquid into the air above animal facilities.

Volatile Solids (VS): Weight lost upon ignition at 550 degrees C (using Method 2540 E of the American Public Health Association). Volatile solids provide an approximation of moisture and organic matter present.

Volatile Synthetic Organic Chemicals: Chemicals that tend to volatize or evaporate.

Volatilization: Loss of gaseous components, such as ammonium nitrogen, from animal manure.

Volcanic Domes: Rounded, steep-sided mounds built by very viscous magma, usually either dacite or rhyolite. Such magmas are typically too viscous (resistant to flow) to move far from the vent before cooling and crystallizing. Domes may consist of one of more individual lava flows. Volcanic domes are also referred to as lava domes.

Voltage: The measure of electrical potential difference.

Volume: Surface area times (x) a third dimension.

Volume Flow Rate (Q): Quantity of air flow in cfm, scfm, or acfm.

Volume Reduction: Processing waste materials to decrease the amount of space they occupy, usually by compacting, shredding, incineration, or composting.

Volumetric Tank Test: One of several tests to determine the physical integrity of a storage tank; the volume of fluid in the tank is measured directly or calculated from product-level changes. A marked drop in volume indicates a leak.

Vomiting Agent: An agent that causes exposed persons to vomit.

Vomitus: Vomited matter.

Vug: A small cavity or chamber in rock that may be line with crystals.

Vulcanization: A process which plastic rubber is converted into the elastic rubber of hard rubber; the process is brought about by linking of macro-molecules at their sites.

Vulnerability: A flaw or weakness in a system's design, implementation, or operation and management that could be exploited to violate the system's security policy.

Vulnerability Analysis: Assessment of elements in the community that are susceptible to damage if hazardous materials are released.

Vulnerability Assessment: A very regulated, controlled, cooperative, and documented evaluation of an organization's security posture from outside-in and inside-out, for the purpose of defining or greatly enhancing security policy.

Vulnerable Zone: An area over which the airborne concentration of a chemical accidentally released could reach the level of concern.

W

Warm Front: Marks the advance of a warm air mass as it rises up over a cold one.

Waste: 1. Unwanted materials left over from a manufacturing process. 2. Refuse from places of human or animal habitation.

Waste Storage Pond: Impoundment made by excavation or earthfill for temporary storage of animal or other agricultural waste.

Waste Treatment Lagoon: Impoundment made by excavation or earthfill for biological treatment of animal or other agricultural wastes. Lagoons can be aerobic, anaerobic, or facultative, depending on their loading and design.

Waste Analysis Plan (WAP): A plan that outlines the procedures necessary to ensure proper treatment, storage, or disposal of hazardous waste.

Waste Characterization: Identification of chemical and microbiological constituents of a waste material.

Waste Exchange: Arrangement in which companies exchange their wastes for the benefit of both parties.

Waste Feed: The continuous or intermittent flow of wastes into an incinerator.

Waste Generation: The weight or volume of materials and products that enter the waste stream before recycling, composting, landfilling, or combustion takes place. Also can represent the amount of waste generated by a given source or category of sources.

Waste-Heat Recovery: Recovering heat discharged as a byproduct of one process to proceed heat needed by a second process.

Waste Load Allocation: 1. The maximum load of pollutants each discharger of waste is allowed to release into a particular waterway. Discharge limits are usually required for each specific water quality criterion being, or expected to be, violated. 2. The portion of a steam’s total assimilative capacity assigned to an individual discharge.

Waste Minimization: An umbrella term that refers to industrial practices that minimize the volume of products, minimize packaging, extend the useful life of products, and minimize the amount of toxic substance in products.

Waste Piles: Waste piled at industrial sites and then eventually disposed of in a landfill.

Waste Reduction: Using source reduction, recycling, or composting to prevent or reduce waste generation.

Waste Stream: The total flow of solid waste from homes, businesses, institutions, and manufacturing plants that is recycled, burned, or disposed of in landfills, or segments thereof such as the “residential waste stream” or the “recyclable waste stream.”

Waste-to-Energy Facility/Municipal-Waste Combustor: Facility where recovered municipal solid waste is converted into a usable form of energy, usually via combustion.

Waste Treatment Lagoon: Impoundment made by excavation of earth, fill for biological treatment of wastewater.

Waste Treatment Plant: A facility containing a series of tanks, screens, filters and other processes by which pollutants are removed from water.

Waste Treatment Stream: The continuous movement of waste from generator to treater and disposer.

Wastewater: The liquid wastestream primarily produced by the five major sources: human and animal waste, household wastes, industrial waste, stormwater runoff, and groundwater infiltration.

Wastewater Infrastructure: The plan or network for the collection, treatment, and disposal of sewage in a community. The level of treatment will depend on the size of the community, the type of discharge, and/or the designated use or the receiving water.

Wastewater Treatment: According Code of Federal Regulations (CFR) 40 CFR Part 403, regulations were established in the late 1970's and early 1980's to help Publicly Owned Treatment Works (POTW) control industrial discharges to sewers. These regulations were designed to prevent pass-through and interference at the treatment plants and interference in the collection and transmission systems.

Pass-through occurs when pollutants literally "pass through" a POTW without being properly treated, and cause the POTW to have an effluent violation or increase the magnitude or duration of a violation.

Interference occurs when a pollutant discharge causes a POTW to violate its permit by inhibiting or disrupting treatment processes, treatment operations, or processes related to sludge use or disposal.

Wastewater Operators

Like waterworks operators, wastewater operators are highly trained and artful practitioners and technicians of their trade. Moreover, wastewater operators, again, like waterworks operators are required by the States to be licensed or certified to operate a wastewater treatment plant.

Wastewater Treatment Process: The Model

Though it is true that in secondary treatment (which provides BOD removal beyond what is achievable by simple sedimentation) there are actually three commonly used approaches (**trickling filter**, **activated sludge**, and **oxidation ponds**); we focus, for instructive and illustrative purposes, on the activated sludge process.

Wastewater Treatment Terminology and Definitions

Wastewater treatment technology, like many other technical fields, has its own unique terms with their own meaning. Though some of the terms are unique, many are common to other professions. Remember that the science of wastewater treatment is a combination of engineering, biology, mathematics, hydrology, chemistry, physics, and other disciplines. Therefore, many of the terms used in engineering, biology, mathematics, hydrology, chemistry, physics, and others are also used in wastewater treatment.

Activated sludge—the solids formed when microorganisms are used to treat wastewater using the activated sludge treatment process. It includes organisms, accumulated food materials and waste products from the aerobic decomposition process.

Advanced waste treatment—treatment technology to produce an extremely high quality discharge.

Aerobic—conditions in which free, elemental oxygen is present. Also used to describe organisms, biological activity, or treatment processes, which require free oxygen.

Anaerobic—conditions in which no oxygen (free or combined) is available. Also used to describe organisms, biological activity or treatment processes which function in the absence of oxygen.

Anoxic—conditions in which no free, elemental oxygen is present, the only source of oxygen is combined oxygen such as that found in nitrate compounds. Also used to describe biological activity or treatment processes, which function only in the presence of combined oxygen.

Average monthly discharge limitation—the highest allowable discharge over a calendar month.

Average weekly discharge limitation—the highest allowable discharge over a calendar week.

Biochemical oxygen demand, BOD_5—the amount of organic matter which can be biologically oxidized under controlled conditions (5 days @ 20°C in the dark).

Biosolids—From *Merriam-Webster's Collegiate Dictionary, Tenth Edition* (1998): biosolid *n* (1977)—solid organic matter recovered from a sewage treatment process and used especially as fertilizer—usually used in plural.

NOTE: In this text, biosolids is used in many places (activated sludge being the exception) to replace the standard term sludge. The author (along with others in the field) views the term sludge as an ugly four-letter word that is inappropriate to use in describing biosolids. Biosolids is a product that can be reused; it has some value. Because biosolids has some value, it should not be classified as a "waste" product and when biosolids for beneficial reuse is addressed, it is not.

Buffer—a substance or solution which resists changes in pH.

Carbonaceous biochemical oxygen demand, $CBOD_5$—the amount of biochemical oxygen demand which can be attributed to carbonaceous material.

Chemical oxygen demand (COD)—the amount of chemically oxidizable materials present in the wastewater.

Clarifier—a device designed to permit solids to settle or rise and be separated from the flow. Also known as a settling tank or sedimentation basin.

Coliform—a type of bacteria used to indicate possible human or animal contamination of water.

Combined sewer—a collection system which carries both wastewater and storm water flows.

Comminution—a process to shred solids into smaller, less harmful particles.

Composite sample—a combination of individual samples taken in proportion to flow.

Daily discharge—the discharge of a pollutant measured during a calendar day or any 24-hour period that reasonably represents a calendar day for the purposes of sampling. Limitations expressed as weight is total mass (weight) discharged over the day. Limitations expressed in other units are average measurements of the day.

Daily maximum discharge—the highest allowable values for a daily discharge.

Detention time—the theoretical time water remains in a tank at a given flow rate.

Dewatering—the removal or separation of a portion of water present in a sludge or slurry.

Discharge Monitoring Report (DMR)—the monthly report required by the treatment plant's NPDES discharge permit.

Dissolved oxygen (DO)—free or elemental oxygen, which is dissolved in water.

Effluent—the flow leaving a tank, channel, or treatment process.

Effluent limitation—any restriction imposed by the regulatory agency on quantities, discharge rates, or concentrations of pollutants which are discharged from point sources into state waters.

Facultative—organisms that can survive and function in the presence or absence of free, elemental oxygen.

Fecal coliform—a type of bacteria found in the bodily discharges of warm-blooded animals. Used as an indicator organism.

Floc—solids which join together to form larger particles which will settle better.

Flume—a flow rate measurement device.

Food-to-microorganism ratio (F/M)—an activated sludge process control calculation based upon the amount of food (BOD_5 or COD) available per pound of mixed liquor volatile suspended solids.

Grab sample —an individual sample collected at a randomly selected time.

Grit—heavy inorganic solids such as sand, gravel, egg shells, or metal filings.

Industrial wastewater—wastes associated with industrial manufacturing processes.

Infiltration/inflow— extraneous flows in sewers; defined by Metcalf & Eddy in *Wastewater Engineering: Treatment, Disposal, Reuse*, 3rd. Ed., New York: McGraw-Hill, Inc., 29–31, 1991 as follows:

- * *Infiltration*—water entering the collection system through cracks, joints or breaks.
- * *Steady inflow*—water discharged from cellar and foundation drains, cooling water discharges, and drains from springs and swampy areas. This type of inflow is steady and is identified and measured along with infiltration.
- * *Direct flow*—those types of inflow that have a direct stormwater runoff connection to the sanitary sewer and cause an almost immediate increase in wastewater flows. Possible sources are roof leaders, yard and areaway drains, manhole covers, cross connections from storm drains and catch basins, and combined sewers.
- * *Total inflow*—the sum of the direct inflow at any point in the system plus any flow discharged from the system upstream through overflows, pumping station bypasses, and the like.
- * *Delayed inflow*—stormwater that may require several days or more to drain through the sewer system. This category can include the discharge of sump pumps from cellar drainage as well as the slowed entry of surface water through manholes in ponded areas.

Influent—the wastewater entering a tank, channel or treatment process.

Inorganic—mineral materials such as salt, ferric chloride, iron, sand, gravel, etc.

License—a certificate issued by the State Board of Waterworks/Wastewater Works Operators authorizing the holder to perform the duties of a wastewater treatment plant operator.

Mean Cell Residence Time (MRCT)—the average length of time a mixed liquor suspended solids particle remains in the activated sludge process. May also be known as sludge retention time.

Mixed liquor—the combination of return activated sludge and wastewater in the aeration tank.

Mixed Liquor Suspended Solids (MLSS)—the suspended solids concentration of the mixed liquor.

Mixed Liquor Volatile Suspended Solids (MLVSS)—the concentration of organic matter in the mixed liquor suspended solids.

Milligrams/Liter (mg/L)—a measure of concentration. It is equivalent to parts per million (ppm).

Nitrogenous Oxygen Demand (NOD)—a measure of the amount of oxygen required to biologically oxidize nitrogen compounds under specified conditions of time and temperature.

NPDES Permit—National Pollutant Discharge Elimination System permit that authorizes the discharge of treated wastes and specifies the condition, which must be met for discharge.

Nutrients—substances required to support living organisms. Usually refers to nitrogen, phosphorus, iron, and other trace metals.

Organic—materials which consist of carbon, hydrogen, oxygen, sulfur, and nitrogen. Many organics are biologically degradable. All organic compounds can be converted to carbon dioxide and water when subjected to high temperatures.

Pathogenic—disease causing. A pathogenic organism is capable of causing illness.

Point source—any discernible, defined, and discrete conveyance from which pollutants is or may be discharged.

Part per million—an alternative (but numerically equivalent) unit used in chemistry is milligrams per liter (mg/L). As an analogy think of a ppm as being equivalent to a full shot glass in a swimming pool.

Return Activated Sludge Solids (RASS)—the concentration of suspended solids in the sludge flow being returned from the settling tank to the head of the aeration tank.

Sanitary wastewater—wastes discharged from residences and from commercial, institutional, and similar facilities, which include both sewage and industrial wastes.

Scum—the mixture of floatable solids and water, which is removed from the surface of the settling tank.

Septic—a wastewater which has no dissolved oxygen present. Generally characterized by black color and rotten egg (hydrogen sulfide) odors.

Settleability—a process control test used to evaluate the settling characteristics of the activated sludge. Readings taken at 30 to 60 minutes are used to calculate the settled sludge volume (SSV) and the sludge volume index (SVI).

Settled Sludge Volume— the volume in percent occupied by an activated sludge sample after 30 to 60 minutes of settling. Normally written as SSV with a subscript to indicate the time of the reading used for calculation (SSV_{60}) or (SSV_{30}).

Sewage—wastewater containing human wastes.

Sludge—the mixture of settleable solids and water, which is removed from the bottom of the settling tank.

Sludge Retention Time (SRT)—See Mean Cell Residence Time.

Sludge Volume Index (SVI)—a process control calculation, which is used to evaluate the settling quality of the activated sludge. Requires the SSV_{30} and mixed liquor suspended solids test results to calculate.

Storm sewer—a collection system designed to carry only storm water runoff.

Storm water—runoff resulting from rainfall and snowmelt.

Supernatant—in a digester it is the amber-colored liquid above the sludge.

Wastewater—the water supply of the community after it has been soiled by use.

Waste Activated Sludge Solids (WASS)—the concentration of suspended solids in the sludge, which is being removed from the activated sludge process.

Weir—a device used to measure wastewater flow.

Zoogleal slime—the biological slime which forms on fixed film treatment devices. It contains a wide variety of organisms essential to the treatment process.

Measuring Plant Performance

To evaluate how well a plant or treatment unit process is operating; *performance efficiency* or *percent (%) removal* is used. The results can be compared with those listed in the plant's operation and maintenance manual (O & M) to determine if the facility is performing as expected. In this chapter sample calculations often used to measure plant performance/efficiency are presented.

Hydraulic Detention Time

The term, *detention time* or *hydraulic detention time (HDT)*, refers to the average length of time (theoretical time) a drop of water, wastewater, or suspended particles remains in a tank or channel. It is calculated by dividing the water/wastewater in the tank by the flow rate through the tank. The units of flow rate used in the calculation are dependent on whether the detention time is to be calculated in seconds, minutes, hours or days. Detention time is used in conjunction with various treatment processes, including sedimentation and coagulation-flocculation.

Generally, in practice, detention time is associated with the amount of time required for a tank to empty. The range of detention time varies with the process. For example, in a tank used for sedimentation, detention time is commonly measured in minutes.

Wastewater Sources and Characteristics

Wastewater treatment is designed to use the natural purification processes (self-purification processes of streams and rivers) to the maximum level possible. It is also designed to complete these processes in a controlled environment rather than over many miles of stream or river. Moreover, the treatment plant is also designed to remove other contaminants, which are not normally subjected to natural processes, as well as treating the solids, which are generated through the treatment unit steps. The typical wastewater treatment plant is designed to achieve many different purposes:

- protect public health
- protect public water supplies
- protect aquatic life
- preserve the best uses of the waters
- protect adjacent lands

Wastewater treatment is a series of steps. Each of the steps can be accomplished using one of more treatment processes or types of equipment. The major categories of treatment steps are:

- **Preliminary Treatment**—removes materials that could damage plant equipment or would occupy treatment capacity without being treated.
- **Primary Treatment**—removes settleable and floatable solids (may not be present in all treatment plants).
- **Secondary Treatment**—Removes BOD_5 and dissolved and colloidal suspended organic matter by biological action; organics are converted to stable solids, carbon dioxide and more organisms.
- **Advanced Waste Treatment**—uses physical, chemical and biological processes to remove additional BOD_5, solids and nutrients (not present in all treatment plants).
- **Disinfection**—removes microorganisms to eliminate or reduce the possibility of disease when the flow is discharged.
- **Sludge Treatment**—stabilizes the solids removed from wastewater during treatment, inactivates pathogenic organisms and/or reduces the volume of the sludge by removing water.

The various treatment processes described above are discussed in detail later.

Wastewater Sources

The principal sources of domestic wastewater in a community are the residential areas and commercial districts. Other important sources include institutional and recreational facilities and storm water (runoff) and groundwater (infiltration). Each source produces wastewater with specific characteristics. In this section wastewater sources and the specific characteristics of wastewater are described.

Generation of Wastewater

Wastewater is generated by five major sources: human and animal wastes, household wastes, industrial wastes, storm water runoff, and groundwater infiltration.

1. *Human and animal wastes*—contain the solid and liquid discharges of humans and animals and are considered by many to be the most dangerous from a human health viewpoint. The primary health hazard is presented by the millions of bacteria, viruses and other microorganisms (some of which may be pathogenic) present in the wastestream.
2. *Household wastes*—are wastes, other than human and animal wastes, discharged from the home. Household wastes usually contain paper, household cleaners, detergents, trash, garbage, and other substances the homeowner discharges into the sewer system.
3. *Industrial wastes*—includes industry specific materials, which can be discharged from industrial processes into the collection system. Typically contains chemicals, dyes, acids, alkalis, grit, detergents, and highly toxic materials.
4. *Storm water runoff*—many collection systems are designed to carry both the wastes of the community and storm water runoff. In this type of system when a storm event occurs, the wastestream can contain large amounts of sand, gravel and other grit as well as excessive amounts of water.
5. *Groundwater infiltration*—groundwater will enter older improperly sealed collection systems through cracks or unsealed pipe joints. Not only can this add large amounts of water to wastewater flows but also additional grit.

Classification of Wastewater

Wastewater can be classified according to the sources of flows: domestic, sanitary, industrial, combined, and storm water.

1. *Domestic (sewage) Wastewater*—mainly contains human and animal wastes, household wastes, small amounts of groundwater infiltration, and small amounts of industrial wastes.
2. *Sanitary Wastewater*—consists of domestic wastes and significant amounts of industrial wastes. In many cases, the industrial wastes can be treated without special precautions. However, in some cases the industrial wastes will require special precautions or a pretreatment program to ensure the wastes do not cause compliance problems for the wastewater treatment plant.

3. *Industrial wastewater*—industrial wastes only. Often the industry will determine that it is safer and more economical to treat its waste independent of domestic waste.
4. *Combined wastewater*—is the combination of sanitary wastewater and storm water runoff. All the wastewater and storm water of the community is transported through one system to the treatment plant.
5. *Storm water*—a separate collection system (no sanitary waste) that carries storm water runoff including street debris, road salt, and grit.

Wastewater Characteristics

Wastewater contains many different substances, which can be used to characterize it. The specific substances and amounts or concentrations of each will vary, depending on the source. Thus, it is difficult to "precisely" characterize wastewater. Instead, wastewater characterization is usually based on and applied to an "average domestic" wastewater.

Note: Keep in mind that other sources and types of wastewater can dramatically change the characteristics.

Wastewater is characterized in terms of its physical, chemical, and biological characteristics.

1. Physical Characteristics

The *physical characteristics* of wastewater are based on color, odor, temperature, and flow.

A. **Color**—fresh wastewater is usually a light brownish-gray color. However, typical wastewater is gray and has a cloudy appearance. The color of the wastewater will change significantly if allowed to go septic (if travel time in the collection system increases). Typical septic wastewater will have a black color.

B. **Odor**—odors in domestic wastewater usually are caused by gases produced by the decomposition of organic matter or by other substances added to the wastewater. Fresh domestic wastewater has a musty odor. If the wastewater is allowed to go septic, this odor will change significantly—to a rotten egg odor associated with the production of hydrogen sulfide (H_2S).

C. **Temperature**—the temperature of wastewater is commonly higher than that of the water supply because of the addition of warm water from households and industrial plants. However, significant amounts of infiltration or storm water flow can cause major temperature fluctuations.

D. **Flow**—the actual volume of wastewater is commonly used as a physical characterization of wastewater and is normally expressed in terms of gallons per person per day. Most treatment plants are designed using an expected flow of 100 to 200 gallons per person per day. This figure may have to be revised to reflect the degree of infiltration or storm flow the plant receives. Flow rates will vary throughout the day. This variation, which can be as much as 50 to 200 percent of the average daily flow is known as the *diurnal flow variation*.

Note: *Diurnal*—means occurs in a day or each day; daily.

2. *Chemical Characteristics*

In describing the chemical characteristics of wastewater, the discussion generally includes topics such as organic matter, the measurement of organic matter, inorganic matter, and gases. For the sake of simplicity, in this handbook we specifically describe chemical characteristics in terms of alkalinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved gases, nitrogen compounds, pH, phosphorus, solids (organic, inorganic, suspended and dissolved solids), and water.

A. *Alkalinity*—is a measure of the wastewater's capability to neutralize acids. It is measured in terms of bicarbonate, carbonate and hydroxide alkalinity. Alkalinity is essential to buffer (hold the neutral pH) of the wastewater during the biological treatment processes.

B. *Biochemical Oxygen Demand (BOD* –a measure of the amount of biodegradable matter in the wastewater. Normally measured by a five day test conducted at 20°C. The BOD_5 domestic waste is normally in the range of 100 to 300 mg/L.

C. *Chemical Oxygen Demand (COD)*—a measure of the amount of oxidizable matter present in the sample. The COD is normally in the range of 200 to 500 mg/L. The presence of industrial wastes can increase this significantly.

D. *Dissolved gases*—gases that are dissolved in wastewater. The specific gases and normal concentrations are based upon the composition of the wastewater. Typical domestic wastewater contains oxygen in relatively low concentrations, carbon dioxide, and hydrogen sulfide (if septic conditions exist).

E. *Nitrogen compounds*—the type and amount of nitrogen present will vary from the raw wastewater to the treated effluent. Nitrogen follows a cycle of oxidation and reduction. Most of the nitrogen in untreated wastewater will be in the forms of organic nitrogen and ammonia nitrogen. Laboratory tests exist for determination of both of these forms. The sum of these two forms of nitrogen is also measured and is known as *Total Kjeldahl Nitrogen (TKN)*. Wastewater will normally contain between 20 to 85 mg/L of nitrogen. Organic nitrogen will normally be in the range of 8 to 35 mg/L and ammonia nitrogen will be in the range of 12 to 50 mg/L.

F. *pH*—a method of expressing the acid condition of the wastewater. pH is expressed on a scale of 1 to 14. For proper treatment wastewater pH should normally be in the range of 6.5 to 9.0 (ideal—6.5 to 8.0).

G. *Phosphorus*—essential to biological activity and must be present in at least minimum quantities or secondary treatment processes will not perform. Excessive amounts can cause stream damage and excessive algal growth. Phosphorus will normally be in the range of 6 to 20 mg/L. The removal of phosphate compounds from detergents has had a significant impact on the amounts of phosphorus in wastewater.

H. *Solids*—most pollutants found in wastewater can be classified as solids. Wastewater treatment is generally designed to remove solids or to convert solids to a form which is more stable or can be removed. Solids can be classified by their chemical composition (organic or inorganic) or by their physical characteristics (settleable, floatable, and colloidal). Concentration of total solids in wastewater is normally in the range of 350 to 1,200 mg/L.

Organic solids—consist of carbon, hydrogen, oxygen, nitrogen and can be converted to carbon dioxide and water by ignition at 550°C. Also known as fixed solids or loss on ignition.

Inorganic solids—mineral solids which are unaffected by ignition. Also known as fixed solids or ash.

Suspended solids—will not pass through a glass fiber filter pad. Can be further classified as Total Suspended Solids (TSS), Volatile Suspended Solids and/or Fixed Suspended Solids. Can also be separated into three components based on settling characteristics. Settleable solids, floatable solids and colloidal solids. Total suspended solids in wastewater are normally in the range of 100 to 350 mg/L.

Dissolved solids—will pass through a glass fiber filter pad. Can also be classified as Total Dissolved Solids (TDS), volatile dissolved solids, and fixed dissolved solids. Total dissolved solids are normally in the range of 250 to 850 mg/L.

I. *Water*—always the major constituent of wastewater. In most cases water makes up 99.5 to 99.9 percent of the wastewater. Even in the strongest wastewater, the total amount of contamination present is less than 0.5 percent of the total and in average strength wastes it is usually less than 0.1 percent.

3. *Biological Characteristics/Processes*

[Note: The biological characteristics of water were discussed in detail earlier in this text].

After undergoing physical aspects of treatment (i.e., screening, grit removal, and sedimentation) in preliminary and primary treatment, wastewater still contains some suspended solids and other solids that are dissolved in the water. In a natural stream, such substances are a source of food for protozoa, fungi, algae and several varieties of bacteria. In secondary wastewater treatment, these same microscopic organisms (which are one of the main reasons for treating wastewater) are allowed to work as fast as they can to biologically convert the dissolved solids to suspended solids which will physically settle out at the end of secondary treatment.

Raw wastewater influent typically contains millions of organisms. The majority of these organisms are non-pathogenic; however, several pathogenic organisms may also be present (these may include the organisms responsible for diseases such as typhoid, tetanus, hepatitis, dysentery, gastroenteritis and others).

Many of the organisms found in wastewater are microscopic (microorganisms); they include algae, bacteria, protozoans (such as amoeba, flagellates, free-swimming ciliates and stalked ciliates), rotifers, and virus.

The Table is a summary of typical domestic wastewater characteristics.

TABLE TYPICAL DOMESTIC WASTEWATER CHARACTERISTICS

Characteristic	Typical Characteristic
Color	Gray
Odor	Musty
Dissolved Oxygen	> 1.0 mg/L
pH	6.5–9.0
TSS	100–350 mg/L
BOD_5	100–300 mg/L
COD	200–500 mg/L
Flow	100–200 gallons/person/day
Total Nitrogen	20–85 mg/L
Total Phosphorus	6 –0 mg/L
Fecal Coliform	500,000–3,000,000 MPN/100 ml

Wastewater Collection Systems

Wastewater collection systems collect and convey wastewater to the treatment plant. The complexity of the system depends on the size of the community and the type of system selected. Methods of collection and conveyance of wastewater include gravity systems, force main systems, vacuum systems and combinations of all three types of systems.

Gravity Collection System

In a *gravity collection system*, the collection lines are sloped to permit the flow to move through the system with as little pumping as possible. The slope of the lines must keep the wastewater moving at a velocity (speed) of 2 - 4 feet per second. Otherwise, at lower velocities, solids will settle out causing clogged lines, overflows, and offensive odors. To keep collection systems lines at a reasonable depth, wastewater must be lifted (pumped) periodically so that it can continue flowing “downhill” to the treatment plant. Pump stations are installed at selected points within the system for this purpose.

Force Main Collection System

In a typical *force main collection system*, wastewater is collected to central points and pumped under pressure to the treatment plant. The system is normally used for conveying wastewater long distances. The use of the force main system allows the wastewater to flow to the treatment plant at the desired velocity without using sloped lines. It should be noted that the pump station discharge lines in a gravity system are considered to be force mains since the content of the lines is under pressure.

Note: Extra care must be taken when performing maintenance on force main systems since the content of the collection system is under pressure.

Vacuum System

In a *vacuum collection system*, wastewaters are collected to central points and then drawn toward the treatment plant under vacuum. The system consists of a large amount of mechanical equipment and requires a large amount of maintenance to perform properly. Generally, the vacuum-type collection systems are not economically feasible.

Pumping Stations

Pumping stations provide the motive force (energy) to keep the wastewater moving at the desired velocity. They are used in both the force main and gravity systems. They are designed in several different configurations and may use different sources of energy to move the wastewater (i.e., pumps, air pressure or vacuum). One of the more commonly used types of pumping station designs is the wet well/dry well design.

Wet Well/Dry Well Pumping Stations

The *Wet Well/Dry Well pumping station* consists of two separate spaces or sections separated by a common wall. Wastewater is collected in one section (wet well section) and the pumping equipment (and in many cases, the motors and controllers) are located in a second section known as the dry well. There are many different designs for this type of system but in most cases the pumps selected for this system are of a centrifugal design. There are a couple of major considerations in selecting centrifugal design: (1) allows for the separation of mechanical equipment (pumps, motors, controllers, wiring, etc.) from the potentially corrosive atmosphere (sulfides) of the wastewater; and (2) this type of design is usually safer for workers because they can monitor, maintain, operate, and repair equipment without entering the pumping station wet well.

Note: Most pumping station wet wells are confined spaces. To ensure safe entry into such spaces compliance with OSHA’s 29 CFR 1910.146 (Confined Space Entry Standard) is required.

Wet Well Pumping Stations

Another type of pumping station design is the *wet well* type. This type consists of a single compartment, which collects the wastewater flow. The pump is submerged in the wastewater with motor controls located in the space or has a weatherproof motor housing located above the wet well. In this type of station, a submersible centrifugal pump is normally used.

Pneumatic Pumping Stations

The *pneumatic pumping station* consists of a wet well and a control system, which controls the inlet and outlet value operations and provides, pressurized air to force or “push” the wastewater through the system. The exact method of operation depends on the system design. When operating, wastewater in the wet well reaches a predetermined level and activates an automatic valve, which closes the influent line. The tank (wet well) is then pressurized to a predetermined level. When the pressure reaches the predetermined level, the effluent line valve is opened and the pressure pushes the wastestream out the discharge line.

Preliminary Treatment

The initial stage in the wastewater treatment process (following collection and influent pumping) is *preliminary treatment*. Raw influent entering the treatment plant may contain many kinds of materials (trash). The purpose of preliminary treatment is to protect plant equipment by removing these materials which could cause clogs, jams or excessive wear to plant machinery. In addition, the removal of various materials at the beginning of the treatment process saves valuable space within the treatment plant.

Preliminary treatment may include many different processes; each designed to remove a specific type of material, which is a potential problem for the treatment process. Processes include: wastewater collections—influent pumping, screening, shredding, grit removal, flow measurement, preaeration, chemical addition, and flow equalization. In this section, we describe and discuss each of these processes and their importance in the treatment process.

Screening

The purpose of *screening* is to remove large solids such as rags, cans, rocks, branches, leaves, roots, etc. from the flow before the flow moves on to downstream processes.

Note: Typically, a treatment plant will remove anywhere from 0.5 to 12 ft^3 of screenings for each million gallons of influent received.

A *bar screen* traps debris as wastewater influent passes through. Typically, a bar screen consists of a series of parallel, evenly spaced bars or a perforated screen placed in a channel. The wastestream passes through the screen and the large solids (*screenings)* are trapped on the bars for removal.

Note: The screenings must be removed frequently enough to prevent accumulation which will block the screen and cause the water level in front of the screen to build up.

The bar screen may be coarse (2- to 4-inch openings) or fine (0.75 to 2.0-inch openings). The bar screen may be manually cleaned (bars or screens are placed at an angle of 30° for easier solids removal) or mechanically cleaned (bars are placed at 45° to 60° angle to improve mechanical cleaner operation).

The screening method employed depends on the design of the plant, the amount of solids expected and whether the screen is for constant or emergency use only.

1. Manually Cleaned Screens

Manually cleaned screens are cleaned at least once per shift (or often enough to prevent buildup which may cause reduced flow into the plant) using a long tooth rake. Solids are manually pulled to the drain platform and allowed to drain before storage in a covered container.

The area around the screen should be cleaned frequently to prevent a buildup of grease or other materials, which can cause odors, slippery conditions, and insect and rodent problems. Because screenings may contain organic matter as well as large amounts of grease they should be stored in a covered container. Screenings can be disposed of by burial in approved landfills or by incineration. Some treatment facilities grind the screenings into small particles, which are then returned to the wastewater flow for further processing and removal later in the process.

2. Mechanically Cleaned Screens

Mechanically cleaned screens use a mechanized rake assembly to collect the solids and move them (carries them) out of the wastewater flow for discharge to a storage hopper. The screen may be continuously cleaned or cleaned on a time or flow controlled cycle. As with the manually cleaned screen, the area surrounding the mechanically operated screen must be cleaned frequently to prevent buildup of materials, which can cause unsafe conditions.

As with all mechanical equipment, operator vigilance is required to ensure proper operation and that proper maintenance is performed. Maintenance includes lubricating equipment and maintaining it in accordance with manufacturer's recommendations or the plant's O & M Manual (Operations & Maintenance Manual).

Screenings from mechanically operated barscreens are disposed of in the same manner as screenings from manually operated screen: landfill disposal, incineration, or ground into smaller particles for return to the wastewater flow.

Shredding

As an alternative to screening, *shredding* can be used to reduce solids to a size, which can enter the plant without causing mechanical problems or clogging. Shredding processes include comminution (comminute means "cut up") and barminution devices.

1. Comminution

The *comminutor* is the most common shredding device used in wastewater treatment. In this device all the wastewater flow passes through the grinder assembly. The grinder consists of a screen or slotted basket, a rotating or oscillating cutter and a stationary cutter. Solids pass through the screen and are chopped or shredded between the two cutters. The comminutor will not remove solids, which are too large to fit through the slots, and it will not remove floating objects. These materials must be removed manually.

Maintenance requirements for comminutors include aligning, sharpening, and replacing cutters and corrective and preventive maintenance performed in accordance with plant O & M Manual.

2. Barminution

In barminution, the *barminutor* uses a bar screen to collect solids, which are then shredded and passed through the bar screen for removal at a later process. In operation each device cutter alignment and sharpness are critical factors in effective operation. Cutters must be sharpened or replaced and alignment must be checked in accordance with manufacturer's recommendations. Solids, which are not shredded, must be removed daily, stored in closed containers and disposed of by burial or incineration.

Barminutor operational problems are similar to those listed above for comminutors. Preventive and corrective maintenance as well as lubrication must be performed by qualified personnel and in accordance with the plant's O & M Manual. Because of higher maintenance requirements the barminutor is less frequently used.

Grit Removal

The purpose of *grit removal* is to remove the heavy inorganic solids, which could cause excessive mechanical wear. Grit is heavier than inorganic solids and includes, sand, gravel, clay, egg shells, coffee grounds, metal filings, seeds, and other similar materials.

There are several processes or devices used for grit removal. All of the processes are based on the fact that grit is heavier than the organic solids, which should be kept in suspension for treatment in following processes. Grit removal may be accomplished in grit chambers or by the centrifugal separation of sludge. Processes use gravity/velocity, aeration or centrifugal force to separate the solids from the wastewater.

Gravity/Velocity Controlled Grit Removal

Gravity/velocity controlled grit removal is normally accomplished in a channel or tank where the speed or the velocity of the wastewater is controlled to about 1 foot per second (ideal)—so that grit will settle while organic matter remains suspended. As long as the velocity is controlled in the range of 0.7 to 1.4 feet per second (fps) the grit removal will remain effective. Velocity is controlled by the amount of water flowing through the channel, the depth of the water in the channel, by the width of the channel, or by cumulative width of channels in service.

Preaeration

In the *preaeration process* (diffused or mechanical), we aerate wastewater to achieve and maintain an aerobic state (to freshen septic wastes), strip off hydrogen sulfide (to reduce odors and corrosion), agitate solids (to release trapped gases and improve solids separation and settling), and to reduce BOD_5. All of this can be accomplished by aerating the wastewater for 10 to 30 minutes. To reduce BOD_5, preaeration must be conducted from 45 to 60 minutes.

Chemical Addition

Chemical addition is made (either via dry chemical metering or solution feed metering) to the wastestream to improve settling, reduce odors, neutralize acids or bases, reduce corrosion, reduce BOD_5, improve solids and grease removal, reduce loading on the plant, add or remove nutrients, add organisms, and/or aid subsequent downstream processes. The particular chemical and amount used depends on the desired result. Chemicals must be added at a point where sufficient mixing will occur to obtain maximum benefit. Chemicals typically used in wastewater treatment include chlorine, peroxide, acids and bases, miner salts (ferric chloride, alum, etc.), and bioadditives and enzymes.

Equalization

The purpose of *flow equalization* (whether by surge, diurnal, or complete methods) is to reduce or remove the wide swings in flow rates normally associated with wastewater treatment plant loading; it minimizes the impact of storm flows. The process can be designed to prevent flows above maximum plant design hydraulic capacity; to reduce the magnitude of diurnal flow variations; and to eliminate flow variations. Flow equalization is accomplished using mixing or aeration equipment, pumps, and flow measurement. Normal operation depends on the purpose and requirements of the flow equalization system. Equalized flows allow the plant to perform at optimum levels by providing stable hydraulic and organic loading. The downside to flow equalization is in additional costs associated with construction and operation of the flow equalization facilities.

Aerated Systems

Aerated grit removal systems use aeration to keep the lighter organic solids in suspension while allowing the heavier grit particles to settle out. Aerated grit removal may be manually or mechanically cleaned; however, the majority of the systems are mechanically cleaned.

In normal operation, the aeration rate is adjusted to produce the desired separation, which requires observation of mixing and aeration and sampling of fixed suspended solids. Actual grit removal is controlled by the rate of aeration. If the rate is too high, all of the solids remain in suspension. If the rate is too low, both the grit and the organics will settle out.

Cyclone Degritter

The *cyclone degritter* uses a rapid spinning motion (centrifugal force) to separate the heavy inorganic solids or grit from the light organic solids. This unit process is normally used on primary sludge rather than the entire wastewater flow. The critical control factor for the process is the inlet pressure. If the pressure exceeds the recommendations of the manufacturer, the unit will flood and grit will carry through with the flow. Grit is separated from the flow and discharged directly to a storage container. Grit removal performance is determined by calculating the percent removal for inorganic (fixed) suspended solids.

Primary Treatment (Sedimentation)

The purpose of primary treatment (primary sedimentation or primary clarification) is to remove settleable organic and flotable solids. Normally, each primary clarification unit can be expected to remove 90-95 percent settleable solids, 40 to 60 percent total suspended solids and 25 to 35 percent BOD_5.

Note: Performance expectations for settling devices used in other areas of plant operation is normally expressed as overall unit performance rather than settling unit performance.

Sedimentation may be used throughout the plant to remove settleable and flotable solids. It is used in primary treatment, secondary treatment and advanced wastewater treatment processes. In this section, we focus on primary treatment or primary clarification, which uses large basins in which primary settling is achieved under relatively quiescent conditions. Within these basins, mechanical scrapers collect the primary settled solids into a hopper, from which they are pumped to a sludge-processing area. Oil, grease, and other floating materials (scum) are skimmed from the surface. The effluent is discharged over weirs into a collection trough.

In primary sedimentation, wastewater enters a settling tank or basin. Velocity is reduced to approximately 1 foot per minute.

Note: Notice that the velocity is based on minutes instead of seconds, as was the case in the grit channels. A grit channel velocity of 1 ft/s would be 60 ft/min.

Solids, which are heavier than water, settle to the bottom while solids which are lighter than water float to the top. Settled solids are removed as sludge and floating solids are removed as scum. Wastewater leaves the sedimentation tank over an effluent weir and on to the next step in treatment. Detention time, temperature, tank design and condition of the equipment control the efficiency of the process.

Overview of Primary Treatment

- Primary treatment reduces the organic loading on downstream treatment processes by removing a large amount of settleable, suspended, and floatable materials.
- Primary treatment reduces the velocity of the wastewater through a clarifier to approximately 1 to 2 ft/min, so that settling and floatation can take place. Slowing the flow enhances removal of suspended solids in wastewater.
- Primary settling tanks remove floated grease and scum, remove the settled sludge solids, and collect them for pumped transfer to disposal or further treatment.
- Clarifiers used may be rectangular or circular. In rectangular clarifiers, wastewater flows from one end to the other, and the settled sludge is moved to a hopper at the one end, either by flights set on parallel chains or by a single bottom scraper set on a traveling bridge. Floating material (mostly grease and oil) is collected by a surface skimmer.
- In circular tanks, the wastewater usually enters at the middle and flows outward. Settled sludge is pushed to a hopper in the middle of the tank bottom, and a surface skimmer removes floating material.
- Factors affecting primary clarifier performance include:
    - rate of flow through the clarifier
    - wastewater characteristics (strength; temperature; amount and type of industrial waste; and the density, size, and shapes of particles)
    - performance of pretreatment processes
    - nature and amount of any wastes recycled to the primary clarifier

Types of Sedimentation Tanks

Sedimentation equipment includes septic tanks, two story tanks and plain settling tanks or clarifiers. All three devices may be used for primary treatment while plain settling tanks are normally used for secondary or advanced wastewater treatment processes.

1. Septic Tanks

   Septic tanks are prefabricated tanks that serve as a combined settling and skimming tank and as an unheated-unmixed anaerobic digester. Septic tanks provide long settling times (6 to 8 hours or more) but do not separate decomposing solids from the wastewater flow. When the tank becomes full, solids will be discharged with the flow. The process is suitable for small facilities (i.e., schools, motels, homes, etc.) but, due to the long detention times and lack of control, it is not suitable for larger applications.

2. Two Story (Imhoff) Tank

   The *two story or Imhoff tank* is similar to a septic tank in the removal of settleable solids and the anaerobic digestion of solids. The difference is that the two story tank consists of a settling compartment where sedimentation is accomplished, a lower compartment where settled solids and digestion takes place, and gas vents. Solids removed from the wastewater by settling pass from the settling compartment into the digestion compartment through a slot in the bottom of the settling compartment. The design of the slot prevents solids from returning to the settling compartment. Solids decompose anaerobically in the digestion section. Gases produced as a result of the solids decomposition are released through the gas vents running along each side of the settling compartment.

3 Plain Settling Tanks (Clarifiers)

   The *plain settling tank or clarifier* optimizes the settling process. Sludge is removed from the tank for processing in other downstream treatment units.

Flow enters the tank, is slowed and distributed evenly across the width and depth of the unit, passes through the unit and leaves over the effluent weir. Detention time within the primary settling tank is from 1-3 hours (2-hour average).

Sludge removal is accomplished frequently on either continuous or intermittent basis. Continuous removal requires additional sludge treatment processes to remove the excess water resulting from removal of sludge which contains less than 2-3 percent solids. Intermittent sludge removal requires the sludge be pumped from the tank on a schedule frequent enough to prevent large clumps of solids rising to the surface but infrequent enough to obtain 4 – 8 percent solids in the sludge withdrawn.

Scum must be removed from the surface of the settling tank frequently. This is normally a mechanical process but may require manual start-up. The system should be operated frequently enough to prevent excessive buildup and scum carryover but not so frequent as to cause hydraulic overloading of the scum removal system.

Settling tanks require housekeeping and maintenance. Baffles (prevent flotable solids, scum, from leaving the tank), scum troughs, scum collectors, effluent troughs and effluent weirs require frequent cleaning to prevent heavy biological growths and solids accumulations. Mechanical equipment must be lubricated and maintained as specified in the manufacturer's recommendations or in accordance with procedures listed in the plant O & M Manual.

Process control sampling and testing is used to evaluate the performance of the settling process. Settleable solids, dissolved oxygen, pH, temperature, total suspended solids and BOD_5, as well as sludge solids and volatile matter testing are routinely accomplished.

Effluent from Settling Tanks

Upon completion of screening, degritting, and settling in sedimentation basins, large debris, grit and many settleable materials have been removed from the wastestream. What is left is referred to as *Primary Effluent*. Usually cloudy and frequently gray in color, primary effluent still contains large amounts of dissolved food and other chemicals (nutrients). These nutrients are treated in the next step in the treatment process (**Secondary Treatment**) which is discussed in the next Section.

Note: Two of the most important nutrients left to remove are phosphorus and ammonia. While we want to remove these two nutrients from the wastestream, we do not want to remove two much. Carbonaceous microorganisms in secondary treatment (biological treatment) need both phosphorus and ammonia.

Secondary Treatment

The main purpose of *secondary treatment* (sometimes referred to as biological treatment) is to provide biochemical oxygen demand (BOD) removal beyond what is achievable by primary treatment. There are three commonly used approaches, all of which take advantage of the ability of microorganisms to convert organic wastes (via biological treatment), into stabilized, low-energy compounds. Two of these approaches, the *trickling filter* [and/or its variation, the *rotating biological contactor (RBC)*] and the *activated sludge* process, sequentially follow normal primary treatment. The third, *ponds* (oxidation ponds or lagoons), however, can provide equivalent results without preliminary treatment.

Secondary treatment refers to those treatment processes which use biological processes to convert dissolved, suspended and colloidal organic wastes to more stable solids which can either be removed by settling or discharged to the environment without causing harm.

Exactly what is secondary treatment? As defined by the Clean Water Act (CWA), secondary treatment produces an effluent with nor more than 30 mg/L BOD_5 and 30 mg/L total suspended solids.

Note: The CWA also states that ponds and trickling filters will be included in the definition of secondary treatment even if they do not meet the effluent quality requirements continuously.

Most secondary treatment processes decompose solids aerobically producing carbon dioxide, stable solids and more organisms. Since solids are produced, all of the biological processes must include some form of solids removal (settling tank, filter, etc.).

Secondary treatment processes can be separated into two large categories: fixed film systems and suspended growth systems.

Fixed film systems are processes, which use a biological growth (biomass or slime) which is attached to some form of media. Wastewater passes over or around the media and the slime. When the wastewater and slime are in contact, the organisms remove and oxidize the organic solids. The media may be stone, redwood, synthetic materials or any other substance that is durable (capable of withstanding weather conditions for many years), provides a large area for slime growth while providing open space for ventilation and is not toxic to the organisms in the biomass. Fixed film devices include trickling filters and rotating biological contactors (RBCs).

Suspended growth systems are processes, which use a biological growth, which is mixed with the wastewater. Typical suspended growth systems consist of various modifications of the activated sludge process.

Treatment Ponds

Wastewater treatment can be accomplished using *ponds*. Ponds are relatively easy to build, to manage, they accommodate large fluctuations in flow, and they can also provide treatment that approaches conventional systems (producing a highly purified effluent) at much lower cost. It is the cost (the economics) that drives many managers to decide on the pond option. The actual degree of treatment provided depends on the type and number of ponds used. Ponds can be used as the sole type of treatment or they can be used in conjunction with other forms of wastewater treatment; that is, other treatment processes followed by a pond or a pond followed by other treatment processes.

Types of Ponds

Ponds can be classified (named) based upon their location in the system, by the type wastes they receive, and by the main biological process occurring in the pond. First we look at the types of ponds according to their location and the type wastes they receive: Raw Sewage Stabilization ponds, oxidation ponds, and polishing ponds. Then, in the following section, we look at ponds classified by the type of processes occurring within the pond: Aerobic Ponds, Anaerobic Ponds, Facultative Ponds, and Aerated Ponds.

Ponds Based on Location & Types of Wastes They Receive

- Raw Sewage Stabilization Pond—The *raw sewage stabilization pond* is the most common type of pond. With the exception of screening and shredding, this type of pond receives no prior treatment. Generally, raw sewage stabilization ponds are designed to provide a minimum of 45 days detention time and to receive no more than 30 pounds of BOD_5 per day per acre. The quality of the discharge is dependent on the time of the year. Summer months produce high BOD_5 removal but excellent suspended solids removals.

  The pond consists of an influent structure, pond berm or walls and an effluent structure designed to permit selection of the best quality effluent. Normal operating depth of the pond is 3 to 5 feet.

  The process occurring in the pond involves bacteria decomposing the organics in the wastewater (aerobically and anaerobically) and algae using the products of the bacterial action to produce oxygen (photosynthesis). Because this type of pond is the most commonly used in wastewater treatment, the process that occurs within the pond is described in greater detail in the following.

  When wastewater enters the stabilization pond several processes begin to occur. These include settling, aerobic decomposition, anaerobic decomposition and photosynthesis. Solids in the wastewater will settle to the bottom of the pond. In addition to the solids in the wastewater entering the pond, solids, which are produced by the biological activity, will also settle to the bottom. Eventually this will reduce the detention time and the performance of the pond. When this occurs (20 to 30 years normal) the pond will have to be replaced or cleaned.

  Bacteria and other microorganisms use the organic matter as a food source. They use oxygen (aerobic decomposition), organic matter and nutrients to produce carbon dioxide, water, and stable solids, which may settle out, and more organisms. The carbon dioxide is an essential component of the photosynthesis process occurring near the surface of the pond.

  Organisms also use the solids that settled out as food material, however, the oxygen levels at the bottom of the pond are extremely low so the process used is anaerobic decomposition. The organisms use the organic matter to produce gases (hydrogen sulfide, methane, etc.) which are dissolved in the water, stable solids, and more organisms.

  Near the surface of the pond a population of green algae will develop which can use the carbon dioxide produced by the bacterial population, nutrients and sunlight to produce more algae and oxygen which is dissolved into the water. The dissolved oxygen is then used by organisms in the aerobic decomposition process.

  When compared with other wastewater treatment systems involving biological treatment, a stabilization pond treatment system is the simplest to operate and maintain. Operation and maintenance activities include collecting and testing samples for dissolved oxygen (D.O), and pH, removing weeds and other debris (scum) from the pond, mowing the berms, repairing erosion, and removing burrowing animals.

  Note: Dissolved oxygen and pH levels in the pond will vary throughout the day. Normal operation will result in very high D.O. and pH levels due to the natural processes occurring.

  Note: When operating properly the stabilization pond will exhibit a wide variation in both dissolved oxygen and pH. This is due to the photosynthesis occurring in the system.

- Oxidation Pond—An *oxidation pond*, which is normally designed using the same criteria as the stabilization pond, receives flows that have passed through a stabilization pond or primary settling tank. This type of pond provides biological treatment, additional settling and some reduction in the number of fecal coliform present.
- Polishing Pond—A *polishing pond*, which uses the same equipment as a stabilization pond, receives

flow from an oxidation pond or from other secondary treatment systems. Polishing ponds remove additional BOD_5, solids and fecal coliform and some nutrients. They are designed to provide 1 to 3 days detention time and normally operate at a depth of 5 to 10 feet. Excessive detention time or too shallow a depth will result in alga growth, which increases influent, suspended solids concentrations.

Ponds Based on the Type of Processes Occurring Within
The type of processes occurring within the pond may also classify ponds. These include the aerobic, anaerobic, facultative, and aerated processes.

- Aerobic Ponds—In *aerobic ponds*, which are not widely used, oxygen is present throughout the pond. All biological activity is aerobic decomposition.
- Anaerobic Ponds—*Anaerobic ponds* are normally used to treat high strength industrial wastes. No oxygen is present in the pond and all biological activity is anaerobic decomposition.
- Facultative Pond—The *facultative pond* is the most common type pond (based on processes occurring). Oxygen is present in the upper portions of the pond and aerobic processes are occurring. No oxygen is present in the lower levels of the pond where processes occurring are anoxic and anaerobic.
- Aerated Pond—In the *aerated pond*, oxygen is provided through the use of mechanical or diffused air systems. When aeration is used, the depth of the pond and/or the acceptable loading levels may increase. Mechanical or diffused aeration is often used to supplement natural oxygen production or to replace it.

Trickling Filters

Trickling filters have been used to treat wastewater since the 1890s. It was found that if settled wastewater was passed over rock surfaces, slime grew on the rocks and the water became cleaner. Today we still use this principle but, in many installations, instead of rocks we use plastic media.

In most wastewater treatment systems, the *trickling filter* follows primary treatment and includes a secondary settling tank or clarifier. Trickling filters are widely used for the treatment of domestic and industrial wastes. The process is a fixed film biological treatment method designed to remove BOD_5 and suspended solids.

A trickling filter consists of a rotating distribution arm that sprays and evenly distributes liquid wastewater over a circular bed of fist-sized rocks, other coarse materials, or synthetic media. The spaces between the media allow air to circulate easily so that aerobic conditions can be maintained. The spaces also allow wastewater to trickle down through, around and over the media. A layer of biological slime that absorbs and consumes the wastes trickling through the bed covers the media material. The organisms aerobically decompose the solids producing more organisms and stable wastes, which either become part of the slime or are discharged back into the wastewater flowing over the media. This slime consists mainly of bacteria, but it may also include algae, protozoa, worms, snails, fungi, and insect larvae. The accumulating slime occasionally sloughs off (*sloughings*) individual media materials and is collected at the bottom of the filter, along with the treated wastewater, and passed on to the secondary settling tank where it is removed. The overall performance of the trickling filter is dependent on hydraulic and organic loading, temperature and recirculation.

To understand the correct operation of the trickling filter, the operator must be familiar with certain terms.

Note: The following list of terms applies to the trickling filter process. We assume that other terms related to other units within the treatment system (plant) are already familiar to operators.

- *Biological towers*—a type of trickling filter that is very deep (10-20 ft). Filled with a lightweight synthetic media, these towers are also know as oxidation or roughing towers or (because of their extremely high hydraulic loading) super-rate trickling filters.
- *Biomass*—the total mass of organisms attached to the media. Similar to solids inventory in the activated sludge process, it is sometimes referred to as the *zoogleal slime.*
- *Distribution arm*—the device most widely used to apply wastewater evenly over the entire surface of the media. In most cases, the force of the wastewater being sprayed through the orifices moves the arm.
- *Filter underdrain*—the open space provided under the media to collect the liquid (wastewater and sloughings) and to allow air to enter the filter. It has a sloped floor to collect the flow to a central channel for removal.
- *High-rate trickling filters*—a classification (see Table 19.4) in which the organic loading is in the range of 25 to 100 pounds of BOD_5 per 1,000 cubic feet of media per day. The standard rate filter may also produce a highly nitrified effluent.
- *Hydraulic loading*—the amount of wastewater flow applied to the surface of the trickling filter media. It can be expressed in several ways: flow per square foot of surface per day (gpd/ft^2); flow per acre per day (MGAD); or flow per acre foot per day (MGAFD). The hydraulic loading includes all flow entering the filter.

- *Media*—an inert substance placed in the filter to provide a surface for the microorganism to grow on. The media can be filed stone, crushed stone, slag, plastic, or redwood slats.
- *Organic loading*—the amount of BOD_5 or chemical oxygen demand (COD) applied to a given volume of filter media. It does no include theBOD_5 or COD contributed to any recirculated flow and is commonly expressed as pounds of BOD_5 or COD per 1,000 cubic feet of media.
- *Recirculation*—the return of filter effluent back to the head of the trickling filter. It can level flow variations and assist in solving operational problems, such as ponding, filter flies, and odors.
- *Roughing filters*—a classification of trickling filters (see Table 19.4) in which the organic is in excess of 200 pounds of BOD_5 per 1,000 cubic feet of media per day. A roughing filter is used to reduce the loading on other biological treatment processes to produce an industrial discharge that can be safely treated in a municipal treatment facility.
- *Sloughing*—the process in which the excess growths break away from the media and wash through the filter to the underdrains with the wastewater. These sloughings must be removed from the flow by settling.
- *Staging*—the practice of operating two or more trickling filters in series. The effluent of one filter is used as the influent of the next. This practice can produce a higher quality effluent by removing additional BOD_5 or COD.

The trickling filter **distribution system** is designed to spread wastewater evenly over the surface of the entire media. The most common system is the **rotary distributor** which moves above the surface of the media and sprays the wastewater on the surface. The force of the water leaving the orifices drives the rotary system. The distributor arms usually have small plates below each orifice to spread the wastewater into a fan-shaped distribution system. The second type of distributor is the **fixed nozzle** system. In this system, the nozzles are fixed in place above the media and are designed to spray the wastewater over a fixed portion of the media. This system is used frequently with deep bed synthetic media filters.

Note: Trickling filters that use ordinary rock are normally only about 3 meters in depth because of structural problems caused by the weight of rocks—which also requires the construction of beds that are quite wide, in many applications, up to 60 feet in diameter. When synthetic media is used, the bed can be much deeper.

No matter which type of **media** is selected, the primary consideration is that it must be capable of providing the desired film location for the development of the biomass. Depending on the type of media used and the filter classification, the media may be 3 to 20 or more feet in depth.

The **underdrains** are designed to support the media, collect the wastewater and sloughings and carry them out of the filter and to provide ventilation to the filter.

Note: In order to ensure sufficient airflow to the filter the underdrains should never be allowed to flow more than 50 percent full of wastewater.

The **effluent channel** is designed to carry the flow from the trickling filter to the secondary settling tank.

The **secondary settling tank** provides 2 to 4 hours of detention time to separate the sloughing materials from the treated wastewater. Design, construction, and operation are similar to that of the primary settling tank. Longer detention times are provided because the sloughing materials are lighter and settle more slowly.

Recirculation pumps and **piping** are designed to recirculate (and thus improve the performance of the trickling filter or settling tank) a portion of the effluent back to be mixed with the filter influent. When recirculation is used, obviously, pumps and metering devices must be provided.

Trickling filters are classified by hydraulic and organic loading. Moreover, the expected performance and the construction of the trickling filter are determined by the filter classification. Filter classifications include: standard rate, intermediate rate, high rate, supers high rate (plastic media) and roughing rate types. Standard rate, high rate, and roughing rate are the filter types most commonly used.

The standard rate filter has a hydraulic loading (gpd/ft^3) of from 25 to 90; a seasonal sloughing frequency; does not employ recirculation; and typically has an 80-85 percent BOD_5 removal rate and 80 to 85 percent TSS removal rate.

The high rate filter has a hydraulic loading (gpd/ft^3) of 230 to 900; a continuous sloughing frequency; always employs recirculation; and typically has a 65 to 80 percent BOD_5 removal rate and 65 to 80% TSS removal rate.

The roughing filter has a hydraulic loading (gpd/ft^3) of >900; a continuous sloughing frequency; does not normally include recirculation; and typically has a 40 to 65 percent removal rate and 40 to 65 percent TSS removal rate.

Standard operating procedures for trickling filters include sampling and testing, observation, recirculation, maintenance, and expectations of performance.

Collection of influent and process effluent **samples** to determine performance and monitor process condition of trickling filters is required. Dissolved oxygen, pH and settleable solids **testing** should be collected daily. BOD_5 and suspended solids testing should be done as often as practical to determine the per cent removal.

The operation and condition of the filter should be **observed** daily. Items to observe include the distributor movement, uniformity of distribution, evidence of operation or mechanical problems, and the presence of objectionable odors. In addition to the items above the normal observation for a settling tank should also be performed.

Recirculation is used to reduce organic loading, improve sloughing, reduce odors and reduce or eliminate filter fly or ponding problems. The amount of recirculation is dependent on the design of the treatment plant and the operational requirements of the process. Recirculation flow may be expressed as a specific flow rate (i.e., 2.0-MGD). In most cases, it is expressed as a ratio (3:1, 0.5: 1.0, etc). The recirculation is always listed as the first number and the influent flow listed as the second number.

Note: Since the second number in the ratio is always 1.0 the ratio is sometimes written as a single number (dropping the: 1.0)

Flows can be recirculated from various points following the filter to various points before the filter. The most common form of recirculation removes flow from the filter effluent or settling tank and returns it to the influent of the trickling filter. Maintenance requirements include lubrication of mechanical equipment, removal of debris from the surface and orifices, as well as adjustment of flow patterns and maintenance associated with the settling tank.

Expected performance ranges for each classification of trickling filter. Moreover, the levels of BOD_5 and suspended solids removal are dependent on the type of filter.

The trickling filter process involves spraying wastewater over a solid media such as rock, plastic, or redwood slats (or laths). As the wastewater trickles over the surface of the media, a growth of microorganisms (bacteria, protozoa, fungi, algae, helminthes or worms, and larvae) develops. This growth is visible as a shiny slime very similar to the slime found on rocks in a stream. As the wastewater passes over this slime, the slime adsorbs the organic (food) matter. This organic matter is used for food by the microorganisms. At the same time, air moving through the open spaces in the filter transfers oxygen to the wastewater. This oxygen is then transferred to the slime to keep the outer layer aerobic. As the microorganisms use the food and oxygen, they produce more organisms, carbon dioxide, sulfates, nitrates, and other stable by-products; these materials are then discarded from the slime back into the wastewater flow and are carried out of the filter.

Organics + Organisms + O_2 = More Organisms + CO_2 + Solid Wastes

The growth of the microorganisms and the buildup of solid wastes in the slime make it thicker and heavier. When this slime becomes too thick, the wastewater flow breaks off parts of the slime. These must be removed in the final settling tank.

In some trickling filters, a portion of the filter effluent is returned to the head of the trickling filter to level out variations in flow and improves operations (recirculation).

Rotating Biological Contactors (RBCs)

The *rotating biological contactor (RBC)* is a biological treatment system and is a variation of the attached growth idea provided by the trickling filter. Still relying on microorganisms that grow on the surface of a medium, the RBC is instead a **fixed film** biological treatment device—the basic biological process, however, is similar to that occurring in the trickling filter. An RBC consists of a series of closely spaced (mounted side by side), circular, plastic (synthetic) disks, that are typically about 3.5 m in diameter and attached to a rotating horizontal shaft. Approximately 40 percent of each disk is submersed in a tank containing the wastewater to be treated. As the RBC rotates, the attached biomass film (zoogleal slime) that grows on the surface of the disk move into and out of the wastewater. While submerged in the wastewater, the microorganisms absorb organics; while they are rotated out of the wastewater, they are supplied with needed oxygen for aerobic decomposition. As the zoogleal slime reenters the wastewater, excess solids and waste products are stripped off the media as **sloughings**. These sloughings are transported with the wastewater flow to a settling tank for removal.

Modular RBC units are placed in series—simply because a single contactor is not sufficient to achieve the desired level of treatment; the resulting treatment achieved exceeds conventional secondary treatment. Each individual contactor is called a **stage** and the group is known as a **train**. Most RBC systems consist of two or more trains with three or more stages in each. The key advantage in using RBCs instead of trickling filters is that RBCs are easier to operate under varying load conditions, since it is easier to keep the solid medium wet at all times. Moreover, the level of nitrification, which can be achieved by a RBC system, is significant—especially when multiple stages are employed.

The equipment that makes up a RBC includes the rotating biological contactor (the media: either standard or high density), a center shaft, drive system, tank, baffles, housing or cover, and a settling tank.

The **rotating biological contactor** consists of circular sheets of synthetic material (usually plastic) which are mounted side by side on a shaft. The sheets (media) contain large amounts of surface area for growth of the biomass.

The **center shaft** provides the support for the disks of media and must be strong enough to support the weight of the media and the biomass. Experience has indicated a major problem has been the collapse of the support shaft.

The **drive system** provides the motive force to rotate the disks and shaft. The drive system may be mechanical or air driven or a combination of each. When the drive system does not provide uniform movement of the RBC, major operational problems can arise.

The **tank** holds the wastewater that the RBC rotates in. It should be large enough to permit variation of the liquid depth and detention time.

Baffles are required to permit proper adjustment of the loading applied to each stage of the RBC process. Adjustment can be made to increase or decrease the submergence of the RBC.

RBC stages are normally enclosed in some type of protective structure (**cover**) to prevent loss of biomass due to severe weather changes (snow, rain, temperature, wind, sunlight, etc.). In many instances this housing greatly restricts access to the RBC.

The **settling tank** is provided to remove the sloughing material created by the biological activity and is similar in design to the primary settling tank. The settling tank provides two- to four-hour detention times to permit settling of lighter biological solids.

During normal operation, operator vigilance is required to observe the RBC movement, slime color, and appearance. However, if the unit is covered, observations may be limited to that portion of the media, which can be viewed through the access door. Slime color and appearance can indicate process condition. For example, when slime color and/or appearance is

- Gray, shaggy slime growth—indicates normal operation
- Reddish brown, golden shaggy growth—indicates nitrification
- White chalky appearance—indicates high sulfur concentrations
- No slime—indicates severe temperature or pH changes

Sampling and testing should be conducted daily for dissolved oxygen content and pH. BOD_5 and suspended solids testing should also be accomplished to aid in assessing performance.

The RBC normally produces a high quality effluent with BOD_5 at 85-95 percent and Suspended Solids Removal at 85-95 percent. The RBC treatment process may also significantly reduce (if designed for this purpose) the levels of organic nitrogen and ammonia nitrogen.

Activated Sludge

The biological treatment systems discussed to this point [ponds, trickling filters, and rotating biological contactors (RBCs)] have been around for years. The trickling filter, for example, has been around and successfully used since the late 1800s. The problem with ponds, trickling filters and RBCs is that they are temperature sensitive, remove less BOD and, trickling filters, for example, cost more to build than the activated sludge systems that were later developed.

Note: Although trickling filters and other systems cost more to build than activated sludge systems, it is important to point out that activated sludge systems cost more to operate because of the need for energy to run pumps and blowers.

The activated sludge process follows primary settling. The basic components of an activated sludge sewage treatment system include an aeration tank and a secondary basin, settling basin, or clarifier. Primary effluent is mixed with settled solids recycled from the secondary clarifier and is then introduced into the aeration tank. Compressed air is injected continuously into the mixture through porous diffusers located at the bottom of the tank, usually along one side.

Wastewater is fed continuously into an aerated tank, where the microorganisms metabolize and biologically flocculate the organics. Microorganisms (activated sludge) are settled from the aerated mixed liquor under quiescent conditions in the final clarifier and are returned to the aeration tank. Left uncontrolled, the number of organisms would eventually become too great; therefore, some must periodically be removed (wasted). A portion of the concentrated solids from the bottom of the settling tank must be removed from the process (waste activated sludge or WAS). Clear supernatant from the final settling tank is the plant effluent.

To better understand the discussion of the activated sludge process presented in the following sections, you must understand the terms associated with the process.

- *Adsorption*—taking in or reception of one substance into the body of another by molecular or chemical actions and distribution throughout the absorber.
- *Activated*—to speed up reaction. When applied to sludge, it means that many aerobic bacteria and other microorganisms are in the sludge particles.
- *Activated sludge*—a floc or solid formed by the microorganisms. It includes organisms, accumulated

food materials, and waste products from the aerobic decomposition process.

- *Activated sludge process*—a biological wastewater treatment process in which a mixture or influent and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated mixed liquor by sedimentation and is returned to the process as needed. The treated wastewater overflows the weir of the settling tank in which separation from the sludge takes place.
- *Adsorption*—the adherence of dissolved, colloidal, or finely divided solids to the surface of solid bodies when they are brought into contact.
- *Aeration*—mixing air and a liquid by one of the following methods: spraying the liquid in the air; diffusing air into the liquid; or agitating the liquid to promote surface adsorption of air.
- *Aerobic*—a condition in which "free" or dissolved oxygen is present in the aquatic environment. Aerobic organisms must be in the presence of dissolved oxygen to be active.
- *Bacteria*—single-cell plants that play a vital role in stabilization of organic waste.
- *Biochemical oxygen demand (BOD)*—a measure of the amount of food available to the microorganisms in a particular waste. It is measured by the amount of dissolved oxygen used up during a specific time period (usually five days, expressed as BOD_5).
- *Biodegradable*—from "degrade" (to wear away or break down chemically) and "bio" (by living organisms). Put it all together, and you have a "substance, usually organic, which can be decomposed by biological action."
- *Bulking*—a problem in activated sludge plants that results in poor settleability of sludge particles.
- *Coning*—a condition that may be established in a sludge hopper during sludge withdrawal, when part of the sludge moves toward the outlet while the remainder tends to stay in place. Development of a cone or channel of moving liquids surrounded by relatively stationary sludge.
- *Decomposition*—generally, in waste treatment, decomposition refers to the changing of waste matter into simpler, more stable forms that will not harm the receiving stream.
- *Diffused air aeration*—a diffused air activated sludge plant takes air, compresses it, then discharges the air below the water surface to the aerator through some type of air diffusion device.
- *Diffuser*—a porous plate or tube through which air is forced and divided into tiny bubbles for distribution in liquids. Commonly made of carborundum, aluminum, or silica sand.
- *Dissolved oxygen*—atmospheric oxygen dissolved in water or wastewater, usually abbreviated as DO.

Note: The typical required DO for a well-operated activated sludge plant is between 2.0 and 2.5 mg/l.

- *Facultative*—facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials. In other words, facultative bacteria can live under aerobic or anaerobic conditions.
- *Filamentous bacteria*—organisms that grow in thread or filamentous form.
- *Food-to-microorganisms ratio*—a process control calculation used to evaluate the amount of food (BOD or COD) available per pound of mixed liquor volatile suspended solids. This may be written as F/M ratio.
- *Fungi*—multicellular aerobic organisms.
- *Gould sludge age*—a process control calculation used to evaluate the amount of influent suspended solids available per pound of mixed liquor suspended solids.
- *Mean cell residence time* (MCRT)—the average length of time mixed liquor suspended solids particle remains in the activated sludge process. This is usually written as MCRT and may also be referred to as *sludge retention rate (*STR).
- *Mixed liquor*—the contribution of return activated sludge and wastewater (either influent or primary effluent) that flows into the aeration tank.
- *Mixed liquor suspended solids (MLSS)*—the suspended solids concentration of the mixed liquor. Many references use this concentration to represent the amount of organisms in the liquor. Many references use this concentration to represent the amount of organisms in the activated sludge process. This is usually written MLSS.
- *Mixed liquor volatile suspended solids (*MLVSS)—the organic matter in the mixed liquor suspended solids. This can also be used to represent the amount of organisms in the process. This is normally written as MLVSS.
- *Nematodes*—microscopic worms that may appear in biological waste treatment systems.
- *Nutrients*—substances required to support plant organisms. Major nutrients are carbon, hydrogen, oxygen, sulfur, nitrogen, and phosphorus.
- *Protozoa*—single-cell animals that are easily observed under the microscope at a magnification of 100x. Bacteria and algae are prime sources of food for advanced forms of protozoa.
- *Return activated sludge*—the solids returned from the settling tank to the head of the aeration tank. This is normally written as RAS.
- *Rising sludge*—rising sludge occurs in the secondary clarifiers or activated sludge plant when the sludge settles to the bottom of the clarifier, is compacted, and then rises to the surface in relatively short time.

- *Rotifiers*—multicellular animals with flexible bodies and cilia near their mouths used to attract food. Bacteria and algae are their major source of food.
- *Secondary treatment*—a wastewater treatment process used to convert dissolved or suspended materials into a form that can be removed.
- *Settleability*—a process control test used to evaluate the settling characteristics of the activated sludge. Readings taken at 30 to 60 minutes are used to calculate the settled sludge volume (SSV) and the sludge volume index (SVI).
- *Settled sludge volume*—the volume of ml/l (or percent) occupied by an activated sludge sample after 30 or 60 minutes of settling. Normally written as SSV with a subscript to indicate the time of the reading used for calculation (SSV_{30} or SSV_{60}).
- *Shock load*—the arrival at a plant of a waste toxic to organisms, in sufficient quantity or strength to cause operating problems, such as odor or sloughing off of the growth of slime on the trickling filter media. Organic overloads also can cause a shock load.
- *Sludge volume index*—a process control calculation used to evaluate the settling quality of the activated sludge. Requires the SSV_{30} and mixed liquor suspended solids test results to calculate.
- *Solids*—material in the solid state.

  Dissolved—solids present in solution. Solids that will pass through a glass fiber filter.

  Fixed—also known as the inorganic solids. The solids that are left after a sample is ignited at 550° Celsius (centigrade) for 15 minutes.

  Floatable solids—solids that will float to the surface of still water, sewage, or other liquid. Usually composed of grease particles, oils, light plastic material, etc. Also called *scum.*
  Non-settleable—finely divided suspended solids that will not sink to the bottom in still water, sewage, or other liquid in a reasonable period, usually two hours. Non-settleable solids are also known as colloidal solids.

  Suspended—the solids that will not pass through a glass fiber filter.

  Total—the solids in water, sewage, or other liquids; it includes the suspended solids and dissolved solids.

  Volatile—the organic solids. Measured as the solids that are lost on ignition of the dry solids at 550°C.
- *Waste activated sludge*—the solids being removed from the activated sludge process. This is normally written as WAS.

The equipment requirements for the activated sludge process are more complex than other processes discussed. Equipment includes an aeration tank, aeration, system-settling tank, return sludge, and waste sludge.

- **Aeration Tank**
  The *aeration tank* is designed to provide the required detention time (depends on the specific modification) and ensure that the activated sludge and the influent wastewater are thoroughly mixed. Tank design normally attempts to ensure no dead spots are created.
- **Aeration**
  Aeration can be mechanical or diffused. **Mechanical aeration** systems use agitators or mixers to mix air and mixed liquor. Some systems use **sparge ring** to release air directly into the mixer **Diffused aeration** systems use pressurized air released through diffusers near the bottom of the tank. Efficiency is directly related to the size of the air bubbles produced. Fine bubble systems have a higher efficiency. The diffused air system has a blower to produce large volumes of low pressure air (5 to 10 psi), air lines to carry the air to the aeration tank, headers to distribute the air to the diffusers which release the air into the wastewater.
- **Settling Tank**
  Activated sludge systems are equipped with plain *settling tanks* designed to provide 2 to hours hydraulic detention time.
- **Return Sludge**
  The *return sludge system* include pumps, a timer or variable speed drive to regulate pump delivery and a flow measurement device to determine actual flow rates.
- **Waste Sludge**
  In some cases the *waste activated sludge* withdrawal is accomplished by adjusting valves on the return system. When a separate system is used it includes pump(s), timer or variable speed drive, and a flow measurement device.

The activated sludge process is a treatment technique in which wastewater and reused biological sludge full of living microorganisms are mixed and aerated. The biological solids are then separated from the treated wastewater in a clarifier and are returned to the aeration process or wasted.

The microorganisms are mixed thoroughly with the incoming organic material, and they grow and reproduce by using the organic material as food. As they grow and are mixed with air, the individual organisms cling together (flocculate). Once flocculated, they more readily settle in the secondary clarifiers.

The wastewater being treated flows continuously into an aeration tank where air is injected to mix the wastewater with the returned activated sludge and to supply the oxygen needed by the microbes to live and feed on the organics. Aeration can be supplied by injection through air diffusers in the bottom of tank or by mechanical aerators located at the surface.

The mixture of activated sludge and wastewater in the aeration tank is called the "mixed liquor." The mixed liquor flows to a secondary clarifier where the activated sludge is allowed to settle.

The activated sludge is constantly growing, and more is produced than can be returned for use in the aeration basin. Some of this sludge must, therefore, be wasted to a sludge handling system for treatment and disposal. The volume of sludge returned to the aeration basins is normally 40 to 60 percent of the wastewater flow. The rest is wasted.

Disinfection of Wastewater

Like drinking water, liquid wastewater effluent is disinfected. Unlike drinking water, wastewater effluent is disinfected not to directly (direct end-of-pipe connection) protects a drinking water supply, but instead is treated to protect public health in general. This is particularly important when the secondary effluent is discharged into a body of water used for swimming or water supply for a downstream water supply.

In the treatment of water for human consumption, treated water is typically chlorinated (although ozonation is also currently being applied in many cases). Chlorination is the preferred disinfection in potable water supplies because of chlorine's unique ability to provide a residual. This chlorine residual is important because when treated water leaves the waterworks facility and enters the distribution system; the possibility of contamination is increased. The residual works to continuously disinfect water right up to the consumer's tap.

Chlorine Disinfection

Chlorination for disinfection, follows all other steps in conventional wastewater treatment. The purpose of chlorination is to reduce the population of organisms in the wastewater to levels low enough to ensure that pathogenic organisms will not be present in sufficient quantities to cause disease when discharged.

Note: Chlorine gas is heavier than (vapor density of 2.5). Therefore, exhaust from a chlorinator room should be taken from floor level.

Note: The safest action to take in the event of a major chlorine container leak is to call the fire department.

Note: You might wonder why it is that chlorination of critical waters such as natural trout streams is not normal practice. This practice is strictly prohibited because chlorine and its by-products (i.e., chloramines) are extremely toxic to aquatic organisms.

Several terms used in discussion of disinfection by chlorination. Because it is important for the operator to be familiar with these terms, we repeat key terms again.

- *Chlorine*—a strong oxidizing agent which has strong disinfecting capability. A yellow-green gas which is extremely corrosive, and is toxic to humans in extremely low concentrations in air.
- *Contact Time*—the length of time the time the disinfecting agent and the wastewater remain in contact.
- *Demand*—the chemical reactions, which must be satisfied before a residual or excess chemical will appear.
- *Disinfection*—refers to the selective destruction of disease-causing organisms. All the organisms are not destroyed during the process. This differentiates disinfection from sterilization, which is the destruction of all organisms.
- *Dose*—the amount of chemical being added in milligrams/liter.
- *Feed Rate*— the amount of chemical being added in pounds per day.
- *Residual*—the amount of disinfecting chemical remaining after the demand has been satisfied.
- *Sterilization*—the removal of all living organisms.

Chlorine Facts:

- Elemental chlorine (Cl_2—gaseous) is a yellow-green gas, 2.5 times heavier than air.
- The most common use of chlorine in wastewater treatment is for disinfection. Other uses include odor control and activated sludge bulking control. Chlorination takes place prior to the discharge of the final effluent to the receiving waters.
- Chlorine may also be used for nitrogen removal, through a process called *breakpoint chlorination.* For nitrogen removal, enough chlorine is added to the wastewater to convert all the ammonium nitrogen gas. To do this, approximately 10 mg/l of chlorine must be added for every 1 mg/l of ammonium nitrogen in the wastewater.
- For disinfection, chlorine is fed manually or automatically into a chlorine contact tank or basin, where it contacts flowing wastewater for at least 30 minutes to destroy disease-causing microorganisms (pathogens) found in treated wastewater.
- Chorine may be applied as a gas, a solid, or in liquid hypochlorite form.
- Chorine is a very reactive substance. It has the potential to react with many different chemicals (including ammonia), as well as with organic matter. When chlorine is added to wastewater, several reactions occur:
- Chlorine will react with any reducing agent (i.e., sulfide, nitrite, iron, and thiosulfate) present in wastewater. These reactions are known as *chlorine demand.*

The chlorine used for these reactions is not available for disinfection.

- Chlorine also reacts with organic compounds and ammonia compounds to form chlor-organics and chloramines. Chloramines are part of the group of chlorine compounds that have disinfecting properties and show up as part of the chlorine residual test.
- After all of the chlorine demands are met, addition of more chlorine will produce free residual chlorine. Producing free residual chlorine in wastewater requires very large additions of chlorine.

Hypochlorite Facts:

Hypochlorite, though there are some minor hazards associated with its use (skin irritation, nose irritation, and burning eyes), is relatively safe to work with. It is normally available in dry form as a white powder, pellet or tablet, or in liquid form. It can be added directly using a dry chemical feeder or dissolved and fed as a solution.

Note: In most wastewater treatment systems, disinfection is accomplished by means of combined residual.

Chlorine is a very reactive substance. Chlorine is added to wastewater to satisfy all chemical demands, that is, to react with certain chemicals (such as sulfide, sulfite, ferrous iron, etc.). When these initial chemical demands have been satisfied, chlorine will react with substances such as ammonia to produce chloramines and other substances which, although not as effective as chlorine, have disinfecting capability. This produces a combined residual, which can be measured using residual chlorine test methods. If additional chlorine is added, free residual chlorine can be produced. Due to the chemicals normally found in wastewater, chlorine residuals are normally combined rather than free residuals. Control of the disinfection process is normally based upon maintaining total residual chlorine of at least 1.0 mg/L for a contact time of at least 30 minutes at design flow.

Note: Residual level, contact time, and effluent quality affect disinfection. Failure to maintain the desired residual levels for the required contact time will result in lower efficiency and increased probability that disease organisms will be discharged.

Based on water quality standards, **total residual limitations** on chlorine are:

- Fresh Water—Less than 11 ppb total residual chlorine.
- Estuaries—Less than 7.5-ppb for halogen produced oxidants.
- Endangered Species—Use of chlorine is prohibited.

Chlorine Systems

Because of the potential hazards associated with the use of chlorine, the equipment requirements are significantly greater than those associated with hypochlorite use. The system most widely used is a **solution feed system**. In this system chlorine is removed from the container at a flow rate controlled by a variable orifice. Water moving through the chlorine injector creates a vacuum, which draws the chlorine gas to the injector and mixes it with the water. The chlorine gas reacts with the water to form hypochlorous and hydrochloric acid. The solution is then piped to the chlorine contact tank and dispersed into the wastewater through a diffuser. Larger facilities may withdraw the liquid form of chlorine and use evaporators (heaters) to convert to the gas form. Small facilities will normally draw the gas form of chlorine from the cylinder. As gas is withdrawn liquid will be converted to the gas form. This requires heat energy and may result in chlorine line freeze-up if the withdrawal rate exceeds the available energy levels.

In either type of system normal operation requires adjustment of feed rates to ensure the required residual levels are maintained. This normally requires chlorine residual testing and adjustment based upon the results of the test. Other activities include removal of accumulated solids from the contact tank, collection of bacteriological samples to evaluate process performance and maintenance of safety equipment (respirator-air pack, safety lines, etc.).

Hypochlorite operation may also include make-up solution (solution feed systems), adding powder or pellets to the dry chemical feeder or tablets to the tablet chlorinator.

Chlorine operations include adjustment of chlorinator feed rates, inspection of mechanical equipment, testing for leaks using ammonia swab (white smoke means leaks), changing containers (requires more than one person for safety) and adjusting the injector water feed rate when required.

Chlorination requires routine testing of plant effluent for total residual chlorine and may also require collection and analysis of samples to determine the Fecal Coliform concentration in the effluent.

Dechlorination

The purpose of *dechlorination* is to remove chlorine and reaction products (chloramines) before the treated wastestream is discharged into its receiving waters. Dechlorination follows chlorination—usually at the end of the contact tank to the final effluent. Sulfur dioxide gas, sodium sulfate, sodium metabisulfate, or sodium bisulfates are the chemicals used to dechlorinate. No matter which chemical is used to dechlorinate, its reaction with chlorine is instantaneous.

Ultraviolet (UV) Irradiation

Although ultraviolet disinfection was recognized as a method for achieving disinfection in the late nineteenth century, its application virtually disappeared with the evolution of chlorination technologies. However, in recent years, there has been resurgence in its use in the wastewater field, largely as a consequence of concern for discharge of toxic chlorine residual. Even more recently, UV has gained more attention because of the tough new regulations on chlorine use imposed by both OSHA and USEPA. Because of this relatively recent increased regulatory pressure, many facilities are actively engaged in substituting chlorine for other disinfection alternatives. Moreover, UV technology itself has made many improvements, which now makes UV attractive as a disinfection alternative.

Ultraviolet light has very good germicidal qualities and is very effective in destroying microorganisms. It is used in hospitals, biological testing facilities, and many other similar locations. In wastewater treatment, the plant effluent is exposed to ultraviolet light of a specified wavelength and intensity for a specified contact period. The effectiveness of the process is dependent upon

- UV light intensity
- Contact time
- Wastewater quality (turbidity)

The Achilles' heel of UV for disinfecting wastewater is turbidity. If the wastewater quality is poor, the ultraviolet light will be unable to penetrate the solids and the effectiveness of the process decreases dramatically. For this reason, many states limit the use of UV disinfection to facilities that can reasonably be expected to produce an effluent containing ≤30 mg/l, or less of BOD_5 and total suspended solids.

In the operation of UV systems, UV lamps must be readily available when replacements are required. The best lamps are those with a stated operating life of at least 7,500 hours and those that do not produce significant amounts of ozone or hydrogen peroxide. The lamps must also meet technical specifications for intensity, output, and arc length. If the UV light tubes are submerged in the wastestream, they must be protected inside quartz tubes, which not only protect the lights but also make cleaning and replacement easier.

Contact tanks must be used with UV disinfection. They must be designed with the banks of UV lights in a horizontal position, either parallel or perpendicular to the flow or with banks of lights placed in a vertical position perpendicular to the flow.

Note: The contact tank must provide, at a minimum, 10-second exposure time.

We stated earlier that turbidity problems have been the problem with using UV in wastewater treatment—and this is the case. However, if turbidity is its Achilles' heel, then the need for increased maintenance (as compared to other disinfection alternatives) is the toe of the same foot.

UV maintenance requires that the tubes be cleaned on a regular basis or as needed. In addition, periodic acid washing is also required to remove chemical buildup.

In operating UV disinfection systems, routine monitoring is required. Monitoring to check on bulb burnout, buildup of solids on quartz tubes, and UV light intensity is required.

Note: UV light is extremely hazardous to the eyes. Never enter an area where UV lights are in operation without proper eye protection. Never look directly into the ultraviolet light.

Ozonation

Ozone is a strong oxidizing gas that reacts with most organic and many inorganic molecules. It is produced when oxygen molecules separate, collide with other oxygen atoms, and form a molecule consisting of three oxygen atoms. For high-quality effluents, ozone is a very effective disinfectant. Current regulations for domestic treatment systems limit use of ozonation to filtered effluents unless the system's effectiveness can be demonstrated prior to installation.

Note: Effluent quality is the key performance factor for ozonation.

For ozonation of wastewater, the facility must have the capability to generate pure oxygen along with an ozone generator. A contact tank with ≥10-minute contact time at design average daily flow is required. Off-gas monitoring for process control is also required. In addition, safety equipment capable of monitoring ozone in the atmosphere and a ventilation system to prevent ozone levels exceeding 0.1 ppm is required.

The actual operation of the ozonation process consists of monitoring and adjusting the ozone generator and monitoring the control system to maintain the required ozone concentration in the off-gas. The process must also be evaluated periodically using biological testing to assess its effectiveness.

Note: Ozone is an extremely toxic substance. Concentrations in air should not exceed 0.1 ppm. It also has the potential to create an explosive atmosphere. Sufficient ventilation and purging capabilities should be provided.

Note: Ozone has certain advantages over chlorine for disinfection of wastewater: (1) Ozone increases DO in the effluent; (2) ozone has a briefer contact time; (3)

ozone has no undesirable effects on marine organisms; and (4) ozone decreases turbidity and odor.

Bromine Chloride

Bromine chloride is a mixture of bromine and chlorine. It forms hydrocarbons and hydrochloric acid when mixed with water. Bromine chloride is an excellent disinfectant that reacts quickly and normally does not produce any long-term residuals.

Note: Bromine chloride is an extremely corrosive compound in the presence of low concentrations of moisture.

The reactions occurring when bromine chloride is added to the wastewater are similar to those occurring when chlorine is added. The major difference is the production of bromamine compounds rather than chloramines. The bromamine compounds are excellent disinfectants but are less stable and dissipate quickly. In most cases, the bromamines decay into other, less toxic compounds rapidly and are undetectable in the plant effluent.

The factors that affect performance are similar to those affecting the performance of the chlorine disinfection process. Effluent quality, contact time, etc. have a direct impact on the performance of the process.

No Disinfection

In a very limited number of cases, treated wastewater discharges without disinfection is permitted. These are approved on a case-by-case basis. Each request must be evaluated based upon the point of discharge, the quality of the discharge, the potential for human contact, and many other factors.

Solids (Sludge/Biosolids) Handling

The wastewater treatment unit processes described to this point remove solids and BOD from the wastestream before the liquid effluent is discharged to its receiving waters. What remains to be disposed of is a mixture of solids and wastes, called *process residuals*—more commonly referred to as *sludge* or *biosolids*.

Note: Sludge is the commonly accepted name for wastewater solids. However, if wastewater sludge is used for beneficial reuse (e.g., as a soil amendment or fertilizer), it is commonly called biosolids.

The most costly and complex aspect of wastewater treatment can be the collection, processing, and disposal of sludge. This is the case because the quantity of sludge produced may be as high as 2 percent of the original volume of wastewater, depending somewhat on the treatment process being used.

Because sludge can be as much as 97 percent water content, and because the cost of disposal will be related to the volume of sludge being processed, one of the primary purposes or goals (along with stabilizing it so it is no longer objectionable or environmentally damaging) of sludge treatment is to separate as much of the water from the solids as possible. Sludge treatment methods may be designed to accomplish both of these purposes.

Note: Sludge treatment methods are generally divided into three major categories: thickening, stabilization, and dewatering. Many of these processes include complex sludge treatment methods (i.e., heat treatment, vacuum filtration, incineration and others).

When we speak of *sludge* or *biosolids*, we are speaking of the same substance or material; each is defined as the suspended solids removed from wastewater during sedimentation, and then concentrated for further treatment and disposal or reuse. The difference between the terms *sludge* and *biosolids* is determined by the way they are managed. (Note: The task of disposing, treating or reusing wastewater solids is called *sludge* or *biosolids management.*) Sludge is typically seen as wastewater solids that are "disposed" of. Biosolids is the same substance managed for reuse—commonly called beneficial reuse (e.g., for land application as a soil amendment, such as biosolids compost).

Note that even as wastewater treatment standards have become more stringent because of increasing environmental regulations, so has the volume of wastewater sludge increased.

Note also that before sludge can be disposed of or reused, it requires some form of treatment to reduce its volume, to stabilize it, and to inactivate pathogenic organisms.

Sludge forms initially as a 3-7 percent suspension of solids, and with each person typically generating about 4 gallons of sludge per week, the total quantity generated each day, week, month, and year is significant. Because of the volume and nature of the material, sludge management is a major factor in the design and operation of all water pollution control plants.

Note: Wastewater solids account for more than half of the total costs in a typical secondary treatment plant.

Wastewater sludge is generated in primary, secondary, and chemical treatment processes. In primary treatment, the solids that float or settle are removed. The floatable material makes up a portion of the solid waste known as scum. Scum is not normally considered sludge; however, it should be disposed of in an environmentally sound way. The settleable material that collects on the bottom of the clarifier is known as *primary sludge.* Primary sludge can also be referred to as raw sludge because it has not undergone decomposition. Raw primary sludge from a typical domestic facility is quite objectionable and has a high percentage of water, two characteristics that make handling difficult.

Those solids not removed in the primary clarifier are carried out of the primary unit. These solids are known as *colloidal suspended solids.* The secondary treatment system (i.e., trickling filter, activated sludge, etc.) is designed to change those colloidal solids into settleable solids that can be removed. Once in the settleable form, these solids are removed in the secondary clarifier. The sludge at the bottom of the secondary clarifier is called *secondary sludge.* Secondary sludges are light and fluffy and more difficult to process than primary sludges—in short, secondary sludges do not de-water well.

The addition of chemicals and various organic and inorganic substances prior to sedimentation and clarification may increase the solids capture and reduce the amount of solids lost in the effluent. This *chemical addition* results in the formation of heavier solids, which trap the colloidal solids or convert dissolved solids to settleable solids. The resultant solids are known as *chemical sludges.* As chemical usage increases, so does the quantity of sludge that must be handled and disposed of. Chemical sludges can be very difficult to process; they do not de-water well and contain lower percentages of solids.

Sludge Characteristics

The composition and characteristics of sewage sludge vary widely and can change considerably with time. Notwithstanding these facts, the basic components of wastewater sludge remain the same. The only variations occur in quantity of the various components as the type of sludge and the process from which it originated changes.

The main component of all sludges is *water.* Prior to treatment, most sludge contain 95 to 99+ percent water. This high water content makes sludge handling and processing extremely costly in terms of both money and time. Sludge handling may represent up to 40 percent of the capital cost and 50 percent of the operation cost of a treatment plant. As a result, the importance of optimum design for handling and disposal of sludge cannot be overemphasized. The water content of the sludge is present in a number of different forms. Some forms can be removed by several sludge treatment processes, thus allowing the same flexibility in choosing the optimum sludge treatment and disposal method.

The forms of water associated with sludges are

- *Free water*—water that is not attached to sludge solids in any way. This can be removed by simple gravitational settling.
- *Floc water*—water that is trapped within the floc and travels with them. Its removal is possible by mechanical de-watering.
- *Capillary water*—water that adheres to the individual particles and can be squeezed out of shape and compacted.
- *Particle water*—water that is chemically bound to the individual particles and can't be removed without inclination.

From a public health view, the second and probably more important component of sludge is the *solids matter.* Representing from 1 to 8 percent of the total mixture, these solids are extremely unstable. Wastewater solids can be classified into two categories based on their origin—organic and inorganic. *Organic solids* in wastewater, simply put, are materials that are of were at one time alive and that will burn or volatilize at 550°C after 15 minutes in a muffle furnace. The percent organic material within a sludge will determine how unstable it is.

The inorganic material within sludge will determine how stable it is. The *inorganic solids* are those solids that were never alive and will not burn or volatilize at 550°C after 15 minutes in a muffle furnace. Inorganic solids are generally not subject to breakdown by biological action and are considered stable. Certain inorganic solids, however, can create problems when related to the environment, for example, heavy metals such as copper, lead, zinc, mercury, and others. These can be extremely harmful if discharged.

Organic solids may be subject to biological decomposition in either an aerobic or anaerobic environment. Decomposition of organic matter (with its production of objectionable by-products) and the possibility of toxic organic solids within the sludge compound the problems of sludge disposal.

Note: Before moving on to a discussion of the fundamentals of sludge treatment methods, it is important to begin by covering sludge pumping calculations. It is important to point out that it is difficult (if not impossible) to treat the sludge unless it is pumped to the specific sludge treatment process.

Release of wastewater solids without proper treatment could result in severe damage to the environment. Obviously, we must have a system to treat the volume of material removed as sludge throughout the system. Release without treatment would defeat the purpose of environmental protection. A design engineer can choose from many processes when developing sludge treatment systems. No matter what the system or combination of systems chosen, the ultimate purpose will be the same: the conversion of wastewater sludges into a form that can be handled economically and disposed of without damage to the environment or creating nuisance conditions. Leaving either condition unmet will require further treatment. The degree of treatment will generally depend on the proposed method of disposal.

Sludge treatment processes can be classified into a number of major categories. In this handbook, we discuss the processes of thickening, digestion (or stabilization), de-watering, incineration, and land application. Each of these categories has then been further subdivided according to the specific processes that are used to accomplish sludge treatment.

As mentioned, the importance of adequate, efficient sludge treatment cannot be overlooked when designing wastewater treatment facilities. The inadequacies of a sludge treatment system can severely affect a plant's overall performance capabilities. The inability to remove and process solids as fast as they accumulate in the process can lead to the discharge of large quantities of solids to receiving waters.

Even with proper design and capabilities in place, no system can be effective unless it is properly operated. Proper operation requires proper operator performance. Proper operator performance begins and ends with proper training.

Sludge Thickening

The solids content of primary, activated, trickling-filter, or even mixed sludge (i.e., primary plus activated sludge) varies considerably, depending on the characteristics of the sludge. Note that the sludge removal and pumping facilities and the method of operation also affect the solids content. *Sludge thickening* (or *concentration*) is a unit process used to increase the solids content of the sludge by removing a portion of the liquid fraction. By increasing the solids content, more economical treatment of the sludge can be effected. Sludge thickening processes include:

- Gravity Thickeners
- Flotation Thickeners
- Solids Concentrators

Gravity Thickening

Gravity thickening is most effective on primary sludge. In operation, solids are withdrawn from primary treatment (and sometimes-secondary treatment) and pumped to the thickener. The solids buildup in the thickener forms a solids blanket on the bottom. The weight of the blanket compresses the solids on the bottom and "squeezes" the water out. By adjusting the blanket thickness the percent solids in the underflow (solids withdrawn from the bottom of the thickener) can be increased or decreased. The supernatant (clear water) which rises to the surface is returned to the wastewater flow for treatment.

Daily operations of the thickening process include pumping, observation, sampling and testing, process control calculations, maintenance and housekeeping.

Note: The equipment employed in thickening depends on the specific thickening processes used.

Equipment used for gravity thickening consists of a thickening tank, which is similar in design to the settling tank used in primary treatment. Generally the tank is circular and provides equipment for continuous solids collection. The collector mechanism uses heavier construction than that in a settling tank because the solids being moved are more concentrated. The gravity thickener pumping facilities (i.e., pump and flow measurement) are used for withdrawal of thickened solids.

Performance of gravity thickeners (i.e., the solids concentrations achieved) typically results in producing 8–10 percent solids from primary underflow, 2–4 percent solids from waste activated sludge, 7–9 percent solids from trickling filter residuals and 4–9 percent from combined primary and secondary residuals.

The performance of gravity thickening processes depends on various factors, including

- type of sludge
- condition of influent sludge
- temperature
- blanket depth
- solids loading
- hydraulic loading
- solids retention time
- hydraulic detention time

Flotation Thickening

Flotation thickening is used most efficiently for waste sludges from suspended-growth biological treatment process, such as the activated sludge process. In operation, recycled water from the flotation thickener is aerated under pressure. During this time the water absorbs more air than it would under normal pressure. The recycled flow together with chemical additives (if used) is mixed with the flow. When the mixture enters the flotation thickener, the excess air is released in the form of fine bubbles. These bubbles become attached to the solids and lift them toward the surface. The accumulation of solids on the surface is called the **float cake**. As more solids are added to the bottom of the float cake it becomes thicker and water drains from the upper levels of the cake. The solids are then moved up an inclined plane by a scraper and discharged. The supernatant leaves the tank below the surface of the float solids and is recycled or returned to the wastestream for treatment. Typically, flotation thickener performance is 3 -5 percent solids for waste activated sludge with polymer addition and 2 - 4 percent solids without polymer addition.

The flotation thickening process requires pressurized air, a vessel for mixing the air with all or part of the process residual flow, a tank for the flotation process to occur, solids collector mechanisms to remove the float cake (solids) from the top of the tank and accumulated heavy solids from the bottom of the tank. Since the process normally requires chemicals be added to improve separation, chemical mixing equipment, storage tanks, and metering equipment to dispense the chemicals at the desired dose are required.

The performance of dissolved air-thickening process depends on various

- bubble size
- solids loading
- sludge characteristics
- chemical selection
- chemical dose

Solids Concentrators

Solids concentrators (belt thickeners) usually consist of a mixing tank, chemical storage and metering equipment and a moving porous belt. In operation, the process residual flow is chemically treated and then spread evenly over the surface of the moving porous belt. As the flow is carried down the belt (similar to a conveyor belt) the solids are mechanically turned or agitated and water drains through the belt. This process is primarily used in facilities where space is limited.

Sludge Stabilization

The purpose of *sludge stabilization* is to reduce volume, stabilize the organic matter, and eliminate pathogenic organisms to permit reuse or disposal. The equipment required for stabilization depends on the specific process used. Sludge stabilization processes include:

- Aerobic Digestion
- Anaerobic Digestion
- Composting
- Lime Stabilization
- Wet Air Oxidation (Heat Treatment)
- Chemical Oxidation (Chlorine Oxidation)
- Incineration

Aerobic Digestion

Equipment used for *aerobic digestion* consists of an aeration tank (digester) which is similar in design to the aeration tank used for the activated sludge process. Either diffused of mechanical aeration equipment is necessary to maintain the aerobic conditions in the tank. Solids and supernatant removal equipment is also required.

In operation, process residuals (sludge) are added to the digester and aerated to maintain a dissolved oxygen (D.O.) concentration of 1.0 mg/L. Aeration also ensures that the tank contents are well mixed. Generally, aeration continues for approximately 20 days retention time. Periodically, aeration is stopped and the solids are allowed to settle. Sludge and the clear liquid supernatant is withdrawn as needed to provide more room in the digester. When no additional volume is available, mixing is stopped for 12-24 hours before solids are withdrawn for disposal. Process control testing should include alkalinity, pH, % Solids, % Volatile solids for influent sludge, supernatant, digested sludge, and digester contents. A typical operational problem associated with an aerobic digester is pH control. When pH drops, for example, this may indicate normal biological activity or low influent alkalinity. This problem is corrected by adding alkalinity (lime, bicarbonate, etc.).

Anaerobic Digestion

Anaerobic digestion is the traditional method of sludge stabilization. It involves using bacteria that thrive in the absence of oxygen and is slower than aerobic digestion, but has the advantage that only a small percentage of the wastes are converted into new bacterial cells. Instead, most of the organics are converted into carbon dioxide and methane gas.

Note: In an anaerobic digester, the entrance of air should be prevented because of the potential for air mixed with the gas produced in the digester which could create an explosive mixture.

Equipment used in anaerobic digestion includes a sealed digestion tank with either a fixed or a floating cover, heating and mixing equipment, gas storage tanks, solids and supernatant withdrawal equipment and safety equipment (e.g., vacuum relief, pressure relief, flame traps, explosion proof electrical equipment).

In operation, process residual (thickened or unthickened sludge) is pumped into the sealed digester. The organic matter digests anaerobically by a two-stage process. Sugars, starches and carbohydrates are converted to volatile acids, carbon dioxide and hydrogen sulfide. The volatile acids are then converted to methane gas. This operation can occur in a single tank (single stage) or in two tanks (two stages). In a single stage system, supernatant and/or digested solids must be removed whenever flow is added. In a two-stage operation, solids and liquids from the first stage flow into the second stage each time fresh solids are added. Supernatant is withdrawn from the second stage to provide additional treatment space. Periodically, solids are withdrawn for dewatering or disposal. The methane gas produced in the process may be used for many plant activities.

Note: The primary purpose of a secondary digester is to allow for solids separation.

Various performance factors affect the operation of the anaerobic digester. For example, % Volatile Matter in raw sludge, digester temperature, mixing, volatile acids/alkalinity ratio, feed rate, % solids in raw sludge and pH are all important operational parameters that the operator must monitor.

Along with being able to recognize normal/abnormal anaerobic digester performance parameters, wastewater operators must also know and understand normal operating procedures. Normal operating procedures include sludge additions, supernatant withdrawal, sludge withdrawal, pH control, temperature control, mixing, and safety requirements.

Other Sludge Stabilization Processes

Along the aerobic and anaerobic digestion, other sludge stabilization processes include composting, lime stabilization, wet air oxidation, and chemical (chlorine) oxidation. These other stabilization processes are briefly described in this section.

1. **Composting**
   The purpose of composting sludge is to stabilize the organic matter, reduce volume, and to eliminate pathogenic organisms. In a *composting operation* dewatered solids are usually mixed with a bulking agent (i.e., hardwood chips) and stored until biological stabilization occurs. The composting mixture is ventilated during storage to provide sufficient oxygen for oxidation and to prevent odors. After the solids are stabilized, they are separated from the bulking agent. The composted solids are then stored for curing and applied to farmlands or other beneficial uses. Expected performance of the composting operation for both % Volatile Matter Reduction and % Moisture Reduction ranges from 40 to 60%+.
2. **Lime Stabilization**
   In *lime stabilization* process residuals are mixed with lime to achieve a pH of 12.0. This pH is maintained for at least 2 hours. The treated solids can then be dewatered for disposal or directly land applied.
3. **Thermal Treatment**
   Thermal treatment (or wet air oxidation) subjects sludge to high temperature and pressure in a closed reactor vessel. The high temperature and pressure rupture the cell walls of any microorganisms present in the solids and causes chemical oxidation of the organic matter. This process substantially improves dewatering and reduces the volume of material for disposal. It also produces a very high strength waste, which must be returned to the wastewater treatment system for further treatment.
4. **Chlorine Oxidation**
   Chlorine oxidation also occurs in a closed vessel. In this process chlorine (100 - 1,000 mg/L) is mixed with a recycled solids flow. The recycled flow and process residual flow are mixed in the reactor. The solids and water are separated after leaving the reactor vessel. The water is returned to the wastewater treatment system and the treated solids are dewatered for disposal. The main advantage of chlorine oxidation is that it can be operated intermittently. The main disadvantage is production of extremely low pH and high chlorine content in the supernatant.

Sludge Dewatering

Digested sludge removed from the digester is still mostly liquid. *Sludge dewatering* is used to reduce volume by removing the water to permit easy handling and economical reuse or disposal. Dewatering processes include sand drying beds, vacuum filters, centrifuges, filter presses (belt and plate), and incineration.

Sand Drying Beds

Drying beds have been used successfully for years to dewater sludge. Composed of a sand bed (consisting of a gravel base, underdrains and 8 - 12 inches of filter grade sand), drying beds include an inlet pipe, splash pad containment walls and a system to return filtrate (water) for treatment. In some cases the sand beds are covered to provide drying solids protection from the elements. In operation, solids are pumped to the sand bed and allowed to dry by first draining off excess water through the sand and then by evaporation. This is the simplest and cheapest method for dewatering sludge. Moreover, no special training or expertise is required. However, there is a downside; namely, drying beds require a great deal of manpower to clean beds; they can create odor and insect problems; and they can cause sludge buildup during inclement weather.

Rotary Vacuum Filtration

Rotary vacuum filters have also been used for many years to dewater sludge. The vacuum filter includes filter media (belt, cloth or metal coils), media support (drum), vacuum system, chemical feed equipment and conveyor belt(s) to transport the dewatered solids.

In operation, chemically treated solids are pumped to a vat or tank in which a rotating drum is submerged. As the drum rotates, a vacuum is applied to the drum. Solids collect on the media and are held there by the vacuum as the drum rotates out of the tank. The vacuum removes additional water from the captured solids. When solids reach the discharge zone, the vacuum is released and the dewatered solids are discharged onto a conveyor belt for disposal. The media is then washed prior to returning to the start of the cycle.

Types of Rotary Vacuum Filters

The three principal types of rotary vacuum filters are rotary drum, coil, and belt. The *rotary drum* filter consists of a cylindrical drum rotating partially submerged in a vat or pan of conditioned sludge. The drum is divided length-wise into a number of sections that are connected through internal piping to ports in the valve body (plant) at the hub. This plate rotates in contact with a fixed valve plate with similar parts, which are connected to a vacuum supply, a compressed air supply, and an atmosphere vent. As the drum rotates, each section is thus connected to the appropriate service.

The *coil type* vacuum filter uses two layers of stainless steel coils arranged in corduroy fashion around the drum. After a de-watering cycle, the two layers of springs leave the drum bed and are separated from each other so that the cake is lifted off the lower layer and is discharged from the upper layer. The coils are then washed and reapplied to the drum. The coil filter is used successfully for all types of sludges; however, sludges with extremely fine particles or ones that are resistant to flocculation de-water poorly with this system.

The media on a *belt filter* leaves the drum surface at the end of the drying zone and passes over a small diameter discharge roll to aid cake discharge. Washing of the media occurs next. Then the media are returned to the drum and to the vat for another cycle. This type of filter normally has a small-diameter curved bar between the point where the belt leaves the drum and the discharge roll. This bar primarily aids in maintaining belt dimensional stability.

Pressure Filtration

Pressure filtration differs from vacuum filtration in that the liquid is forced through the filter media by a positive pressure instead of a vacuum. Several types of presses are available, but the most commonly used types are plate and frame presses and belt presses.

Filter presses include the belt or plate & frame types. The belt filter includes two or more porous belts, rollers, and related handling systems for chemical makeup and feed, and supernatant and solids collection and transport.

The plate and frame filter consists of a support frame, filter plates covered with porous material, hydraulic or mechanical mechanism for pressing plates together, and related handling systems for chemical makeup and feed, and supernatant and solids collection and transport.

In the plate ans frame filter, solids are pumped (sandwiched) between plates. Pressure (200 to 250 psi) is applied to the plates and water is "squeezed" from the solids. At the end of the cycle the pressure is released and as the plates separate the solids drop out onto a conveyor belt for transport to storage or disposal.

Performance factors for plate and frame presses include feed sludge characteristics, type and amount of chemical conditioning, operating pressures, and the type and amount of precoat.

In operation, the belt filter uses a coagulant (polymer) mixed with the influent solids. The chemically treated solids are discharged between two moving belts. First water drains from the solids by gravity. Then, as the two belts move between a series of rollers, pressure "squeezes" additional water out of the solids. The solids are then discharged onto a conveyor belt for transport to storage/disposal.

Performance factors for the belt press include sludge feed rate, belt speed, belt tension, belt permeability, chemical dosage, and chemical selection.

Filter presses have lower operation and maintenance costs than vacuum filters or centrifuges. They typically produce a good quality cake and can be batch operated. However, construction and installation costs are high. Moreover, chemical addition is required and the presses must be operated by skilled personnel.

Centrifugation

Centrifuges of various types have been used in dewatering operations for at lease 30 years and appear to be gaining in popularity. Depending on the type of centrifuge used, in addition to centrifuge pumping equipment for solids feed and centrate removal, chemical makeup and feed equipment and support systems for removal of dewatered solids are required.

Sludge Incineration

Not surprisingly, incinerators produce the maximum solids and moisture reductions. The equipment required depend on whether the unit is a multiple hearth or fluid-bed incinerator. Generally, the system will require a source of heat to reach ignition temperature, solids feed system and ash handling equipment. It is important to note that the system must also include all required equipment (e.g., scrubbers) to achieve compliance with air pollution control requirements.

In operation, solids are pumped to the incinerator. The solids are dried then ignited (burned). As they burn the organic matter is converted to carbon dioxide and water vapor and the inorganic matter is left behind as ash or "fixed" solids. The ash is then collected for reuse of disposal.

The incineration process first dries then burns the sludge. The process involves the following steps:

1. The temperature of the sludge feed is raised to 212°F.
2. Water evaporates from the sludge.
3. The temperature of the water vapor and air mixture increases.

4. The temperature of the dried sludge volatile solids raises to the ignition point.

Note: Incineration will achieve maximum reductions if sufficient fuel, air, time, temperature, and turbulence are provided.

Incineration Processes

1. **Multiple Hearth Furnace**
   The *multiple hearth furnace* consists of a circular steel shell surrounding a number of hearths. Scrappers (rabble arms) are connected to a central rotating shaft. Units range from 4.5 to 21.5 feet in diameter and have from four to 11 hearths.

   In operation, de-watered sludge solids are placed on the outer edge of the top hearth. The rotating rabble arms move them slowly to the center of the hearth. At the center of the hearth, the solids fall through ports to the second level. The process is repeated in the opposite direction. Hot gases generated by burning on lower hearths dry solids. The dry solids pass to the lower hearths. The high temperature on the lower hearths ignites the solids. Burning continues to completion. Ash materials discharge to lower cooling hearths where they are discharged for disposal. Air flowing inside center column and rabble arms continuously cools internal equipment.
2. **Fluidized Bed Furnace**
   The *fluidized bed* incinerator consists of a vertical circular steel shell (reactor) with a grid to support a sand bed and an air system to provide warm air to the bottom of the sand bed. The evaporation and incineration process takes place within the super-heated sand bed layer.

   In operation, air is pumped to the bottom of the unit. The airflow expands (fluidize) the sand bed inside. The fluidized bed is heated to its operating temperature (1,200-1,500°F). Auxiliary fuel is added when needed to maintain operating temperature. The sludge solids are injected into the heated sand bed. Moisture immediately evaporates. Organic matter ignites and reduces to ash. Residues are ground to fine ash by the sand movement. Fine ash particles flow up and out of unit with exhaust gases. Ash particles are removed using common air pollution control processes. Oxygen analyzers in the exhaust gas stack control the airflow rate.

Note: Because these systems retain a high amount of heat in the sand, the system can be operated as little as four hours per day with little or no reheating.

Land Application of Biosolids

The purpose of land application of biosolids is to dispose of the treated biosolids in an environmentally sound manner by recycling nutrients and soil conditioners. In order to be land applied, wastewater biosolids must comply with state and federal biosolids management/disposal regulations. Biosolids must not contain materials that are dangerous to human health (i.e., toxicity, pathogenic organisms, etc.) or dangerous to the environment (i.e., toxicity, pesticides, heavy metals, etc.).

Wastewater-Treatment Return Flow: Water returned to the environment by wastewater-treatment facilities.

Waterborne Disease Outbreak: The significant occurrence of acute illness associated with drinking water from a public water system that is deficient in treatment, as determined by appropriate local or state agencies.

Waterborne Diseases: Caused by pathogenic microorganisms which are directly transmitted when contaminated drinking water is consumed.

Waterborne Pathogens: The transmission conduit for some pathogenic microorganisms.

Water Carrier Requirements (49 CFR): This section is based on Part 176 of the HMR and covers the requirements for accepting and/or transporting hazardous materials by most commercial vessels, foreign or domestic, when in the navigable waters of the United States. Exceptions are found in §176.5(b). Part 176 requirements for vessel transportation are in addition to those contained in Parts 171, 172, and 173 of the HMR.

The International Maritime Dangerous Goods Code may be used when carrying hazardous materials by vessel, as long as the requirements listed in §171.12 and §176.11 of the HMR are also followed.

Part 176 is divided into Subparts A through O:

- Subparts A through D provides general information and operating requirements, as well as general handling, stowage, and segregation requirements.
- Subparts E and F provide special requirements for transport vehicles and barges loaded with hazardous materials.
- Subparts G through O provide detailed requirements for specific classes of hazardous materials.

Each carrier must ensure that its employees involved in the transportation of hazardous materials are trained in accordance with the HMR, Part 172, Subpart H. The record of training required by §172.704(d) must be kept on board the vessel while the crewmember is in service on board the vessel.

Definitions for the terms used in Part 176 are given in §176.2; these are also listed and defined below. Familiarity with these terms is important in properly applying the regulations in this part.

Definitions

- **Cantline**—the v-shaped groove between two abutting, parallel horizontal cylinders.
- **Cargo net**—a net made of fiber or wire used to provide convenience in handling loose or packaged cargo to and from a vessel.
- **Cargo transport unit**—a transport vehicle, a freight container or a portable tank.
- **Clear of living quarters**—the hazardous material must be located so that in the event of release of the material, leakage or vapors will no penetrate accommodations, machinery spaces or other work areas by means of entrances or other openings in bulkheads or ventilation ducts.
- **Close freight container**—a freight container which totally encloses its contents by permanent structures. A freight container formed partly by a tarpaulin, plastic sheet, or similar material is not a closed freight container.
- **Combustible material**—a material which may or may not be classed as a hazardous material but which is easily ignited and supports combustion. Examples of readily combustible materials include wood, paper, straw, vegetable fibers, products made from such materials, coal, lubricants, and oils. This definition does not apply to packaging material or Dunnage.
- **Compartment**—any space on a vessel that is enclosed by the vessel's decks and its sides or permanent steel bulkheads.
- **Deck structure**—a structure of substantial weight and size located on the weather deck of a vessel and integral with the deck. This term includes superstructures, deck houses, mast houses, and bridge structures.
- **Draft**—a load or combination of loads capable of being hoisted into o out of a vessel in a single lift.
- **Dunnage**—lumber of not less than 25 mm (0.98 inch) commercial thickness or equivalent material laid over or against structures such as tank topes decks, bulkheads, frames, plating, or ladders, or used for filling voids or fitting round cargo, to prevent damage during transportation.
- **Explosives anchorage**—an anchorage so designated under 33 CFR part 110, subpart B.
- **Explosive article**—an article or device which contains one or more explosive substances. Individual explosive substances are identified in column 17 of the Dangerous Goods List in the IMDG Code.
- **Explosives handling facility**:
  1. A "designated waterfront facility" designated under 33 CFR part 126 when loading, handling, and unloading Class 1 (explosives) materials; or
  2. A facility for loading, unloading, and handling military Class 1 (explosives) materials which is operated or controlled by an agency of the Department of Defense.
- **Explosive substance**—a solid or liquid material, or a mixture of materials, which is n itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to its surroundings. Individual explosive substances are identified in column 17 of the Dangerous Goods List in the IMDG Code.
- **Handling**—the operation of loading and unloading a vessel; transfer to, from, or with a vessel, and any ancillary operations.
- **Hold**—a compartment below deck that is used exclusively for the carriage of cargo.
- **In containers or the like**—any clean, substantial, weatherproof box structure which can be secured to the vessel's structure, including a portable magazine or a closed cargo transport unit. Whenever this stowage is specified, stowage in deckhouses, mast lockers and oversized weatherproof packages (overpacks) is also acceptable.
- **Incompatible materials**—two materials whose stowage together may result in undue hazards in the case of leakage, spillage, or other accident.
- **INF cargo**—packaged irradiated nuclear fuel, plutonium or high-level radioactive wastes as those terms are defined in the "International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships" (INF Code) contained in the IMDG Code
- **Landing mat**—a shock absorbing pad used in loading Class 1 (explosive) materials on vessels.
- **Machinery Spaces of Category A**—are those spaces, and trunks to such spaces, which contain:
  1. Internal combustion machinery used for main propulsion
  2. Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kw
  3. Any oil-fired boiler or fuel unit.
- **Magazine**—an enclosure designed to protect certain goods of Class 1 (explosive) materials from damage by other cargo and adverse weather conditions during loading, unloading, and when in transit; and to prevent unauthorized access. A magazine may be a fixed structure or compartment in the vessel, a closed fright

container, a closed transport vehicle, or a portable magazine. Magazine may be positioned in any part of the ship conforming with the relevant provisions for Class 1 (explosive) materials contained in Subpart G of this part provided that magazines which are fixed structures are sited so that their doors, where fitted, are easily accessible.

- **Open freight container**—means freight container that does not totally enclose its contents by permanent structures.
- **Overstowed**—a package or container is stowed directly o top of another. However, with regard to Class 1 (explosive) stowage, such goods may themselves be stacked to a safe level but other goods should not be stowed directly on top of them.
- **Pallet**—a portable platform for stowing, handling, and moving cargo.
- **Palletized unit**—means packages of unpackaged objects stacked on a pallet, banded and secured to the pallet by metal, fabric, or plastic straps for the purpose of handling as a single unit.
- **Pie plate**—a round, oval, or hexagonal pallet without sideboards, used in conjunction with a cargo net to handle loose cargo on board a vessel.
- **Portable magazine**—a strong, closed, prefabricated, steel or wooden, closed box or container, other than a freight container, designed and used to handle Class 1 (explosive) materials either by hand or mechanical means.
- **Responsible person**—a person empowered by the master of the vessel to make all decisions relating to his or her specific task and having the necessary knowledge and experience for that purpose.
- **Safe working load**—the maximum gross weight that cargo handling equipment is approve to lift.
- **Skilled person**—a person having the knowledge and experience to perform a certain duty.
- **Splice**—used in §176.172 of this part, means any repair of a fright container main structural member which replaces material, other than complete replacement of the member.
- **Tray**—a type of pallet constructed to specific dimensions for handling a particular load.

✔ **Important Point**: All hazardous materials must be prepared for transportation in accordance with Parts 172 and 173 of the HMR before they can be transported by vessel. Explosives forbidden under §173.54 may not be transported by vessel.

Water Carrier General Requirements

- You may not transport hazardous materials by vessel unless they are properly described and certified on the shipping paper as set forth in Part 172.
- At the time a freight container or transport vehicle containing hazardous materials is offered for transportation by vessel, the person responsible for packing or loading it must give the vessel operator assigned container packing certificate stating the container or transport unit is serviceable for the material loaded therein; in contains no incompatible goods; that it is properly marked, labeled, and placarded as applicable; and the packages contained within the container have been properly inspected, marked, labeled or placarded, and secured, and are not damaged. The signed certification may be on the shipping paper or on a separate document stating that the packing of the container has been carried out in accordance with the provisions of 49 CFR 176.27(c) and/or the IMDG code. Sample wording can be found in §176.27(c). The container packing certification statement is in addition to the shipper's certification in §172.204.

✔ **Important Point**: The term stowage as used in this chapter refers to where a cargo may be located on the vessel and how it is secured. The term segregation refers to a separation of hazardous cargo from other hazardous cargoes by distance or barriers. Stowage and segregation are critical on a vessel because of the forces and stresses threat affect it while it is underway. Rotational and linear forces can cause shifts of cargo that can result in significant damage.

- The carrier must prepare a dangerous cargo manifest, list, or stowage plan of materials subject to the requirements of 49 CFR or the IMDG Code. You must keep this document in a designated holder on or near the vessel's bridge. Each carrier must retain a copy of the dangerous cargo manifest for at least one year.
- After stowage is complete, the carrier must inspect each hold or compartment containing hazardous materials, to ensure that stowage has been accomplished properly and that there are no visible signs of damage. The carrier must inspect again after periods of heavy weather, and, unless the vessel is equipped with smoke- or fire-detecting systems with automatic monitoring capability, every 24 hours.
- If an accident occurs on board a vessel damaging hazardous materials packages, then damaged or unauthorized packagings may be used on an emergency basis only, but may not be offered to any forwarding carrier for transportation. The master of the vessel must request instructions for disposition of the packages from the nearest United States Coast Guard Captain of the Port (COTP). The master of the vessel may decide to jettison hazardous materials only to prevent or substantially reduce a hazard to human life or reduce a substantial risk to property.

- A carrier may not transport by vessel any damaged package containing hazardous materials that appears to have leaked or may leak. Packages may be repaired or restored to the satisfaction of the master of the vessel. A package containing radioactive materials (other than low specific activity), may not be repaired or restored.
- A carrier may not knowingly transport by vessel any hazardous material offered under a deceptive name, marking, invoice, or shipping paper. If a shipment is found to be in violation while in transit, the master of the vessel must take whatever measures are necessary to ensure the safety of the vessel, its passengers, and its crew. If the vessel is in port, the carrier may not deliver the shipment to any party, and the master must immediately request instructions for disposal of the material from the nearest Captain of the Port.

✔ **Important Point**: The carrier must not repair a vessel containing hazardous materials using welding, burning, or power-actuated tools and appliances that may produce intense heat, unless the emergency repairs are necessary for safety reasons, or the work has previously been approved by the Captain of the Port.

Stowage Requirements

- You may handle or stow hazardous materials on board a vessel only under the direction and observation of a responsible person who has been assigned this duty. On domestic vessels, this person must be a licensed office assigned to the vessel, except it may also be an employee of the carrier when the vessel is engaged in a coastwise voyage or on rivers, bays, sounds, or lakes. On a foreign vessel, the responsible person must be an officer of the vessel.
- Before you may stow hazardous materials on board a vessel, each hold or compartment must be free of debris. This requires examination of the bilges to ensure that residue from previous cargo has been removed.

✔ **Important Point**: Column 10 of The Hazardous Materials Table, or HMT, in §172.101 contains specific information relating to authorized vessel stowage locations. Column 10A, Vessel stowage, Location, specifies the authorized stowage locations on board cargo and passenger vessels. They are defined in §172.101(k). Column 10B, vessel stowage, Other, specifies codes for vessel stowage requirements for specific hazardous materials. The meaning of each code found in Column 10B is defined in §176.84**.** Also note that Column 7 of the HMT specifies codes for special provisions applicable to hazardous materials. The "W" codes, in particular, only apply to transportation by water. The meaning and requirements of each special provision is found in §172.102.

- If the prescribed stowage location is shown to be impractical for a vessel, the Captain of the Port may authorize in writing an alternative stowage location or method of segregation as long as it will afford the same level of safety.
- Hazardous materials must be stowed in a manner that will facilitate inspection during the voyage, removal from a potentially dangerous situation, and removal in case of fire. If a package contains liquid hazardous materials, it must have orientation markings on it and be stowed with the markings pointing up.
- You must properly stow and secure marine pollutants to minimize the hazards to the marine environment without impairing the safety of the ship and the people on board.
- You may not use a metal bale hook to handle any packages of hazardous materials. You may not use equipment designed to lift or move cargo by means of pressure exerted on the package, if the package was not designed to be moved in that manner, or if it could cause damage to the package. Other equipment used must supply adequate support to the packages to prevent them from falling during loading.
- When carrying transport vehicles, freight containers, and portable tanks containing hazardous materials by vessel, additional conditions including those shown here must be met.

✔ **Important Point**: Power-operated trucks or cargo handling vehicles, like forklifts, must conform to the requirements of §176.78 before they may be used on board a vessel in a space containing hazardous materials. Truck ratings and special operating conditions are designated in §176.78, with minimum safety features identified in §176.78(f).

Segregation

General requirements for segregation are found in Part 176, Subpart D. When you stow hazardous materials together, you must segregate them according to the General Segregation Table found in §176.83(b). additional requirements for segregation are found in Column 10B of the Hazardous Materials Table 172.101. Additional notes for Class 1 (explosive) material can be found in §176.84(c)(2). If the requirements differ, you must use the most restrictive segregation requirements.

You use the General Segregation Table by finding one class of material in the vertical column, and then finding another class by horizontal row. The intersection of the vertical column and the horizontal row contains a number or symbol that represents the method of segregation that you must use between the two classes. The terms associated with these numbers and symbols are listed at the bottom of the table.

- “Away from” means that incompatible hazardous materials may be carried in the same compartment hold, or on deck provided they are horizontally separated by 3 meters (10 feet).
- “Separated from” means packages must be carried in different compartments or holds if “under deck” and separated horizontally by 6 meters (20 feet) if “on deck.”
- “Separated by a complete compartment or hold from” means packages may be separated between decks as long as one of the decks is resistant to fire and liquid or, if “on deck,” horizontally separated by 12 meters (39 feet).
- “Separated longitudinally by an intervening complete compartment or hold from” means, for packages separated between “under deck” and “on deck”, a complete compartment must separate them, as well as a longitudinal distance of 24 meters (79 feet). For “on deck” stowage, a separation of at least 14 meters (79 feet) longitudinally must be maintained.
- Where the code in column (10B) of the §172.101 Table specifies that “Segregation as for” applies, the segregation requirements applicable to that class in the §173.83(b) General Segregation Table must be applied.
- Separate segregation tables govern freight containers on board container vessels and transport units carried on board trailerships and trainships.

✔ **Important Point**: Except as provided in §176.145 of this subpart, Class 2 (explosive) materials may be stowed within the same compartment, magazine, portable magazine, or transport unit as indicated in Table 176.144(a).

The person in charge of a transport vehicle containing hazardous materials must provide to the vessel’s representative a copy of the shipping papers required by §176.24 and certification stating that the hazardous materials were prepared in accordance with the HMR as required by §176.27. A transport vehicle, a private automobile, or a motorboat containing hazardous materials may be transported on board ferry vessels subject to the conditions found in Part 176, Subpart E.

- You may transport packaged hazardous materials on a barge, provided the barge is constructed of steel, and is not a dump scow. You may need a permit from the Captain of the Port (COTP) to carry certain hazardous materials. Refer to §176.99 for a list of these materials. A barge loaded with these materials, while being placed on, removed from, or handled on board a barge-carrying vessel, is not subject to these permits. Barges carried on board barge-carrying vessels must be stowed in accordance with the requirements in §176.77.

Loading and Unloading Requirements

Before Divisions 1.1 and 1.2 may be discharged from or loaded on board a vessel in the United States, the Carrie must obtain a permit from the COTP. The COTP may assign a US Coast Guard supervisory detail to any vessel during loading, handling, or unloading Class 1 (explosive) materials.

✔ **Important Point**: §176.104 list specific points concerning the loading and unloading of Class 1 (explosive) materials.

Loading and unloading requirements for Class 1 materials include:

- You may only use safety hooks or hooks that have been closed by wire.
- Wire rope or assemblies must remain unpainted and kept bare to permit inspection of their safe working conditions.
- You must load and unload unpalletized packages of Division 1.1 and 1.2 materials using a chute, a conveyer, or a mechanical hoist, and a pallet, skipboard, tray or pie plate fitted with a cargo net or sideboards.
- You must mechanically hoist unpackaged explosive devices on a pallet, or load them using a chute or conveyor. Do not handle them by their lifting lugs.
- You may not load or unload packages through a hatch at the same time that other cargo is being handled in a hold served by that hatch.
- You may not lift packages over any other hazardous material.

A responsible person who is aware of the hazards involved in handling Class 1 (explosive) materials and the steps to be taken in an emergency must be in constant attendance during loading, unloading and stowage of Class 1 (explosive) materials and the steps to be taken in an emergency must be in constant attendance during loading, unloading and stowage of Class 1 (explosive) materials, including the preparation of the holds.

General/Special Stowage

§176.116 set forth general stowage conditions for Class 1 (explosive) materials. They include keeping this material away from heat sources, dry, secured, and fully braced.

- Electrical equipment and cables in compartments where Class 1 (explosive) materials re stowed must be disconnected from the power source or, if energized, must meet minimum requirements for grounding and safety defined in 46 CFR, Subchapter J, Chapter 1.

✔ **Important Point**: Ordinary stowage is authorized for most explosive articles carried by vessel except those requiring "magazine" or "special" stowage.

Magazine stowage is required for all explosive substances except for "Explosive Substances, n.o.s." in compatibility groups G, L, or S. A compatibility group is designated by a letter used to categorize explosive substances and articles for purposes of stowage and segregation. Table 1 in §173.52 contains a description for each compatibility group.

Magazine stowage is sub-divided into three different types of magazines designated by the letters A, B, and C.

- Type A magazine stowage guards against friction between any spilled contents of packages and the vessel's sides and bulkheads. The magazine must be tightly sheathed with wood on its inner sides and floor. When utilized as part of the magazine structure, the vessel's sides and bulkheads must be clean, free from rust of scale, and protected by battening or sweatboards. Type A stowage is required for explosive substances that must be kept clear of steelwork.
- Type B magazine stowage is the same as Type A except the floor must be sparred or protected by wooden pallets or Dunnage instead of sheathed in wood. Also, battening of the vessel's sides, bulkheads, and stanchions is not required.
- Type C magazine stowage requirements are the same as Type B except the magazine must be located as near as possible to the centerline of the vessel.
- You may use closed transport vehicles as magazines to transport Class 1 (explosive) materials by vessel, if they meet the requirements of the appropriate magazine stowage type and any additional requirements listed in §176.168.
- Special stowage is required for certain articles presenting both explosive and chemical hazards. §176.16 list stowage requirements for specific Class 1 (explosive) articles and substances.
- Each portable magazine used for the stowage of Class I (explosive) materials on board vessels must meet the requirements explained in detail in §176.137**.**
- You may not stow Class 1 (explosive) materials within a horizontal distance of 6 meters (20 feet) of any fire, machinery exhaust, gallery uptake, locker used for combustible stores, or other potential sources of ignition, or within 8 meters (26 feet) of the bridge, accommodation areas, and lifesaving appliances. Freight containers containing Class 1 (explosive) materials my be overstowed by containers of compatible Class 1 (explosive) materials or non-hazardous cargo only n vessels fitted with containers loaded with Class 1 (explosive) materials may only be stowed on the bottom tier of the stowage.

Safety Requirements

Extremely flammable hazardous materials may not be transported in a vessel carrying Class 1 (explosive) materials. These prohibited materials are listed in §176.142.

- With the exception of mail, baggage, and personal and household effects, you need not segregate Class 1 (explosive) materials from non-dangerous cargo. Explosives with a secondary hazard of POISON or CORROSIVE must be separated from all foodstuffs.
- Specific precautionary measures involving artificial lighting, radio and radar use, fueling, security, fire precautions and firefighting must be taken during the loading and unloading of Class 1 (explosive) materials.

✔ **Important Point**: Electric lights, except arc lights, are the only form of artificial lighting permitted.

- All sources of electromagnetic radiation, such as radio and radar transmitters, must be de-energized or removed to the distances specified in 176.150.
- Vessels may not be fueled (bunkering) during loading or unloading, and fueling (bunkering) may not take place with the hatches open unless authorized by the COTP.
- Defective packages containing Class 1 (explosive) materials may not be accepted for shipment. Defective packages must be set aside for examination and repair, or legal disposal, as directed by the shipper. These packages must not be repaired on board a vessel. In the case of spillage, the appropriate emergency response must be taken as required under 172.602 and reported to the COTP as soon as possible.

✔ **Important Point**: The carrier must take adequate measures to prevent packages from becoming wet due to weather. In addition, a responsible person must be present at all times when the hatches of spaces containing class 1 (explosive) materials are open, and no unauthorized entry may be permitted.

Sources of fire are prohibited on or near any vessel during loading or unloading. No repair work involving fire, flame, spark, or arc-producing equipment may be conducted on board except in an emergency and, if in a port, when authorized by the COTP. A fire hose long enough to reach very part of the loading area must be laid and connected to the water main, ready for immediate use. Each compartment containing Class I (explosive) materials must have a fixed fire extinguishing system. Adjacent compartments must have the same type system or be accessible for firefighting operations.

✔ **Important Point**: Certain extremely flammable hazardous materials may not be transported in a vessel carrying Class 1 (explosive) materials. These prohibited materials are listed in §176.142.

- Transport vehicles carrying Class 1 (explosive) materials must be properly secured and meet the structural serviceability requirements in §176.172. You must stow Class 1 (explosive) materials of different compatibility groups except as allowed under §176.144, and vehicles must be separated from each other a provided in §176.144.
- Special handling is required for Class 1 (explosive) materials while in port. Some of these special requirements involve the use of signals, mooring lines and watchkeeping.
- When loading, handling, or unloading Class 1 (explosive) materials in port, the vessel must exhibit a "B" (Bravo) of international code of signals by day, and an all-round fixed red light by night.
- Mooring lines must be of sufficient strength, type, and number for the size of the vessel and local conditions. The mooring arrangements must be such that the vessel can be released quickly in an emergency. While in port, towing wires of adequate size and length must be properly secured at the bow and stern, ready for immediate use.
- When in port, a vessel carrying Class 1 (explosive) materials must have sufficient crew on board to maintain a proper watch and to operate the propulsion and firefighting equipment in case of an emergency.
- Class 1 (explosive) materials must not be handled on board a vessel during electrical storms or other weather conditions that may increase the hazards of the Class 1 (explosive) materials; during hours of darkness unless prior consent has been obtained from the COTP; in insufficient lighting to safely perform the handling operation; or by a person impaired by the influence of alcohol or drugs. In addition, smoking is prohibited on the vessel while Class 1 (explosive) materials are being handled or stowed except in places designated by the master of the vessel, and No Smoking signs must be posted and clearly visible at all locations where Class 1 (explosive) materials are handled or stored.
- Class 1 (explosive) materials in Compatibility Group L may not be handled in any port area without special permission from, and subject to any special precautions required by, the COTP.
- Except in an emergency, only equipment specifically designed for the handling of freight containers may be used for loading, handling, and unloading containers containing Division 1.1 or 1.2 (explosive) materials. The gross weight of the freight container containing Class 1 (explosive) materials may not exceed the safe working load for the handling gear.
- §176.194 describe the special requirements for the stowage of Class 1 (explosive) materials on a magazine vessel.
- You must stow Cylinders of Class 2 (compressed gas) materials in such a way that the cylinders do not make direct contact with the vessel's deck, side, or bulwark. The carrier must keep them as cool as practicable, stow them away from all sources of heat and ignition, and keep them separate from all foodstuffs
- Cylinders of Class 2 (compressed gas) may not be stowed "on-deck" over a hold a compartment containing coal and must be protected from radiant heat, including the direct rays of the sun.
- Cylinders of Class 2 (compressed gas) when stowed "under dick" must be mechanically ventilated with no source of artificial heat and clear of living quarters.
- The carrier must keep Class 3 (flammable) or combustible liquids as cool as reasonably possible, and stow them away from all sources of heat and ignition. You must stow them "on deck" if they are equipped with vents or safety relief devices.
- You must keep a dry chemical, foam fire extinguisher or a fire hose fitted with an approved portable mechanical foam nozzle accessible t the tank it is intended to cover.
- Only flashlights suitable for use in locations where fire or explosion hazards are possible may be used. Smoking or the use of an open flame is prohibited in any hold or compartment containing Class 3 (flammable) or combustible liquid and warning signs must be posted.
- Class 4 (flammable solids) and Division 5.2 (organic peroxide) materials must also be kept cool and be stowed away from all sources of heat and ignition. You must stow Division 5.2 materials away from living quarters or access to them. You may not stow Division 1.5 or Class 5 (oxidizers and organic peroxides) in the same hold or compartment as any readily combustible material, or in or near a hold containing sulfur in bulk.
- You must follow special provisions and procedures when transporting Division 1.5, ammonium nitrate, and ammonium nitrate mixtures. Under certain circumstances, written permission from the nearest COTP is necessary before Division 1.5, ammonium nitrates, and certain ammonium nitrate fertilizers may be loaded on or unloaded from a vessel at any waterfront facility.
- You must stow each package required to have a POISON GAS, POISON INHALATION HAZARD, or POISON label clear of living quarters and any ventilation ducts serving living quarters. You must

also separate such packages from foodstuffs, except when the hazardous materials and the foodstuffs are in different closed transport units.

- No person may remain unnecessarily in a hold or compartment, or in the immediate vicinity of the package on deck containing radioactive materials. A package of radioactive materials with a surface temperature of more than 5°C (9°F) above the ambient air may not be overstowed with any other cargo. If the package is stowed under deck, the hold or compartment must be ventilated.
- Certain packages of Class 7 (radioactive) materials should be marked with transport indexes. The sum of these indexes may not exceed the limits specified.
- If an accident occurs involving Class 7 (radioactive) materials, you must segregate the materials from unnecessary contact with personnel. If the package has leaked, you must isolate the hold or compartment containing the cargo. Do not use the hold or compartment for any other cargo until it has been decontaminated in accordance with §176.715.
- General stowage requirements for Class 8 (corrosive) materials are found in §176.800 and §176.800 and include prohibitions against stowing these materials near living quarters, foodstuffs, combustible materials or cotton.
- When you stow break bulk Class 8 materials on deck, you must make provisions in case of leakage. Dunnage must be provided on the deck and arranged so that any leakage will be apparent. You must wash down any leakage using liberal quantities of water.
- Cotton and vegetable fibers that are transported on a vessel must be securely baled and bound. Each bale must be covered with bagging on at least three-fourths of its surface. You must stow each bale of wet cotton separately from dry bales of cotton or vegetable fiber.

Incidents and Accidents

Despite all safety efforts, incidents do occur. When hazardous materials are involved in a transportation incident a report may be required. For certain incidents, you must notify either the National Response Center (NRC) or, for infectious substances, the Centers for Disease Control (CDC), as soon as practical, but not later than 12 hours after the incident occurs. For any such incident, you must also follow up with a written Hazardous Materials Incident Report.

- You must also file a written Hazardous Materials Incident Report within 30 days of discovering any unintentional release of hazardous materials or unintentional discharge of hazardous waste, as well as under certain other conditions. But unless a requirement listed in 171.15 applies, you do not need to notify the NRC or CDC by phone.
- You must notify the NRC as soon as practical in the event of fire, breakage, spillage, or suspected radioactive contamination from a radioactive material. You must notify the CDC as soon as practical in the event of fire, breakage, spillage, or suspected contamination involving an infectious substance other than a diagnostic specimen or regulated medical waste.
- You must report a large release of a marine pollutant, by phone, as soon as possible, to the NRC. This requirement applies to a release of over 400 kilograms of a sold, and to the release of over 450 liters of a liquid.

Hazmat incidents that result in any of the following require notification as soon as possible to the National Response Center or the Center for Disease Control, if applicable, when due to the hazardous materials:

- death of injury requiring hospitalization
- change in the operational flight pattern or routine of an aircraft
- the shutdown of a major facility or transportation artery for more than one hour
- an evacuation of the general public that lasts more than one hour
- a situation that, in your judgment, requires notification, even if none of the above conditions are met—for example, a continuing danger to life, although no death has yet occurred.

Water Content: In in-situ volatilization, the influence water content has on rate of volatilization by affecting the rates at which chemicals can diffuse through the vadose zone. An increase in solid water content decreases the rate at which volatile compounds are transported to the surface via vapor diffusion.

Water Cycle: Simply, the water cycle describes how water moves through the environment and identifies the links between groundwater, surface water, and the atmosphere. As illustrated, water is taken from the earth's surface to the atmosphere by evaporation from the surface of lakes, rivers, streams, and oceans. This evaporation process occurs when the sun heats water. The sun's heat energizes surface molecules, allowing them to break free of the attractive force binding them together, and then evaporate and rise as invisible vapor in the atmosphere. Water vapor is also emitted from plant leaves by a process called *transpiration.* Every day, an actively growing plant transpires five to ten times as much water as it can hold at once. As water vapor rises, it cools and eventually condenses, usually on tiny particles of dust in the air. When it condenses, it becomes a liquid again or turns directly into a solid (ice, hail, or snow). These water particles then collect and form clouds. The atmospheric water formed in clouds eventually falls to earth as precipitation. The precipitation can contain contaminants from air pollution. The precipitation may fall directly onto surface waters, be intercepted by plants or structures, or fall onto the ground. Most precipitation falls in coastal areas or in high elevations. Some of the water that falls in high elevations becomes runoff water, the water that runs over the ground (sometimes collecting nutrients from the soil) to lower elevations to form streams, lakes, and fertile valleys.

Waterfowl: Birds that swim and live near water, including ducks, geese, and swans.

Water Management System: Planned system in which the available water supply is effectively used by managing and controlling the moisture environment of crops to promote the desired crop response, to minimize soil erosion and loss of plant nutrients, to control undesirable water loss, and to protect water quality.

Water Pollutants: Unwanted contaminants that can pollute water.

Water Pollution: Any physical or chemical change in surface water or groundwater that can adversely affect living organisms.

Water Purveyor: A public utility mutual water company, country water district, or municipality that delivers drinking water to customers.

Water Quality: 1. The excellence of water in comparison with its intended use or uses. 2. The physical, chemical and biological characteristics of water.

Water Quality-Based Performance Requirement: A specific, measurable, and enforceable, standard that establishes limits for pollutant concentrations or mass loads in treated wastewater discharge to ground water or surface waters.

Water Quality Criteria: Levels of water quality expected to render a body of water suitable for its designated use. Criteria are based on specific levels or pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Water Quality Standards: State-adopted and EPA-approved ambient standards for water bodies. The standards prescribe the use of the water body and establish the water quality criteria that must be met to protect designated uses.

Water Quality-Based Limitations: Effluent limitations applied to dischargers when more technology-based limitations would cause violations of water quality standards. Usually applied to dischargers into small streams.

Water Quality-Based Permit: A permit with an effluent limit more stringent than one based on technology performance. Such limits may be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry or water supply).

Watershed: The land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large watersheds, like the Mississippi River basin contain thousands of smaller watersheds.

Watershed Approach: A coordinated framework for environmental management that focuses public and private efforts on the highest priority problems within hydrologically-defined geographic areas taking into consideration both ground and surface water flow.

Watershed Area: A topographic area within a line drawn connecting the highest points uphill of a drinking water-intake into which overland flow drains.

Watershed Divide: A ridge of high land dividing two areas drained by different river systems.

Water Solubility: The maximum possible concentration of a chemical compound dissolved in water. If a substance is water soluble it can very readily disperse through the environment.

Water-Soluble Packaging: Packaging that dissolves in water; used to residue exposure risks to pesticide mixers and loaders.

Water-Source Heat Pump: Heat pump that uses wells or heat exchangers to transfer heat from water to the inside of a building. Most such units use ground water.

Water Stagnation: Water at rest; it allows for the growth of pathogenic microorganisms to take place.

Water Storage Pond: An impound for liquid wastes designed to accomplish some degree of biochemical treatment.

Water Supplier: One who owns or operates a public water system.

Water Supply System: The collection, treatment, storage, and distribution of potable water from source to consumer.

Water Table: The upper surface of the saturation zone below which all void spaces are filled with water.

Water Treatment: Municipal water treatment operations and associated treatment unit processes are designed to provide reliable, high quality water service for customers, and to preserve and protect the environment for future generations.

Water management officials and treatment plant operators are tasked with exercising responsible financial management, ensuring fair rates and charges, providing responsive customer service, providing a consistent supply of safe potable water for consumption by the user, and promoting environmental responsibility.

Waterworks Operators

Operation of a water treatment system, no matter the size or complexity, requires operators. To perform their functions at the highest knowledge and experience level possible, operators must understand the basis concepts and theories behind many complex water treatment concepts and treatment systems. Under new regulations, waterworks operators must be certified/licensed.

Actual water treatment protocols and procedures are important, however, without proper implementation, they are nothing more than hollow words occupying space on reams of paper. This is where the waterworks operator comes in. To successfully treat water requires skill, dedication, and vigilance. The waterworks operator must not only be highly trained and skilled, but also must be conscientious—the ultimate user demands nothing less. The role of the waterworks operator can be succinctly stated:

- Waterworks operators provide water that complies with state Waterworks Regulations, water that is safe to drink and ample in quantity and pressure without interruption.
- Waterworks operators must know their facilities.
- Waterworks operators must be familiar with bacteriology, chemistry, and hydraulics.
- Waterworks operators must stay abreast of technological change and stay current with water supply information.

In operating a waterworks facility, waterworks operator duties include:

- Maintaining distribution system
- Collecting or analyzing water samples
- Operating chemicals feed equipment
- Keeping records
- Operating treatment unit processes
- Performing sanitary surveys of the water supply watershed
- Operating a cross-connection control program

Purpose of Water Treatment

As mentioned, the purpose of water treatment is to condition, modify, or remove undesirable impurities, to provide water that is safe, palatable, and acceptable to users. While this is the obvious purpose of treating water, various regulations also require water treatment. Some regulations state that if the contaminants listed under the various regulations are found in excess of maximum contaminant levels (MCLs), the water must be treated to reduce the levels. If a well or spring source is surface influenced, treatment is required, regardless of the actual presence of contamination. Some impurities affect the aesthetic qualities of the water; if they exceed secondary MCLs established by USEPA and the state, the water may need to be treated.

If we assume that the water source used to feed a typical water supply system is groundwater (usually the case in the U.S.), a number of common groundwater problems may require water treatment. Keep in mind that water that must be treated for one of these problems may also exhibit several other problems. Among these other problems are:

- bacteriological contamination
- hydrogen sulfide odors
- hard water
- corrosive water
- iron and manganese

Pretreatment

Simply stated, water pretreatment (also called preliminary treatment) is any physical, chemical, or mechanical process used before main water treatment processes. It can include screening, presedimentation, and chemical addition. Pretreatment usually consists of oxidation or other treatment for the removal of tastes and odors, iron and manganese, trihalomethane precursors, or entrapped gases (like hydrogen sulfide). Treatment processes may include chlorine, potassium permanganate or ozone oxidation, activated carbon addition, aeration, and presedimentation.

Pretreatment of surface water supplies accomplishes the removal of certain constituents and materials that interfere with or place an unnecessary burden on conventional water treatment facilities.

Based on experience and according to the Texas Water Utilities Association's Manual of Water Utility Operations, 8th edition, typical pretreatment processes include the following:

1. Removal of debris from water from rivers and reservoirs that would clog pumping equipment.
2. Destratification of reservoirs to prevent anaerobic decomposition that could result in reducing iron and manganese from the soil to a state that would be soluble in water. This can cause subsequent removal problems in the treatment plant. The production of hydrogen sulfide and other taste- and odor-producing compounds also results from stratification.
3. Chemical treatment of reservoirs to control the growth of algae and other aquatic growths that could result in taste and odor problems.
4. Presedimentation to remove excessively heavy silt loads prior to the treatment processes.
5. Aeration to remove dissolved odor-causing gases such as hydrogen sulfide and other dissolved gases or volatile constituents, and to aid in the oxidation of iron and manganese, although manganese or high concentrations of iron are not removed in the detention provided in conventional aeration units.
6. Chemical oxidation of iron and manganese, sulfides, taste- and odor-producing compounds, and organic precursors that may produce trihalomethanes upon the addition of chlorine.
7. Adsorption for removal of tastes and odors.

√ Note: An important point to keep in mind is that in small systems, using groundwater as a source, pretreatment may be the only treatment process used.

Pretreatment generally involves aeration or the addition of chemicals to oxidize contaminants that exist in the raw water. It may be incorporated as part of the total treatment process or may be located adjacent to the source before the water is sent to the treatment facility.

Aeration

Aeration is commonly used to treat water that contains trapped gases (such as hydrogen sulfide) that can impart an unpleasant taste and odor to the water. Just allowing the water to rest in a vented tank will (sometimes) drive off much of the gas, but usually some form of forced aeration is needed. Aeration works well (about 85 percent of the sulfides may be removed) whenever the pH of the water is less than 6.5.

Aeration may also be useful in oxidizing iron and manganese, oxidizing humic substances that might form trihalomethanes when chlorinated, eliminating other sources of taste and odor, or imparting oxygen to oxygen-deficient water.

√ Note: Iron is a naturally occurring mineral found in many water supplies. When the concentration of iron exceeds 0.3 mg/l, red stains will occur on fixtures and clothing. This increases customer costs for cleaning and replacement of damaged fixtures and clothing.

Manganese, like iron, is a naturally occurring mineral found in many water supplies. When the concentration of manganese exceeds 0.05 mg/l, black stains occur on fixtures and clothing. As with iron, this increases customer costs for cleaning and replacement of damaged fixtures and clothing. Iron and manganese are commonly found together in the same water supply. We discuss iron and manganese later.

Screening

Screening is usually the first important step in the water pretreatment process. It is defined as the process whereby relatively large and suspended debris is removed from the water before it enters the plant. River water, for example, typically contains suspended and floating debris varying in size from small rags to logs. Removing these solids is important, not only because these items have no place in potable water, but also because this river trash may cause damage to downstream equipment (clogging and damaging pumps, etc.), increase chemical requirements, impede hydraulic flow in open channels or pipes, or hinder the treatment process. The most important criteria used in the selection of a particular screening system for water treatment technology are the screen opening size and flow rate. Other important criteria include: costs related to operation and equipment; plant hydraulics; debris handling requirements; and operator qualifications and availability.

Large surface water treatment plants may employ a variety of screening devices including rash screens (or trash rakes), traveling water screens, drum screens, bar screens, or passive screens.

Chemical Addition

√ [Note: much of the procedural information presented in this section applies to both water and wastewater operations].

Two of the major chemical pretreatment processes used in treating water for potable use are iron and manganese and hardness removal. Another chemical treatment process that is not necessarily part of the pretreatment process, but is also discussed in this section, is corrosion control. Corrosion prevention is effected by chemically treatment—not only in the treatment process but is also in the distribution process. Before discussing each of these treatment methods in detail, however, it is important to describe chemical addition, chemical feeders, and chemical feeder calibration.

When chemicals are used to in the pretreatment process, they must be the proper ones, fed in the proper concentration and introduced to the water at the proper locations. Determining the proper amount of chemical to be used is accomplished by testing. The operator must test the raw water periodically to determine if the chemical dosage should be adjusted. For surface supplies, this checking must be done more frequently than for groundwater (remember, surface water supplies are subject to change on short notice, while groundwaters generally remain stable). The operator must be aware of the potential for interactions between various chemicals and how to determine the optimum dosage (e.g., adding both chlorine and activated carbon at the same point will minimize the effectiveness of both processes, as the adsorptive power of the carbon will be used to remove the chlorine from the water).

√ Note: Sometimes using too many chemicals can be worse than not using enough.

Prechlorination (distinguished from chlorination used in disinfection at the end of treatment) is often used as an oxidant to help with the removal of iron and manganese. However, currently, concern for systems that prechlorinate is prevalent because of the potential for the formation of total trihalomethanes (TTHMs), which form as a by-product of the reaction between chlorine and naturally occurring compounds in raw water.

√ Note: TTHMs such as chloroform are known or suspected to be carcinogenic and are limited by water and state regulations.

USEPA's TTHM standard does not apply to water systems that serve less than 10,000 people, but operators should be aware of the impact and causes of TTHMs. Chlorine dosage or application point may be changed to reduce problems with TTHMs.

√ Note: To be effective, pretreatment chemicals must be thoroughly mixed with the water. Short-circuiting or slug flows of chemicals that do not come in contact with most of the water will not give proper treatment.

All chemicals intended for use in drinking water must meet certain standards. Thus, when ordering water treatment chemicals, the operator must be assured that they meet all appropriate standards for drinking water use.

Chemicals are normally fed with dry chemical feeders or solution (metering) pumps. Operators must be familiar with all of the adjustments needed to control the rate at which the chemical is fed to the water (wastewater). Some feeders are manually controlled and must be adjusted by the operator when the raw water quality or the flow rate changes; other feeders are paced by a flow meter to adjust the chemical feed so it matches the water flow rate. Operators must also be familiar with chemical solution and feeder calibration.

As mentioned, a significant part of waterworks operator's important daily operational functions includes measuring quantities of chemicals and applying them to water at preset rates. Normally accomplished semiautomatically by use of chemical feed devices, waterworks operators must still know what chemicals to add, how much to add to the water (wastewater), and the purpose of the chemical addition.

Chemical Solutions

A water solution is a homogeneous liquid made of the solvent (the substance that dissolves another substance) and the solute (the substance that dissolves in the solvent). Water is the solvent. The solute (whatever it may be) may dissolve up to a certain limit. This is called its solubility—that is, the solubility of the solute in the particular solvent (water) at a particular temperature and pressure.

√ Note: Temperature and pressure influence Stability of solutions but not by filtration, because only suspended material can be eliminated by filtration or by sedimentation.

Remember, in chemical solutions, the substance being dissolved is called the solute, and the liquid present in the greatest amount in a solution (and that does the dissolving) is called the solvent. We should also be familiar with another term, concentration—the amount of solute dissolved in a given amount of solvent.

When working with chemical solutions, you should also be familiar with two chemical properties we briefly described earlier: density and specific gravity. Density is defined as the weight of a substance per a unit of its volume; for example pounds per cubic foot or pounds per gallon. Specific gravity is defined as the ratio of the density of a substance to a standard density.

Chemical Feeders

Simply put, a chemical feeder is a mechanical device for measuring a quantity of chemical and applying it to water at a preset rate.

Types of Chemical Feeders

Two types of chemical feeders are commonly used: solution (or liquid) feeders and dry feeders. Liquid feeders apply chemicals in solutions or suspensions. Dry feeders apply chemicals in granular or powdered forms.

- Solution Feeder: chemical enters feeder and leaves feeder in a liquid state.
- Dry Feeder: chemical enters and leaves feeder in a dry state.

Solution Feeders

Solution feeders are small, positive displacement metering pumps of three types: (1) reciprocating (piston-plunger or diaphragm types); (2) vacuum type (e.g., gas chlorinator); or (3) gravity feed rotameter (e.g., drip feeder).

Positive displacement pumps are used in high pressure, low flow applications; they deliver a specific volume of liquid for each stroke of a piston or rotation of an impeller.

Dry Feeders

Two types of dry feeders are volumetric and gravimetric, depending on whether the chemical is measured by volume (volumetric-type) or weight (gravimetric-type). Simpler and less expensive than gravimetric pumps, volumetric dry feeders are also less accurate. Gravimetric dry feeders are extremely accurate, deliver high feed rates, and are more expensive than volumetric feeders.

Iron and Manganese Removal

Iron and manganese are frequently found in groundwater and in some surface waters. They do not cause health-related problems but are objectionable because they may cause aesthetic problems. Severe aesthetic problems may cause consumers to avoid an otherwise safe water supply in favor of one of unknown or of questionable quality, or may cause them to incur unnecessary expense for bottled water.

Aesthetic problems associated with iron and manganese include the discoloration of water (iron = reddish water, manganese = brown or black water); staining of plumbing fixtures; imparting a bitter taste to the water; and stimulating the growth of microorganisms.

As mentioned, there are no direct health concerns associated with iron and manganese, although the growth of iron bacteria slimes may cause indirect health problems.

Economic problems include damage to textiles, dye, paper, and food. Iron residue (or tuberculation) in pipes increases pumping head, decrease carrying capacity, may clog pipes, and may corrode through pipes.

√ Note: Iron and manganese are secondary contaminants. Their secondary maximum contaminant levels (SMCLs) are: iron = 0.3 mg/l; manganese = 0.05 mg/l.

Iron and manganese are most likely found in groundwater supplies, industrial waste, and acid mine drainage, and as by-products of pipeline corrosion. They may accumulate in lake and reservoir sediments, causing possible problems during lake/reservoir turnover. They are not usually found in running waters (streams, rivers, etc.).

Iron and Manganese Removal Techniques

Chemical precipitation treatments for iron and manganese removal are called deferrization and demanganization. The usual process is aeration; dissolved oxygen in the chemical causing precipitation; chlorine or potassium permanganate may be required.

Precipitation

Precipitation (or pH adjustment) or iron and manganese from water in their solid forms can be effected in treatment plants by adjusting the pH of the water by adding lime or other chemicals. Some of the precipitate will settle out with time, while the rest is easily removed by sand filters. This process requires pH of the water to be in the range of 10-11.

√ Note: While the precipitation or pH adjustment technique for treating water containing iron and manganese is effective, note that the pH level must be adjusted higher (10-11 range) to cause the precipitation, which means that the pH level must then also be lowered (to the 8.5 range or a bit lower) to use the water for consumption.

Oxidation

One of the most common methods of removing iron and manganese is through the process of oxidation (another chemical process), usually followed by settling and filtration. Air, chlorine, or potassium permanganate can oxidize these minerals. Each oxidant has advantages and disadvantages, an each operates slightly differently. We discuss each oxidant in turn.

1. Air—To be effective as an oxidant, the air must come in contact with as much of the water as possible. Aeration is often accomplished by bubbling diffused air through the water by spraying the water up into the air, or by trickling the water over rocks, boards, or plastic packing materials in an aeration tower. The more finely divided the drops of water, the more oxygen comes in contact with the water and the dissolved iron and manganese.
2. Chlorine—This is one of the most popular oxidants for iron and manganese control because it is also widely used as a disinfectant; iron and manganese control by prechlorination can be as simple as adding a new chlorine feed point in a facility already feeding chlorine. It also provides a pre-disinfecting step that can help control bacterial growth through the rest of the treatment system. The downside to chorine use, however, is that when chlorine reacts with the organic materials found in surface water and some groundwaters, it forms TTHMs. This process also requires that the pH of the water be in the range of 6.5 to 7; because many groundwaters are more acidic than this, pH adjustment with lime, soda ash, or caustic soda may be necessary when oxidizing with chlorine.

3. Potassium permanganate—This is the best oxidizing chemical to use for manganese control removal. An extremely strong oxidant, it has the additional benefit of producing manganese dioxide during the oxidation reaction. Manganese dioxide acts as an adsorbent for soluble manganese ions. This attraction for soluble manganese provides removal to extremely low levels.

The oxidized compounds form precipitates that are removed by a filter. Note that sufficient time should be allowed from the addition of the oxidant to the filtration step. Otherwise, the oxidation process will be completed after filtration, creating insoluble iron and manganese precipitates in the distribution system.

Ion Exchange

While the iron exchange process is used mostly to soften hard waters, it will also remove soluble iron and manganese. The water passes through a bed of resin that adsorbs undesirable ions from the water, replacing them with less troublesome ions. When the resin has given up all its donor ions, it is regenerated with strong salt brine (sodium chloride); the sodium ions from the brine replace the adsorbed ions and restore the ion exchange capabilities.

Sequestering

Sequestering or stabilization may be used when the water contains mainly low concentration of iron, and the volumes needed are relatively small. This process does not actually remove the iron or manganese from the water but complexes (binds it chemically) it with other ions in a soluble form that is not likely to come out of solution (i.e., not likely oxidized).

Aeration

The primary physical process uses air to oxidize the iron and manganese. The water is either pumped up into the air or allowed to fall over an aeration device. The air oxidizes the iron and manganese that is then removed by use of a filter. The addition of lime to raise the pH is often added to the process. While this is called a physical process, removal is accomplished by chemical oxidation.

Potassium Permanganate Oxidation and Manganese Greensand

The continuous regeneration potassium greensand filter process is another commonly used filtration technique for iron and manganese control. Manganese greensand is a mineral (gluconite) that has been treated with alternating solutions manganous chloride and potassium permanganate.

The result is a sand-like (zeolite) material coated with a layer of manganese dioxide—an adsorbent for soluble iron and manganese. Manganese greensand has the ability to capture (adsorb) soluble iron and manganese that may have escaped oxidation, as well as the capability of physically filtering out the particles of oxidized iron and manganese. Manganese greensand filters are generally set up as pressure filters, totally enclosed tanks containing the greensand.

The process of adsorbing soluble iron and manganese "uses up" the greensand by converting the manganese dioxide coating to manganic oxide, which does not have the adsorption property. The greensand can be regenerated in much the same way as ion exchange resins, by washing the sand with potassium permanganate.

Hardness Treatment

Hardness in water is caused by the presence of certain positively charged metallic irons in solution in the water. The most common of these hardness-causing ions are calcium and magnesium; others include iron, strontium, and barium.

As a general rule, groundwaters are harder than surface waters, so hardness is frequently of concern to the small water system operator. This hardness is derived from contact with soil and rock formations such as limestone. Although rainwater itself will not dissolve many solids, the natural carbon dioxide in the soil enters the water and forms carbonic acid (HCO), which is capable of dissolving minerals. Where soil is thick (contributing more carbon dioxide to the water) and limestone is present, hardness is likely to be a problem. The total amount of hardness in water is expressed as the sum of its calcium carbonated ($CaCO_3$) and its magnesium hardness. However, for practical purposes, hardness is expressed as calcium carbonate. This means that regardless of the amount of the various components that make up hardness, they can be related to a specific amount of calcium carbonate (e.g., hardness is expressed as mg/l as $CaCO_3$—milligrams per liter as calcium carbonate).

√ Note: The two types of water hardness are temporary hardness and permanent hardness. Temporary hardness is also known as carbonate hardness (hardness that can be removed by boiling); permanent hardness is also known as noncarbonate hardness (hardness that cannot be removed by boiling).

Hardness is of concern in domestic water consumption because hard water increases soap consumption, leaves a soapy scum in the sink or tub, can cause water heater electrodes to burn out quickly, can cause discoloration of plumbing fixtures and utensils, and is perceived as a less desirable water. In industrial water use, hardness is a concern because it can cause boiler scale and damage to industrial equipment.

The objection of customers to hardness is often dependent on the amount of hardness they are used to. People familiar with water with a hardness of 20 mg/l might think that a hardness of 100 mg/l is too much. On the other hand, a person who has been using water with a hardness of 200 mg/l might think that 100 mg/l was very soft. The Table lists the classifications of hardness.

Classification of Hardness

Classification	*mg/l $CaCO_3$*
Soft	0–75
Moderately hard	75–150
Hard	150–300
Very hard	Over 300

Treatment Methods

Two common methods are used to reduce hardness: ion exchange and cation exchange.

Ion Exchange Process

The ion exchange process is the most frequently used process for softening water. Accomplished by charging a resin with sodium ions, the resin exchanges the sodium ions for calcium and/or magnesium ions. Naturally occurring and synthetic cation exchange resins are available.

Natural exchange resins include such substances as aluminum silicate, zeolite clays [zeolites are hydrous silicates found naturally in the cavities of lavas (greensand); glauconite zeolites; or synthetic, porous zeolites], humus, and certain types of sediments. These resins are placed in a pressure vessel. Salt brine is flushed through the resins. The sodium ions in the salt brine attach to the resin. The resin is now said to be charged. Once charged, water is passed through the resin and the resin exchanges the sodium ions attached to the resin for calcium and magnesium ions, thus removing them from the water.

The zeolite clays are most common because they are quite durable, can tolerate extreme ranges in pH, and are chemically stable. They have relatively limited exchange capacities, however, so they should be used only for water with a moderate total hardness. One of the results is that the water may be more corrosive than before. Another concern is that addition of sodium ions to the water may increase the health risk of those with high blood pressure.

Cation Exchange Process

The cation exchange process takes place with little or no intervention from the treatment plant operator. Water containing hardness-causing cations (Ca^{++}, Mg^{++}, Fe^{+3}) is passed through a bed of cation exchange resin. The water coming through the bed contains hardness near zero, although it will have elevated sodium content. (The sodium content is not likely to be high enough to be noticeable, but it could be high enough to pose problems to people on highly restricted salt-free diets.) The total lack of hardness in the finished water is likely to make it very corrosive, so normal practice bypasses a portion of the water around the softening process. The treated and untreated waters are blended to produce an effluent with a total hardness around 50 to 75 mg/l as $CaCO_{3.}$

Corrosion Control

Water operators add chemicals (e.g., lime or sodium hydroxide) to water at the source or at the waterworks to control corrosion. Using chemicals to achieve slightly alkaline chemical balance prevents the water from corroding distribution pipes and consumers' plumbing. This keeps substances like lead from leaching out of plumbing and into the drinking water.

For our purpose, we define corrosion as the conversion of a metal to a salt or oxide with a loss of desirable properties such as mechanical strength. Corrosion may occur over an entire exposed surface, or may be localized at micro- or macroscopic discontinuities in metal. In all types of corrosion a gradual decomposition of the material occurs, often due to an electrochemical reaction. Corrosion may be caused by (1) stray current electrolysis, (2) galvanic corrosion caused by dissimilar metals, or (3) differential concentration cells. Corrosion starts at the surface of a material and moves inward.

The adverse effects of corrosion can be categorized according to health, aesthetics, economic effects, and/or other effects.

The corrosion of toxic metal pipe made from lead creates a serious health hazard. Lead tends to accumulate in the bones of humans and animals. Signs of lead intoxication include gastrointestinal disturbances, fatigue, anemia, and muscular paralysis. Lead is not a natural contaminant in either surface waters or groundwaters, and the MCL of 0.005 mg/l in source waters is rarely exceeded. It is a corrosion by-product from high lead solder joints in copper and lead piping. Small dosages of lead can lead to developmental problems in children. The USEPA's Lead and Copper Rule addresses the matter of lead in drinking water exceeds specified action levels.

√ Note: The USEPA's Lead and Copper Rule requires that a treatment facility achieve optimum corrosion control.

Cadmium is the only other toxic metal found in samples from plumbing systems. Cadmium is a contaminant found in zinc. Its adverse health effects are best known for being associated with severe Conn's and kidney syndrome in Japan. The PMCL for cadmium is 0.01 mg/l.

Aesthetic effects that are a result of corrosion of iron are characterized by "pitting" and are a consequence of the deposition of ferric hydroxide and other products and the solution of iron—tuberculation. Tuberculation reduces the hydraulic capacity of the pipe. Corrosion of iron can cause customer complaints of reddish or reddish-brown staining of plumbing fixtures and laundry. Corrosion of copper lines can cause customer complaints of bluish or blue-green stains on plumbing fixtures. Sulfide corrosion of copper and iron lines can cause a blackish color in the water. The by-products of microbial activity (especially iron bacteria) can cause foul tastes and/or odors in the water.

The economic effects of corrosion may include the need for water main replacement, especially when tuberculation reduces the flow capacity of the main. Tuberculation increases pipe roughness, causing an increase in pumping costs and reducing distribution system pressure. Tuberculation and corrosion can cause leaks in distribution mains and household plumbing. Corrosion of household plumping may require extensive treatment, public education, and other actions under the Lead and Copper Rule.

Other effects of corrosion include short service life of household plumbing caused by pitting. Buildup of mineral deposits in the hot water system may eventually restrict hot water flow. Also the structural integrity of steel water storage tanks may deteriorate, causing structural failures. Steel ladders in clearwells or water storage tanks may corrode, introducing iron into the finished water. Steel parts in flocculation tanks, sedimentation basins, clarifiers, and filters may also corrode.

Types of Corrosion

Three types of corrosion occur in water mains: galvanic, tuberculation, and/or pitting.

- Galvanic—when two dissimilar metals are in contact and are exposed to a conductive environment, a potential exists between them and current flows. This type of corrosion is the result of an electrochemical reaction when the flow of electric current itself is an essential part of the reaction.
- Tuberculation—this refers to the formation of localized corrosion products scattered over the surface in the form of knob-like mounds. These mounds increase the roughness of the inside of the pipe, increasing resistance to water flow and decreasing the C-factor of the pipe.
- Pitting—localized corrosion is generally classified as pitting when the diameter of the cavity at the metal surface is the same or less than the depth.

Factors Affecting Corrosion

The primary factors affecting corrosion are pH, alkalinity, hardness (calcium), dissolved oxygen, and total dissolved solids. Secondary factors include temperature, velocity of water in pipes, and carbon dioxide (CO_2).

Determination of Corrosion problems

To determine if corrosion is taking place in water mains, materials removed from the distribution system should be examined for sings of corrosion damage. A primary indicator of corrosion damage is pitting. (Note: measure depth of pits to gauge the extent of damage.) Another common method used to determine if corrosion or scaling is taking place in distribution lines is by inserting special steel specimens of known weight (called coupons) in the pipe and examining them for corrosion after a period of time.

Evidence of leaks, conducting flow tests and chemical tests for dissolved oxygen and toxic metals, as well as customer complains (red or black water and/or laundry and fixture stains) are also used to indicate corrosion problems.

Formulas can also be used to determine corrosion (to an extent). The Langlier Saturation Index (L.I.) and Aggressive Index (A.I.) are two of the commonly used indices. The L.I. is a method used to determine if water is corrosive. A.I refers to waters that have low natural pH, are high in dissolved oxygen, are low in total dissolved solids, and have low alkalinity and low hardness. These waters are very aggressive and can be corrosive. Both the Langlier Saturation and Aggressive Indices are typically used as starting points in determining the adjustments required to produce a film.

- L.I. aproximately 0.5
- A.I. value of 12 or higher

√ L.I and A.I. are based on the dissolving of and precipitation of calcium carbonate; therefore, the respective indices may not actually reflect the corrosive nature of the particular water for a specific pipe material. However, they can be useful tools in selecting materials or treatment options for corrosion control.

Corrosion Control

As mentioned, one method used to reduce the corrosive nature of water is chemical addition. Selection of chemicals depends on the characteristics of the water where the chemicals can be applied, how they can be applied and mixed with water, and the cost of the chemicals.

Chemical Addition: Corrosion Control Parameters

1. If the product of the calcium hardness times the alkalinity of the water is less than 100 treatment may be required. Both lime and CO_2 may be required for proper treatment of the water.
2. If the calcium hardness and alkalinity levels are between 100 and 500, either lime or soda ash (Na_2CO_3)

will be satisfactory. The decision regarding which chemical to use depends on the cost of the equipment and chemicals.

3. If the product of the calcium hardness times the alkalinity is greater than 500, either lime or caustic (NaOH) may be used. Soda ash will be ruled out because of the expense.
4. The chemicals chosen for treatment of public drinking water supplies modify the water characteristics, making the water less corrosive to the pipe. Modification of water quality can increase the pH of the water, reducing the hydrogen ions available for galvanic corrosion, as well as reducing the solubility of copper, zinc, iron, lead, and calcium, and increasing the possibility of forming carbonate protective films.
5. Calcium carbonate stability is the most effective means of controlling corrosion. Lime, caustic soda, or soda ash is added until the pH and the alkalinity indicates the water is saturated with calcium carbonate. Saturation does not always assure non-corrosiveness. Utilities should also exercise caution when applying sodium compounds, since high sodium content in water can be a health concern for some customers.
6. By increasing the alkalinity of the water, the bicarbonate and carbonate available to form protective carbonate film increase.
7. By decreasing the dissolved oxygen of the water, the rate of galvanic corrosion is reduced, along with the possibility of iron tuberculation.
8. Use of inorganic phosphates:
   a. Zinc phosphates: Use! This phosphate causes algae blooms on open reservoirs.
   b. Sodium silicate: individual customers, such as apartments, houses, and office buildings use this method of treatment.
   c. Sodium polyphosphates (tetrasodium pyrophosphate or sodium hexametaphosphate): These chemicals control scale formation in supersaturated waters and are known as sequestering agents.
   d. Silicates (SiO_2): Silicates form a film. An initial dosage of 12 to 16 mg/l for about 30 days will adequately coat the pipes. Then 1.0 mg/l concentration should be maintained.

√ Caution: Great care and caution must be exercised any time feeding corrosion control chemicals into a public drinking water system!

Other Corrosion Control Methods

Another corrosion control method is aeration. Aeration works to remove carbon dioxide (CO_2); it can be reduced to about 5 mg/l.

Cathodic protection, often employed to control corrosion, is achieved by applying an outside electric current to the metal to reverse the electromechanical corrosion process. The application of D-C current prevents normal electron flow. Cathodic protection uses a sacrificial metal electrode (a magnesium anode) that corrodes instead of the pipe or tank.

Linings, coatings, and paints can also be used in corrosion control. Slip-line with plastic liner, cement mortar, zinc or magnesium, polyethylene, epoxy, and coal tar enamels are some of the materials that can be used.

√ Caution: Before using any protective coatings, consult the district engineer first!

Several corrosive resistant pipe materials are used to prevent corrosion, including:

1. PVC plastic pipe
2. Aluminum
3. Nickel
4. Silicon
5. Brass
6. Bronze
7. Stainless steel
8. Reinforced concrete

In addition to internal corrosion problems, waterworks operators must also be concerned with external corrosion problems. The primary culprit involved with external corrosion of distribution system pips is soil. The measure of corrosivity of the soil is the soil resistivity. If the soil resistivity is greater than 5,000 ohms/cm, serious corrosion is unlikely. Steel pipe may be used under these conditions. If soil resistivity is less than 500 ohms/cm, plastic PVC pipe should be used. For intermediate ranges of soil resistivity (500 to 5,000 ohms/cm), use ductile iron pipe, lining, and coating.

Common operating problems associated with corrosion control include:

1. $CaCO_3$ not depositing a film: usually a result of poor pH control (out of the normal range of 6.5 to 8.5). This may also cause excessive film deposition.
2. Persistence of red water problems: most probably a result of poor flow patterns, insufficient velocity, tuberculation of pipe surface, and presence of iron bacteria.
   a. Velocity—Chemicals need to make contact with pipe surface. Dead ends and low-flow areas should have flushing program; dead ends should be looped.
   b. Tuberculation—the best approach is to clean with "pig." In extreme cases, clean pipe with metal scrapers and install cement-mortar lining.
   c. Iron bacteria—Slime prevents film contact with pipe surface. Slime will grow and lose coating. Pipe cleaning and disinfection program are needed.

Coagulation

The primary purpose in surface-water treatment is chemical clarification by coagulation and mixing, flocculation, sedimentation, and filtration. These units processes, along with disinfection, work to remove particles, naturally occurring organic matter (NOM—i.e., bacteria, algae, zooplankton, and organic compounds), microbes from water and to produce water that is non-corrosive. Specifically, coagulation/flocculation work to destabilize particles and agglomerate dissolved and particulate matter. Sedimentation removes solids and provides ½ log Giardia and 1 log virus removal. Filtration removes solids and provides 2 log Giardia and 1 log virus removal. Finally, disinfection provides microbial inactivation and ½ Giardia and 2 log Virus removal.

Following screening and the other pretreatment processes, the next unit process in a conventional water treatment system is a mixer where chemicals are added in what is known as coagulation. The exception to this unit process configuration occurs in small systems using groundwater, when chlorine or other taste and odor control measures are introduced at the intake and are the extent of treatment.

Materials present in raw water may vary in size, concentration, and type. Dispersed substances in the water may be classified as suspended, colloidal, or solution.

Suspended particles may vary in mass and size and are dependent on the flow of water. High flows and velocities can carry larger material. As velocities decrease, the suspended particles settle according to size and mass.

Other material may be in solution, for example, salt dissolves in water. Matter in the colloidal state does not dissolve, but the particles are so small they will not settle out of the water. Color (as in tea-colored swamp water) is mainly due to colloids or extremely fine particles of matter in suspension. Colloidal and solute particles in water are electrically charged. Because most of the charges are alike (negative) and repel each other, the particles stay dispersed and remain in the colloidal or soluble state.

Suspended matter will settle without treatment, if the water is still enough to allow it to settle. The rate of settling of particles can be determined, as this settling follows certain laws of physics. However, much of the suspended matter may be so slow in settling that the normal settling processes become impractical, and if colloidal particles are present, settling will not occur. Moreover, water drawn from a raw water source often contains many small unstable (un-sticky) particles. Therefore, sedimentation alone is usually an impractical way to obtain clear water in most locations, and another method of increasing the settling rate must be used: coagulation. Simply, coagulation is designed to convert stable (un-sticky) particles to unstable (sticky) particles.

The term coagulation refers to the series of chemical and mechanical operations by which coagulants are applied and made effective. These operations are comprised of two distinct phases: (1) rapid mixing to disperse coagulant chemicals by violent agitation into the water being treated and (2) flocculation to agglomerate small particles into well-defined floc by gentle agitation for a much longer time.

The coagulant must be added to the raw water and perfectly distributed into the liquid; such uniformity of chemical treatment is reached through rapid agitation or mixing.

Coagulation results from adding salts of iron or aluminum to the water. Common coagulants (salts) are as follows:

- alum—aluminum sulfate
- sodium aluminate
- ferric sulfate
- ferrous sulfate
- ferric chloride
- polymers

Coagulation is the reaction between one of these salts and water. The simplest coagulation process occurs between alum and water. Alum or aluminum sulfate is made by a chemical reaction of bauxite ore and sulfuric acid. The normal strength of liquid alum is adjusted to 8.3 percent, while the strength of dry alum is 17 percent.

When alum is placed in water, a chemical reaction occurs that produces positively charged aluminum ions. The overall result is the reduction of electrical charges and the formation of a sticky substance—the formation of floc, which when properly formed, will settle. These two destabilizing factors are the major contributions that coagulation makes to the removal of turbidity, color, and microorganisms.

Liquid alum is preferred in water treatment because it has several advantages over other coagulants, including the following:

- Ease of handling
- Lower costs
- Less labor required to unload, store and convey
- Elimination of dissolving operations
- Less storage space required
- Greater accuracy in measurement and control provided
- Elimination of the nuisance and unpleasantness of handling dry alum
- Easier maintenance

The formation of floc is the first step of coagulation; for greatest efficiency, rapid, intimate mixing of the raw water and the coagulant must occur. After mixing, the water should be slowly stirred so that the very small, newly formed particles can attract and enmesh colloidal particles, holding them together to form larger floc. This slow mixing is the second stage of the process (flocculation), covered later.

A number of factors influence the coagulation process—pH, turbidity, temperature, alkalinity, and the use of polymers. The degree to which these factors influence coagulation depends upon the coagulant use.

`The raw water conditions, optimum pH for coagulation, and other factors must be considered before deciding which chemical is to be fed and at what levels.

To determine the correct chemical dosage, a Jar Test or Coagulation Test is performed. Jar tests (widely used for many years by the water treatment industry) simulate full-scale coagulation and flocculation processes to determine optimum chemical dosages. It is important to note that jar testing is only an attempt to achieve a ballpark approximation of correct chemical dosage for the treatment process. The test conditions are intended to reflect the normal operation of a chemical treatment facility.

The test can be used to:

- select the most effective chemical
- select the optimum dosage
- determine the value of a flocculant aid and the proper dose

Flocculation

Flocculation follows coagulation in the conventional water treatment process. Flocculation is the physical process of slowly mixing the coagulated water to increase the probability of particle collision—unstable particles collide and stick together to form fewer larger flocs. Through experience, we see that effective mixing reduces the required amount of chemicals and greatly improves the sedimentation process, which results in longer filter runs and higher quality finished water.

Flocculation's goal is to form a uniform, feather-like material similar to snowflakes—a dense, tenacious floc that entraps the fine, suspended, and colloidal particles and carries them down rapidly in the settling basin.

Proper flocculation requires from 15-45 minutes. The time is based on water chemistry, water temperature, and mixing intensity. Temperature is the key component in determining the amount of time required for floc formation.

To increase the speed of floc formation and the strength and weight of the floc, polymers are often added.

Sedimentation

After raw water and chemicals have been mixed and the floc formed, the water containing the floc (because it has a higher specific gravity than water) flows to the sedimentation or settling basin.

Sedimentation is also called clarification. Sedimentation removes settleable solids by gravity. Water moves slowly through the sedimentation tank/basin with a minimum of turbulence at entry and exit points with minimum short-circuiting. Sludge accumulates at bottom of tank/basin. Typical tanks or basins used in sedimentation include conventional rectangular basins, conventional center-feed basins, peripheral-feed basins, and spiral-flow basins.

In conventional treatment plants, the amount of detention time required for settling can vary from 2 to 6 hours. Detention time should be based on the total filter capacity when the filters are passing 2 gpm per square foot of superficial sand area. For plants with higher filter rates, the detention time is based on a filter rate of 3 to 4 gpm per square foot of sand area. The time requirement is dependent on the weight of the floc, the temperature of the water, and how quiescent (still) the basin.

A number of conditions affect sedimentation: (1) uniformity of flow of water through the basin; (2) stratification of water due to difference in temperature between water entering and water already in the basin; (3) release of gases that may collect in small bubbles on suspended solids, causing them to rise and float as scum rather than settle as sludge; (4) disintegration of previously formed floc; and (5) size and density of the floc.

Filtration

In the conventional water treatment process, filtration usually follows coagulation, flocculation, and sedimentation. At present, filtration is not always used in small water systems. However, recent regulatory requirements under USEPA's Interim Enhanced Surface

Water Treatment rules may make water filtering necessary at most water supply systems.

Water filtration is a physical process of separating suspended and colloidal particles from water by passing water through a granular material. The process of filtration involves straining, settling, and adsorption. As floc passes into the filter, the spaces between the filter grains become clogged, reducing this opening and increasing removal. Some material is removed merely because it settles on a media grain. One of the most important processes is adsorption of the floc onto the surface of individual filter grains. This helps collect the floc and reduces the size of the openings between the filter media grains.

In addition to removing silt and sediment, floc, algae, insect larvae, and any other large elements, filtration also contributes to the removal of bacteria and protozoans such as Giardia lamblia and Cryptosporidium. Some filtration processes are also used for iron and manganese removal.

Types of Filter Technologies

The Surface Water Treatment Rule (SWTR) specifies four filtration technologies, although SWTR also allows the use of alternate filtration technologies, e.g., cartridge filters. These include slow sand filtration/rapid sand filtration, pressure filtration, diatomaceous earth filtration, and direct filtration. Of these, all but rapid sand filtration are commonly employed in small water systems that use filtration. Each type of filtration system has advantages and disadvantages. Regardless of the type of filter, however, filtration involves the processes of straining (where particles are captured in the small spaces between filter media grains), sedimentation (where the particles land on top of the grains and stay there), and adsorption (where a chemical attraction occurs between the particles and the surface of the media grains).

Slow Sand Filters

The first slow sand filter was installed in London in 1829 and was used widely throughout Europe, though not in the U.S. By 1900, rapid sand filtration began taking over as the dominant filtration technology, and a few slow sand filters are in operation today. However, with the advent of the Safe Drinking Water Act and its regulations (especially the Surface Water Treatment Rule) and the recognition of the problems associated with Giardia lamblia and Cryptosporidium in surface water, the water industry is reexamining slow sand filters. Because of low technology requirements may prevent many state water systems from using this type of equipment.

On the plus side, slow sand filtration is well suited for small water systems. It is a proven, effective filtration process with relatively low construction costs and low operating costs (it does not require constant operator attention). It is quite effective for water systems as large as 5,000 people, beyond that, surface area requirements and manual labor required to recondition the filters make rapid sand filters more effective. The filtration rate is generally in the range of 45 to 150 gallons per day per square foot.

Components making up a slow sand filter include the following:

- a covered structure to hold the filter media
- an underdrain system
- graded rock that is placed around and just above the underdrain
- the filter media, consisting of 30 to 55 inches of sand with a grain size of 0.25 to 0.35 mm
- inlet and outlet piping to convey the water to and from the filter, and the means to drain filtered water to waste

Flooding the area above the top of the sand layer with water to a depth of 3 to 5 feet and allowing it to trickle down through the sand operates slow sand filters. An overflow device prevents excessive water depth. The filter must have provisions for filling it from the bottom up, and it must be equipped with a loss-of-head gauge, a rate-of-flow control device (such as a weir, orifice, or butterfly valve), a weir or effluent pipe that assures that the water level cannot drop below the sand surface, and filtered waste sample taps.

When the filter is first placed in service, the head loss through the media caused by the resistance of the sand is about 0.2 feet (i.e., a layer of water 0.2 feet deep on top of the filter will provide enough pressure to push the water downward through the filter). As the filter operates, the media becomes clogged with the material being filtered out of the water, and the head loss increase. When it reaches about 4 to 5 feet, the filter needs to be cleaned.

For efficient operation of a slow sand filter, the water being filtered should have a turbidity average less than 5 TU, with a maximum of 30 TU.

Slow sand filters are not backwashed the way conventional filtration units are. The 1 to 2 inches of material must be removed on a periodic basis to keep the filter operating.

Rapid Sand Filters

The rapid sand filter, which is similar in some ways to slow sand filter, is one of the most widely used filtration units. The major difference is in the principle of operation; that is, in the speed or rate at which water passes through the media. In operation, water passes downward through a sand bed that removes the suspended particles. The suspended particles consist of the coagulated matter remaining in the water after sedimentation, as well as a small amount of uncoagulated suspended matter.

Some significant differences exist in construction, control, and operation between slow sand filters and rapid sand filters. Because of the construction and operation of the rapid sand filtration with its higher filtration the land area needed to filter the same quantity of water is reduced.

The rapid sand filter structure and equipment includes the following:

- structure to house media
- filter media
- gravel media support layer
- underdrain system
- valves and piping system
- filter backwash system
- waste disposal system

Usually 2 to 3 feet deep, the filter media is supported by approximately 1 foot of gravel. The media may be fine sand or a combination of sand, anthracite coal, and coal (dual- multimedia filter).

Water is applied to a rapid sand filter at a rate of 1.5 to gallons per minute per square foot of filter media surface.

When the rate is between 4 and 6 gpm/ft^2, the filter is referred to as a high-rate filter; at a rate over 6 gpm/ft^{2,} the filter is called ultra-high-rate. These rates compare to the slow sand filtration rate of 45 to 150 gallons per day per square foot. High-rate and ultra-high-rate filters must meet additional conditions to assure proper operation.

Generally, raw water turbidity is not that high. However, even if raw water turbidity values exceed 1,000 TU, properly operated rapid sand filters can produce filtered water with a turbidity or well under 0.5 TU. The time the filter is in operation between cleanings (filter runs) usually lasts from 12 to 72 hours, depending on the quality of the raw water; the end of the run is indicated by the head loss approaching 6 to 8 feet. Filter breakthrough (when filtered material is pulled through the filter into the effluent) can occur if the head loss becomes too great. Operation with head loss too high can also cause air binding (which blocks part of the filter with air bubbles), increasing the flow rate through the remaining filter area.

Rapid sand filters have the advantage of lower land requirement, and they have other advantages, too. For example, rapid sand filters cost less, are less labor-intensive to clean, and offer higher efficiency with highly turbid waters. On the downside, operation and maintenance costs of rapid sand filters are much higher because of the increased complexity of the filter controls and backwashing system.

In backwashing a rapid sand filter, cleaning the filter is accomplished by passing treated water backwards (upwards) through the filter media and agitating the top of the media. The need for backwashing is determined by a combination of filter run time (i.e., the length of time since the last backwashing), effluent turbidity, and head loss through the filter. Depending on the raw water quality, the run time varies from one filtration plant to another (and may even vary from one filter to another in the same plant).

√ Note: Backwashing usually requires 3 to 7 percent of the water produced by the plant.

Pressure Filter Systems

When raw water is pumped or piped from the source to a gravity filter, the head (pressure) is lost as the water enters the floc basin. When this occurs, pumping the water from the plant clearwell to the reservoir is usually necessary. One way to reduce pumping is to place the plant components into pressure vessels, thus maintaining the head. This type of arrangement is called a pressure filter system. Pressure filters are also quite popular for iron and manganese removal and for filtration of water from wells. They may be placed directly in the pipeline from the well or pump with little head loss. Most pressure filters operate at a rate of about 3 gpm/ft^2.

Operationally the same, and consisting of components similar to those of a rapid sand filter, the main difference between a rapid sand filtration system and a pressure filtration system is that the entire pressure filter is contained within a pressure vessel. These units are often highly automated and are usually purchased as self-contained units with all necessary piping, controls, and equipment contained in a single unit. They are backwashed in much the same manner as the rapid sand filter.

The major advantage of the pressure filter is its low initial cost. They are usually prefabricated, with standardized designs. A major disadvantage is that the operator is unable to observe the filter in the pressure filter and so is unable to determine the condition of the media. Unless the unit has an automatic shutdown feature on high effluent turbidity, driving filtered material through the filter is possible.

Diatomaceous Earth Filters

Diatomaceous earth is a white material made from the skeletal remains of diatoms. The skeletons are microscopic, and in most cases, porous. There are different grades of diatomaceous earth, and the grade is selected based on filtration requirements.

These diatoms are mixed in water slurry and fed onto a fine screen called a septum, usually of stainless steel, nylon, or plastic. The slurry is fed at a rate of 0.2 lb per square foot of filter area. The diatoms collect in a precoat over the septum, forming an extremely fine screen. Diatoms are fed continuously with the raw water, causing the buildup of a filter cake approximately 1/8 to 1/5 inch thick. The openings are so small that the fine particles that cause turbidity are trapped on the screen. Coating the septum with diatoms gives it the ability to filter out very small microscopic material. The fine screen and the buildup of filtered particles cause a high head loss through the filter. When the head loss reaches a maximum level (30 psi on a pressure-type filter or 15 inches or mercury on a vacuum-type filter), the filter cake must be removed by backwashing.

Slurry of diatoms is fed with raw water during filtration in a process called body feed. The body feed prevents premature clogging of the septum cake. These diatoms are caught on the septum, increasing the headloss and preventing the cake from clogging too rapidly by the particles being filtered. While the body feed increases headloss, headloss increases are more gradual than if body feed were not use.

Although diatomaceous earth filters are relatively low in cost to construct, they have high operating costs and can give frequent operating problems if not properly operated and maintained. They can be used to filter raw surface waters or surface-influenced groundwaters, with low turbidity (<5 NTU), low coliform concentrations (no more than 50-coliforms/100 ml) and may also be used for iron and manganese removal following oxidation. Filtration rates are between 1.0 and 1.5 gpm/ft^2.

Direct Filtration
The term direct filtration refers to a treatment scheme that omits the flocculation and sedimentation steps prior to filtration. Coagulant chemicals are added, and the water is passed directly onto the filter. All solids removal takes place on the filter, which can lead to much shorter filter runs, more frequently back-washing, and a greater percentage of finished water used for backwashing. The lack of a flocculation process and sedimentation basin reduces construction cost but increases the requirement for skilled operators and high quality instrumentation. Direct filtration must be used only where the water flow rate and raw water quality are fairly consistent and where the incoming turbidity is low.

Alternate Filters
A cartridge filter system can be employed as an alternate filtering system to reduce turbidity and remove Giardia. A cartridge filter is made of a synthetic media contained in a plastic or metal housing. These systems are normally installed in a series of three or four filters. Each filter contains a media that is successively smaller than the previous filter. The media sizes typically range from 50µ to 5µ or less. The filter arrangement is dependent on the quality of the water, the capability of the filter, and the quantity of water needed. The USEPA and state agencies have established criteria for the selection and use of cartridge filters. Generally, cartridge filter systems are regulated in the same manner as other filtration systems.

Because of new regulatory requirements and the need to provide more efficient removal of pathogenic protozoans (e.g., Giardia and Cryptosporidium) from water supplies, membrane filtration systems are finding increased application in water treatment systems. A membrane is a thin film separating two different phases of a material acting as a selective barrier to the transport of matter operated by some driving force. Simply, a membrane can be regarded as a sieve with very small pores. Membrane filtration processes are typically pressure, electrically, vacuum, or thermally driven. The types of drinking water membrane filtration systems include microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. In a typical membrane filtration process, there is one input and two outputs. Membrane performance is largely a function of the properties of the materials to be separated and can vary throughout operation.

Common Filter Problems
Two common types of filter problems occur: those caused by filter runs that are too long (infrequent backwash), and those caused by inefficient backwash (cleaning).

Too long a filter run can cause breakthrough (the pushing of debris removed from the water through the media and into the effluent) and air binding (the trapping of air and other dissolved gases in the filter media).

Air binding occurs when the rate at which water exits the bottom of the filter exceeds the rate at which the water penetrates the top of the filter. When this happens, a void and partial vacuum occurs inside the filter media. The vacuum causes gases to escape from the water and fill the void. When the filter is backwashed, the release of these gases may cause a violent upheaval in the media and destroy the layering of the media bed, gravel, or underdrain.

Two solutions to the problems are as follows: (1) check the filtration rates to assure they are within the design specifications and (2) remove the top 1 inch of media and replace with new media. This keeps the top of the media from collecting the floc and sealing the entrance into the filter media.

Another common filtration problem is associated with poor backwashing practices: the formation of mud balls that get trapped in the filter media. In severe cases, mud balls can completely clog a filter. Poor agitation of the surface of the filter can form a crust on top of the filter; the crust later cracks under the water pressure, causing uneven distribution of water through the filter media. Filter cracking can be corrected by removing the top 1-inch of the filter media, increasing the backwash rate, or checking the effectiveness of the surface wash (if installed). Backwashing at too high a rate can cause the filter media to wash out of the filter over the effluent troughs and may damage the filter underdrain system.

Two possible solutions are as follows: (1) check the backwash rate to be sure that it meets the design criteria, and (2) check the surface wash (if installed) for proper operation.

Disinfection

[Note: Disinfection is a unit process used both in water and wastewater treatment. Many of the terms, practices, and applications discussed in this section apply to both water and wastewater treatment. There are also some differences—mainly in the types of disinfectants used and applications—between the use of disinfection in water and wastewater treatment. Thus, in this section we discuss disinfection as it applies to water treatment. Later we cover disinfection as it applies to wastewater treatment.]

The chemical or physical process used to control waterborne pathogenic organisms and prevent waterborne disease is called disinfection. The goal in proper disinfection in a water system is to destroy all disease-causing organisms. Disinfection should not be confused with sterilization. Sterilization is the complete killing of all living organisms. Waterworks operators disinfect by destroying organisms that might be dangerous, they do not attempt to sterilize water.

In water treatment, disinfection is almost always accomplished by adding chlorine or chlorine compounds after all other treatment steps, although in the U.S. ultraviolet (UV) light and ozone processes may be encountered.

The effectiveness of disinfection in a drinking water system is measured by testing for the presence or absence of coliform bacteria.

Coliform bacteria found in water are generally not pathogenic, though they are good indicators of contamination. Their presence indicates the possibility of contamination, and their absence indicates the possibility that the water is potable—if the source is adequate, the waterworks history is good, and an acceptable chlorine residual is present.

Desired characteristics of a disinfectant include the following:

- It must be able to deactivate or destroy any type or number of disease-causing microorganisms that may be in a water supply, in a water supply, in reasonable time, within expected temperature ranges, and despite changes in the character of the water (pH, for example).
- It must be nontoxic.
- It must not add unpleasant taste or odor to the water.
- It must be readily available at a reasonable cost and be safe and easy to handle, transport, store, and apply.
- It must be quick and easy to determine the concentration of the disinfectant in the treated water.
- It should persist within the disinfected water at a high enough concentration to provide residual protection through the distribution.

Disinfection is effective in reducing waterborne diseases because most pathogenic organisms are more sensitive to disinfection than are nonpathogens. However, disinfection is only as effective as the care used in controlling the process and assuring that all of the water supply is continually treated with the amount of disinfectant required producing safe water.

The methods of disinfection are as follows:

1. Heat—possibly the first method of disinfection. Disinfection is accomplished by boiling water for 5 to 10 minutes. Good, obviously, only for household quantities of water when bacteriological quality is questionable.
2. Ultraviolet (UV) light—while a practical method of treating large quantities, adsorption of UV light is very rapid, so the use of this method is limited to nonturbid waters close to the light source.
3. Metal ions—silver, copper, mercury.
4. Alkalis and acids
5. pH adjustment—to under 3.0 or over 11.0
6. Oxidizing agents—bromine, ozone, potassium permanganate, and chlorine

The vast majority of water systems in the U.S. use chlorine for disinfection. Along with meeting the desired characteristics listed above, chlorine has the added advantage of a long history of use—it is fairly well understood. Although some small water systems may use other disinfectants, we concentrate on chlorine.

Water Treatment Lagoon: An impound for liquid waste designed to accomplish some degree of biochemical treatment.

Water Use: Water that is used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use pertains to human's interaction with and influence on the hydrological cycle, and includes elements, such as water withdrawal from surface- and ground-water sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater-treatment plants, water returned to the environment, and instream uses, such as using water to produce hydroelectric power.

Water Vapor: The most visible constituent of the atmosphere (H_2O in vapor form).

Water Well: A excavation where the intended use is for location, acquisition, development, or artificial recharge of ground water.

Water Spray (Fog): Method or way to apply or distribute water. The water is finely divided to provide for high heat absorption. Water spray patterns can range from about 10 to 90 degrees. Water spray steams can be used to extinguish or control the burning of a fire or to provide exposure protection for personnel, equipment, buildings, etc. (From U.S. DOT ERG 2000)

Waters of the United States: According to the Code of Federal regulations, waters of the United States are defined as follows:

a. All waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;
b. All interstate waters including interstate wetlands;
c. All other waters such as interstate lakes, rivers streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet

meadows, playa lakes, or natural ponds the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce including any such waters:

1. Which are or could be used by interstate or foreign travelers for recreational or other purposes;
2. From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or
3. Which are used or could be used for industrial purposes by industries in interstate commerce;

d. All impoundments of waters otherwise defined as waters of the United States under this definition;
e. Tributaries of waters identified in paragraphs (a) through (d) of this definition;
f. The territorial sea; and
g. Wetlands adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs (a) through (f) of this definition.

Waste treatment systems, including treatment ponds or lagoons designed to meet the requirements of the Clean Water Act (other than cooling ponds as defined in 40 CFR 423.11(m) which also meet the criteria of this definition) are not waters of the United States. This exclusion applies only to manmade bodies of water which neither were originally created in waters of the Unites States (such as disposal area in wetlands) nor resulted from the impoundment of waters of the United States. [At 45 FR 48620, July 21, 1980, the Environmental Protection Agency suspended until further notice in § 122.2, the last sentence, beginning "This exclusion applies …" in the definition of "Waters of the United States."] Waters of the United States do not include prior converted cropland. Notwithstanding the determination of an area's status as prior converted cropland by any other federal agency, for the purposes of the Clean Water Act, the final authority regarding Clean Water Act jurisdiction remains with EPA [40 CFR 122.2].

Watt (Electric): The electrical unit of power. The rate of energy transfer equivalent to 1 ampere of eclectic current flowing under a pressure of 1 volt at unity power factor.

Watt (Thermal): A unit of power in the metric system, expressed in terms of energy per second, equal to the work done at a rate of 1 joule per second.

Watthour (Wh): An electrical energy unit of measure equal to one water of power supplied to, or taken from, an electrical circuit steadily for one hour.

Wave Energy:[1] Waves are caused by the wind blowing over the surface of the ocean. In many areas of the world, the wind blows with enough consistency and force to provide continuous waves. Wave energy does not have the tremendous power of tidal fluctuations but the regular pounding of the waves should not be underestimated because there is tremendous energy in the ocean waves. The total power of waves breaking on the world's coastlines is estimated at between 2 and 3 million megawatts. In optimal wave areas, more than 65 megawatts of electricity could be produced along a single mile of shoreline, according to the U.S. Office of Energy Efficiency and Renewable Energy (EERE, 2004). In essence, because the wind is originally derived from the sun, we can actually consider the energy in ocean waves to be a stored, moderately high-density form of solar energy. According to certain estimates, wave technologies could feasibly fulfill 10 percent of the global electricity supply if fully developed (World Energy 2010). The west coasts of the United States and Europe and the coast of Japan and New Zealand are good sites for harnessing wave energy.

Wave Energy: Facts, Parameters, and Equations

- Three main processes create waves: air flowing over the sea exerts a tangential stress on the water surface, resulting in the formation and growth of waves; turbulent air flow close to the water surface creates rapidly varying shear stresses and pressure fluctuations (when these oscillations are in phase with existing waves, further wave development occurs); and when waves have reached a certain size, the wind can exert a stronger force on the up-wind face of the wave, resulting in additional wave growth.
- Waves located within or close to the areas where they are generated are called storm waves.
- *Swell waves* can develop at great distances from the point of origin.
- The distance over which wind energy is transferred into the ocean to form waves is called the *fetch*.
- *Sea state* is the general condition of the free surface on a large body of water—with respect to wind waves and swell—at a certain location and moment. The World Meteorological Organization sea state code largely adopts the 'wind se' definition of the Douglas Sea Scale.

WMO Sea State Code	*Wave Height (meters)*	*Characteristics*
0	0	Calm (glassy)
1	0 to 0.1	Calm (rippled)
2	0.1 to 0.5	Smooth (wavelets)
3	0.5 to 1.25	Slight
4	1.25 to 2.5	Moderate
5	2.5 to 4	Rough
6	4 to 6	Very Rough
7	6 to 9	High
8	9 to 14	Very high
9	Over 14	Phenomenal

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[1] From DOI (2010) *Ocean Energy*. Accessed 03/31/10 @ www.mms.gov.

- The shape of a typical wave is described as *sinusoidal* (that is, it has the form of a mathematical sine function). The difference in height between the peaks troughs is known as the *height*, H, and the distance between successive peaks (or troughs) of the wave is known as the wavelength, λ. The time in seconds taken for successive peaks (or troughs) to pass a given fixed point is known as the *period*, *T*. The *frequency*, *v*, of the wave describes the number of peak-to-peak (or trough-to-trough) oscillations of the wave surface per second, as seen by a fixed observer, and is the reciprocal of the period. That is, v =1/T.

  If a wave is traveling at velocity v past a given fixed point, it will travel a distance equal to its wavelength λ in a time equal to the wave period T (i.e., $v = \lambda/T$). The power, P, (Kw/m) of an idealized ocean wave is approximately equal to the square of the height, H (meters), multiplied by the wave period, T (seconds). The exact expression is the following:

  $$P = \frac{g^2 H^2 T}{32}$$

  where P is in units of watts/m and g is the acceleration due to gravity (9.81 m s^{-2}) (Phillips, 1977).
- Deep water waves—the velocity of a long ocean wave can be shown to be proportional to the period (if the depth of water is greater than about half of the wavelength λ) as follows:

  $$v = \frac{gT}{2\pi}$$

  A useful approximation can be derived from this: velocity in meters/second is about 1.5 times the wave period in seconds. The result leads to deep ocean waves traveling faster than the shorter waves. Moreover, if the above relationships hold, we can find the deep water wavelength, λ, for any given wave period.

  $$\lambda = \frac{gT}{2\pi}$$

- Intermediate depth waves—as the water becomes shallower, the properties of the waves become increasingly dominated by water depth. When waves reach shallow water, their properties are completely governed by the water depth, but in intermediate depths (i.e., between $d = \lambda/4\pi$) the properties of the waves will be influenced by both water depth d and wave period T (Phillips 1977; Goda, 2000).
- Shallow water waves—as waves approach the shore, the seabed starts to have an effect on their speed, and it can be shown that if the water depth d is less than a quarter of the wavelength, the velocity is given by:

  $$v = \sqrt{gd}$$

- As waves propagate, their energy is transported. The energy transport velocity is the group velocity. As a result, the wave energy flux, through a vertical plane of unit width perpendicular to the wave propagation direction, equal to:

  $$P = E\, c_g$$

  where c_g is the group velocity (m/s).

Did You Know?

The wave height increases with increases in:

- wind speed
- time duration of the wind blowing
- fetch
- water depth

Wave Energy Conversion Technology: In the early 1970s, the harnessing of wave power focused on using floating devices such as Cockerell Rafts (a wave power hydraulic device), Salter Duck (curved-cam like device that can capture 90 percent of waves for energy conversion), Rectifier (concerts A-C to D-C electricity), and the Clam (a floating rigid toroid—i.e., doughnut-shaped—that converts wave energy to electrical energy). Wave energy converters can be classified in terms of their location: fixed to the seabed, generally in shallow water; floating offshore in deep water; or tethered in intermediate depths. At present, these floating devices are not cost effective and have very difficult moving problems. So current practice is to move in shore, sacrificing some energy but fixed devices, according to Tovey (2005), have several advantages, including:

- easier maintenance
- easier to land on device
- no mooting problem
- easier power transmission
- enhanced productivity
- better design life

Did You Know?

Hydro (water) Kinetic Energy is the energy possessed by a body of water because of its motion (KE = 1.2 mv2). Hydro-Static (at rest) Energy is the energy possessed by a body because of its position or location at an elevation or height above a reference or datum (PE = mgh)

Wave energy devices can be classified by means of their reaction system, but it is often more instructive to discuss how they interact with the wave field. In this context, each moving body may be lasted as either displace or reactor.

- Displacer—this is the body moved by the waves. It might be a buoyant vessel or a mass of water. If buoyant, the displacer may pierce the surface of the waves or be submerged.
- Reactor—this is the body that provides reaction to the displacer. As suggested above, it could a body fixed to the seabed, or the seabed itself. It could also be another structure or mass that is not fixed, but moves in such a way that reaction forces are created (e.g., by moving by a different amount or at different times). A degree of control over the forces acting on each body and/or acting between the bodies (particularly stiffness and damping characteristics) are often required to optimize the amount of energy captured.

Note: In some designs, the reactor is actually inside the displacer, while in others it is an external body. Internal reactors are not subject to wave forces, but external ones may experience loads that cause them to move in ways similar to a displacer. This can be extended to the view that some devices do not have dedicated reactors at all, but rather a system of displacers whose relative emotion create a reaction system (INEL 2005).

There are three types of well-known Wave Energy Conversion devices: Point absorbers, terminators, and attenuators.

- Point absorber—this is a floating structure that absorbs energy in all directions by virtue of its movements at or near the water surface. It many be designed so as to resonate—that its, move with larger amplitudes than the waves themselves. This feature is useful to maximize the amount of power that is available for capture. The power take-off system may take a number of forms, depending on the figuration of displacers/reactors.
- Terminator—this is also a floating structure that moves at or near the water surface, but it absorbs energy in only a single direction. The device extends in the direction normal to the predominant wave direction, sot that as waves arrive, the device restrains them. Again, resonance may be employed and the power take-off system may take a variety of forms.
- Attenuator—this device is a long floating structure like the terminator, but is orientated parallel to the waves rather than normal to them. It rides the waves like a ship and movements of the device at its bow and along its length can be restrained so as to extract energy. A theoretical advantage of the attenuator over the terminator is that its area normal to the waves is small and therefore the forces it experiences are much lower.

Weather: The day-to-day pattern of precipitation, temperature, wind, barometric pressure, and humidity.

Web Server: A software process that runs on a host computer connected to the Internet, intended to respond to HTTP requests for documents from client web browsers.

Weight: The force exerted upon any object by gravity.

Weight of Scientific Evidence: Considerations in assessing the interpretation of published information about toxicity—quality of testing methods, size and power of study design, consistency of results across studies, and biological plausibility of exposure-response relationships and statistical associations.

Weir: 1. A wall or plate placed in an open channel to measure the flow of water. 2. A wall or obstruction used to control flow from settling tanks and clarifiers to ensure a uniform flow rate and avoid short-circuiting.

Welding: The process of joining two or more pieces of material by applying heat, pressure, or both, with or without filler material, to produce a localized union through fusion or recrystallization across the interface.

Welding Safety: Welding is typically thought of as the electric arc and gas (fuel gas/oxygen) welding process. However, welding can involve many types of processes. Some of these other processes include inductive welding, thermite welding, flash welding, percussive welding, plasma welding, and others. McElroy (1980) points out that the most common type of electric arc welding also has many variants including gas shielded welding, metal arc welding, gas-metal arc welding, gas-tungsten arc welding, and flux cored arc welding.

Welding, cutting, and brazing are widely used processes. OSHA's Subpart Q contains the standards relating to these processes in all of their various forms. The primary health and safety concerns are fire protection, employee personal protection, and ventilation. The standards contained in this subpart include:

1910.251	Definitions
1910.2512	General Requirements
1910.2513	Oxygen-fuel gas welding and cutting
1910.2514	Arc welding and cutting
1910.2515	Resistance welding
1910.2516	Sources of standards
1910.2517	Standards organization

In examining an OSHA study (reported in *Professional Safety*, Feb. 1989) on deaths related to welding/cutting incidents, it is striking to note that of 200 such deaths over an eleven-year period, 80 percent were caused by failure to practice safe work procedures. Surprisingly, only 11 percent of deaths involved malfunctioning or failed equipment, and only 4 percent were related to environmental factors. The implications of this study should be obvious: equipment malfunctions or failures are not the primary causal factor of hazards presented to workers. Instead, the safety engineer's emphasis should be on establishing and ensuring safe work practices for welding tasks.

The Fire Prevention and Protection element of any welding safety program begins with basic precautions. These basic precautions include the following:

1. Fire Hazards—if the material or object cannot be readily moved, all movable fire hazards in the area must be moved to a safe location.
2. Guards—if the object to be welded or cut can't be moved, and if all the fire hazards can't be removed, then guards must be used to confine the heat, sparks, and slag, and to protect the immovable fire hazards.
3. Restrictions—if the welding or cutting can't be performed without removing or guarding against fire hazards, then the welding and cutting should not be performed.
4. Combustible material—wherever floor openings or cracks in the flooring can't be closed, precautions must be taken so that no readily combustible materials on the floor below are exposed to sparks that might drop through the floor. The same precautions should be taken with cracks or holes in walls, open doorways, and open or broken windows.
5. Fire extinguishers—suitable fire extinguishing equipment must be maintained in a state of readiness for instant use. Such equipment may consist of pails of water, buckets of sand, hoses or portable extinguishers, depending upon the nature and quantity of the combustible material exposed.
6. Fire watch—firewatchers are required whenever welding or cutting is performed in locations where other than a minor fire might develop. Firewatchers must have fire-extinguishing equipment readily available, and must be trained in its use. They must be familiar with facilities for sounding an alarm in the event of fire. They must watch for fires in all exposed areas, try to extinguish them only when obviously within the capacity of the equipment available, or otherwise sound the alarm. A fire watch must be maintained for at least a half-hour after completion of welding or cutting operations, to detect and extinguish possible smoldering fires.
7. Authorization—before cutting or welding is permitted, the individual responsible for authorizing cutting and welding operations must inspect the area. The responsible individual must designate precautions to be followed in granting authorization to proceed preferably in the form of a written permit (Hot Work Permit).
8. Floors—Where combustible materials such as paper clippings, wood shavings, or textile fibers are on the floor, the floor must be swept clean for a radius of at least 35 feet (OSHA requirement). Combustible floors must be kept wet, covered with damp sand, or protected by fire-resistant shields. Where floors have been wet down, personnel operating arc welding or cutting equipment must be protected from possible shock.
9. Prohibited areas—welding or cutting must not be permitted in areas that are not authorized by management. Such areas include: in sprinklered buildings while such protection is impaired; in the presence of explosive atmospheres, or explosives atmospheres that may develop inside uncleaned or improperly prepared tanks or equipment that have previously contained such materials, or that may develop in areas with an accumulation of combustible dusts; and in areas near the storage of large quantities of exposed, readily ignitable materials such as bulk sulfur, baled paper, or cotton.
10. Relocation of combustibles—where practicable, all combustibles must be relocated at least 35 feet from the work site. Where relocation is impracticable, combustibles must be protected with fireproofed covers, or otherwise shielded with metal of fire-resistant guards or curtains.
11. Ducts—ducts and conveyor systems that might carry sparks to distant combustibles must be suitably protected or shut down.
12. Combustible walls—where cutting or welding is done near walls, partitions, ceilings or roofs of combustible construction, fire-resistant shields or guards must be provided to prevent ignition.
13. Noncombustible walls—if welding is to be done on a metal wall, partition, ceiling or roof, precautions must be taken to prevent ignition of combustibles on the other side from conduction or radiation, preferably by relocating the combustibles. Where combustibles are not relocated, a fire watch on the opposite side from the work must be provided.
14. Combustible cover—welding must not be attempted on a metal partition wall, ceilings or roofs that have combustible coverings, nor on any walls or partitions, ceilings or roofs that have combustible coverings, or on walls or partitions of combustible sandwich-type panel construction.

15. Pipes—cutting or welding on pipes or other metal in contact with combustible walls, partitions, ceilings or roofs must not be undertaken if the work is close enough to cause ignition by conduction.
16. Management—management must recognize its responsibility for the safe usage of cutting and welding equipment on its property, must establish areas for cutting and welding, and must establish procedures for cutting and welding in other areas. Management must also designate an individual responsible for authorizing cutting and welding operations in areas not specifically designed for such processes. Management must also insist that cutters or welders and their supervisors are suitably trained in the safe operation of their equipment, and the safe use of the process. Management has a duty to inform contractors about flammable materials or hazardous conditions of which they may not be aware.
17. Supervisor—The supervisor has many responsibilities in welding and cutting operations, including:
    - responsibility for the safe handling of the cutting or welding equipment, and the safe use of the cutting or welding process.
    - determining the combustible materials and hazardous area present or likely to be present in the work location.
    - protecting combustibles from ignition by whatever means necessary.
    - securing authorization for the cutting or welding operations from the designated management representative.
    - ensuring that the welder or cutter secures his or her approval that conditions are safe before going ahead.
    - determining that fire protection and extinguishing equipment are properly located at the site.
    - ensuring that when fire watches are required, fire watchers are available at the site.
18. Fire prevention precautions—cutting and welding must be restricted to areas that are or have been made fire safe. When work can't be move practically, as in most construction work, the area must be made safe by removing combustibles or protecting combustibles from ignition sources.
19. Welding and cutting used containers—no welding, cutting, or other hot work is to be performed on used drums, barrels, tanks or other containers until they have been cleaned so thoroughly as to make absolutely certain that no flammable materials are present, or any substances such as greases, tars, acids, or other materials that when subjected to heat, might produce flammable or toxic vapors. Any pipelines or connections to the drum or vessel must be disconnected or blanked.
20. Venting and purging—all hollow spaces, cavities or containers must be vented to permit the escape of air or gases before preheating, cutting or welding. Purging with inert gas (e.g., nitrogen) is recommended.
21. Confined Spaces—to prevent accidental contact in confined space operations involving hot work, when arc welding is to be suspended for any substantial period of time (such as during lunch or overnight), all electrodes are to be removed from the holders and the holders carefully located so that accidental contact can't occur. The machine must be disconnected from the power source. To eliminate the possibility of gas escaping through leaks or improperly closed valves, when gas welding or cutting, the torch valves must be closed and the gas supply to the torch positively shut off at some point outside the confined area whenever the torch is not to be used for a substantial period of time (such as during lunch hour or overnight). Where practicable, the torch and hose must also be removed from the confined space.

Personnel involved in welding or cutting operations must not only learn and abide by safe work practices, but also must be aware of possible bodily dangers during such operations. They must learn about the PPE (personal protective equipment) and other protective devices/measures designed to protect them.

1 Railing and welding cable—a welder or helper working on platforms, scaffolds, or runways must be protected against falling. This may be accomplished by the use of railings, safety harnesses, lifelines, or other equally effective safeguards. Welders must place welding cable and other equipment so that it is clear of passageways, ladders, and stairways.

2. Eye protection—Helmets or hand shields must be used during all arc welding or arc cutting operations (excluding submerged operations). Helpers or attendants must be provided with the same level of proper eye protection.

   Goggles or other suitable eye protection must be used during all gas welding or oxygen cutting operations. Spectacles without side shields with suitable filter lenses are permitted for use during gas welding operations on light work, for torch brazing, or for inspection.

   Operators and attendants of resistance welding or resistance brazing equipment must use transparent face shields or goggles (depending on the particular job) to protect their faces or eyes as required.

   Helmets and hand shields must meet certain specifications, including being made of a material that is an insulator for heat and electricity. Helmets, shields and goggles must not be readily flammable and must be capable of sterilization. Helmets and hand shields must be so arranged to protect the face, neck and ears from direct radiant energy from the arc. Helmets must be provided with filter plates and cover plates designed for easy removal. All parts must be constructed of a material that will not readily corrode or discolor the skin.

Goggles must be ventilated to prevent fogging of the lenses as much as possible. All glass for lenses must be tempered and substantially free from striae, air bubbles, waves and other flaws. Except when a lens is ground to provide proper optical correction for defective vision, the front and rear surfaces of lenses and windows must be smooth and parallel. Lenses must also bear some permanent distinctive marking by which the source and shade may be readily identified. The table below provides a guide for the section of the proper shade numbers. These recommendations may be varied to suit the individual's needs.

Light Shield-Shade Guide

WELDING OPERATION	*SHADE NUMBER*
Shielded metal-arc welding	10
Gas-shielded arc welding (nonferrous)	11
Gas-shielded arc welding (ferrous)	12
Shielded metal-arc welding:	
3/16-, 7/32-, 1/4-inch electrodes	12
5/16-, 3/8-inch electrodes	14
Atomic hydrogen welding	10-14
Carbon arc welding	14
Soldering	14
Torch brazing	2
Light cutting, up to 1 inch	3 or 4
Medium cutting, 1 inch to 6 inches	4 or 5
Heavy cutting, 6 inches and over	5 or 6
Gas welding (light) up to 1/8 inch	4 or 5
Gas welding (medium) 1/8 inch to 1/2 inch	5 or 6
Gas welding (heavy) 1/2 inch and over	6 or 8

Note: In gas welding or oxygen cutting where the torch produces a high yellow light, use a filter or lens that absorbs the yellow or sodium line in the visible light of the operation.
Source: 29 CFR 1910.252, OSHA.

All filter lenses and plates must meet the test for transmission of radiant energy prescribed in ANSI Z87.1 -1968-American National Standard Practice for Occupational and Educational Eye and Face Protection.

Where the work permits, the welder should be enclosed in an individual booth painted with a finish of low reflectivity (such as zinc oxide and lamp black), or must be enclosed with noncombustible screens similarly painted. Booths and screens must permit circulation of air at floor level. Workers or other persons adjacent to the welding areas must be protected from the rays by noncombustible or flameproof screens or shields, or must be required to wear appropriate eye protection.

3. Protective clothing—employees exposed to the hazards created by welding, cutting, or brazing operations must be protected by personal protective equipment, including appropriate protective clothing required for any welding operation.
4. Confined spaces—for welding or cutting operations conducted in confined spaces (i.e., in spaces that are relatively small, or restricted spaces such as tanks, boilers, pressure vessels, or small compartments of a ship) personal protective and other safety equipment must be provided.

Protection of personnel performing hot work in confined spaces includes:

- Proper ventilation;
- Gas cylinders and welding machines must be left on the outside and secured to prevent movement;
- Where a welder must enter a confined space through a manhole or other small opening, means (lifelines) must be provided for quickly removing him or her in case of emergency;
- When arc welding is to be suspended for any substantial period of time, all electrodes must be removed from the holds, the holders carefully located so that accidental contact can't occur, and the machine disconnected from the power source;
- To eliminate the possibility of gas escaping through leaks of improperly closed valves, when performing gas welding or cutting, the torch valves must be closed and the fuel-gas and oxygen supply to the torch positively shut off at some point outside the confined area whenever the torch is not to be used for a substantial period of time;
- After welding operations are completed, the welder must mark the hot metal or provide some other means of warning others.

All welding should be accomplished in well-ventilated areas, with sufficient movement of air to prevent accumulation of toxic fumes or possible oxygen deficiency. Adequate ventilation becomes extremely critical in confined spaces where dangerous fumes, smoke, and dust are likely to collect.

Where considerable hot work is to be performed, an exhaust system is necessary to keep toxic gases below the prescribed health limits. An adequate exhaust system is especially necessary when hot work is performed on zinc, brass, bronze, lead, cadmium, or beryllium-bearing metals. This also includes galvanized steel, and metal painted with lead-bearing paint. Fumes from these materials are toxic—they are very hazardous.

What does OSHA require for ventilation for hot work operations? The requirements include:

Ventilation must be provided when:

- hot work is performed in a space of less than 10,000 cubic feet per welder;
- hot work is performed in a room having a ceiling height of less than 16 feet;
- hot work is performed in confined spaces where the hot workspace contains partitions, balconies, or other structural barriers to the extent that they significantly obstruct cross ventilation.

The minimum rate of ventilation must be:

- the minimum rate of 2,000 cubic feet per minute per welder, except where local exhaust hoods and booths are provided, or where approved airline respirators are provided.

Well (Water): An artificial excavation put down by any method for the purposes of withdrawing water from the underground aquifers. A bored, drilled, or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies or oil, or to store or bury fluids below ground.

Well Field: Area containing one or more wells that produce usable amounts of water or oil.

Well Injection: The subsurface emplacement of fluids into a well.

Well Log: Logging includes measurements of the diameter of the well and various electrical, mass, and nuclear properties of the rock which can be correlated with physical properties of the rock. The well log is a chart of the measurement relative to depth in the well.

Well Monitoring: Measurement by on-site instruments or laboratory methods of well water quality.

Well Plug: A watertight, gastight seal installed in a bore hole or well to prevent movement of fluids.

Well Point: A hollow vertical tube, rod, or pipe terminating in a perforated pointed shoe and fitted with a fine-mesh screen.

Well Systems: The most common method for withdrawing groundwater is to penetrate the aquifer with a vertical well, then pump the water up to the surface.

In the past, when someone wanted a well, they simply dug (or hired someone to dig) and hoped (gambled) that they would find water in a quantity suitable for their needs. Today, in most locations in the U.S., for example, developing a well supply usually involves a more complicated step-by-step process.

Local, state, and federal requirements specify the actual requirements for development of a well supply in the United States. The standard sequence for developing a well supply generally involves a seven-step process. This process includes

Step 1: Application—Depending on location, filling out and submitting an application (to the applicable authorities) to develop a well supply is standard procedure.

Step 2: Well site approval—Once the application has been made, local authorities check various local geological and other records to ensure that the siting of the proposed well coincides with mandated guidelines for approval.

Step 3: Well drilling—The well is then drilled.

Step 4: Preliminary engineering report—after the well id drilled and the results documented, a preliminary engineering report is made on the suitability of the site to serve as a water source. This procedure involves performing a pump test to determine if the well can supply the required amount of water. The well is generally pumped for at least six hours at a rate equal to or greater than the desired yield. A stabilized drawdown should be obtained at that rate and the original static level should be recovered within 24 hours after pumping stops. During this test period, samples are taken and tested for bacteriological and chemical quality.

Step 5: Submission of documents for review and approval—The application and test results are submitted to an authorized reviewing authority that determines if the well site meets approval criteria.

Step 6: Construction permit—If the site is approved, a construction permit is issued.

Step 7: Operation permit—When the well is ready for use, an operation permit is issued.

Wet Basis: Refers to the fraction of a given constituent in a moist mixture as a proportion of the total weight of dry matter plus incorporated water. Is always numerically less than the corresponding “dry basis” proportion.

Wetland: A lowland area, such as a marsh or swamp, saturated with moisture and usually thought of as natural wildlife habitat.

Wet Scrubber: A treatment device (a stacked tower, for example) in which the contaminant wastestream is passed through microorganism- laden media or through a chemical spray (such as caustic) to degrade and/or neutralize the harmful affects of the contaminant(s).

Wettability: The relative degree to which a fluid will spread into or coat a solid surface in the presence of other immiscible fluids.

Wettable Powder: Dry formulation that must be mixed with water or other liquid before it is applied.

Wetted Perimeter: The line on which the stream's surface meets the channel walls.

Wet-Weight Percentage: The ratio of the weight of any constituent to the typical hydrated weight of the whole plant part as harvested.

Wheal: A small elevation or swelling on the skin that usually itches or burns.

Wheeling: The transmission of electricity owned by one entity through the facilities owned by another (usually a utility).

White Goods: Large solid waste items such as household appliances (refrigerators, stoves, dish washers, washers and dryers, etc.)

Whole Body Vibration: Exposure of the whole body to vibration (usually through the feet/buttocks when riding in a vehicle). Whole body vibration may increase the risk for injury, including low back pain and internal organ disruption.

Whole-Effluent-Toxicity Tests: Tests to determine the toxicity levels of the total effluent from a single source as opposed to a series of tests for individual contaminants.

Wicket Gate: Adjustable elements that control the flow of water to the turbine passage.

Wicking: Te phenomenon of liquid transmission within the fabric yarns of reinforced geomembranes via capillary action.

Wildlife Refuge: An area designated for the protection of wild animals, within which hunting fishing are either prohibited or strictly controlled.

Wilfley Table: A plane rectangle is mounted horizontally and can be slopped about its axis. Gentle and rapid throwing motion is used on the tab le longitudinally. Sands usually classified for size range are fed continuously and worked along the table with the aid of feedwater, and across riffles downslope by gravity tilt adjustment, and added washwater. At the discharge end, the sands have separated into bands, the heaviest and smallest upper most, the lightest and largest lower.

Willow Carr: A pool or wetland dominated by willow trees or shrubs.

Wind: Horizontal air motion.

Wind and Breezes: Local conditions caused by the circulating movement of warm and cold air (convection) and differences in heating.

Wind Energy: Energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators Wind pushes against sails, vanes, or blades radiating from a central rotating shaft.

Wind Power Plant: A group of wind turbines interconnected to a common utility system through a system of transformers, distribution lines, and (usually) one substation. Operation, control, and maintenance functions are often centralized through a network of computers monitoring systems, supplement by visual inspection. This a term commonly used in the United States. In Europe, it is called a generating station.

Wind Rose: A diagram that indicates the average percentage of time that the wind blows from different directions on a monthly or annual basis.

Wind Turbine or Windmill: A device for harnessing the kinetic energy of the wind and using it to do work, or generate electricity.

Wind Vane: Wind direction measurement device, used to send data to the yaw drive.

Windward: Into, or facing the direction of the wind. Opposite of Leeward.

Winter Kill: A condition that can occur in a lake or pond when the entire water mass is frozen, thereby killing all inhabitants.

Winter Stratification: In a lake in winter, the condition that occurs when the epilimnion is icebound, is at the lowest temperature and thus lightest, the thermocline is at medium temperature and medium weight, and the hypolimnion is at about 4C and heaviest.

Wire and Cable: Used for the distribution of electric power and consists of a conducting medium, usually enclosed within an insulating sheath, and sometimes further protected by an outer jacket.

Wire Rope: The most widely used type of rope sling in industry is the cable-laid 6 x 19 and 6 x 37 wire rope. By definition, wire rope is a twisted bundle of cold drawn steel wires, usually composed of wires, strands, and a core. When used in rope slings, wire ropes must have a minimum clear length of wire rope 10 times the component rope diameter between splices, sleeves, or end fittings. The main reasons for the wide usage of wire over fiber rope are its greater strength, durability, predictability of stretch characteristics when placed under heavy stresses and stable physical characteristics over a wide variety of environmental conditions. The main advantages of pre-formed wire rope are its lessened tendency to unwind, set, kink, or generate sharp protruding wires.

Wiretapping: Monitoring and recording data t flowing between two points in a communication system.

Wire-to-Wire Efficiency: The efficiency of a pump and motor together.

Withdrawal: Water removed from a ground- or surface-water source for use.

Wood-Burning-Stove Pollution: Air pollution caused by emissions of particulate matter, carbon monoxide, total suspended particulates, and polycyclic organic matter from wood-burning stoves.

Wood Packaging: Wood products such as pallets, crate, and barrels.

Wood Treatment Facility: An industrial facility that treats lumber and other wood products for outdoor use. The process employees chromated copper arsenate, which is regulated as a hazardous material

Wood/Wood Waste: The category of biomass energy includes: black liquor; wood/wood waste liquids (red liquor, sludge wood, spent sulfite liquor); wood/wood waste solids (peat, paper pellets, railroad ties, utility poles, wood/wood waste).

Worker Population Limit (WPL): An airborne exposure limit designed to protect workers. It is expressed as a time-weighted average (TWA) of exposure over an 8-hour work shift.

Workers' Compensation: A system of insurance required by state law and financed by employers that provides payments to employees and their families for occupational illnesses, injuries, or fatalities incurred while at work and resulting in loss of wage income, usually regardless of the employer's or employee's negligence.

Working Level (WL): A unit of measure for documenting exposure to radon decay products, the so-called "daughters." One working level is equal to approximately 200 picocuries per liter.

Working Level Month (MLM): A unit of measure used to determine cumulative exposure to radon.

Workplace Violence

Glen (Coffee shop employee, behind the counter):Anything wrong, Davy?
Davy (customer seated at the counter):Yeah. I got paid today.
Glen: Oh, yeah. I know what that's like.
Davy: No, you don't understand. They laid me off. I got one of these. (holds up pink slip.)
Glen: Yeah, I know how that feels.
Davy: You know what I'd like to do?
Glen: Yeah. I know what you'd like to do. You'd like to find the guy who did it, rip his still-beating heart out of his chest and hold it in front of his eyes so he can see how black it is before he dies.
Davy: Actually, I was thinking about filing a grievance with the union.
Glen: Well, the world's a twisted place.
M. Myers. *Wayne's World.* Paramount Pictures. 1992

Virtually unheard of thirty years ago, murder in the workplace is now one of the fastest growing types of homicide in the United States. OSHA (2002) and the Bureau of Labor (2003) statistics estimated that the rate of workplace homicide has tripled in the last decade. In 1992 an average of three people were murdered on the job every working day. Workplace homicide is now the number one cause of occupational death for women and the third for men, after driving and machinery accidents.

The number-one attacker in the workplace is the customer at 45 percent; 25 percent of attacks are by strangers; 20 percent by co-workers; 7 percent by bosses; and only 3 percent by former employees. The three most common known reasons for workplace violence are revenge, jealousy, and financial gain (Revenge and jealousy are by far the most troublesome: an estimated one out of every six emergency 911 calls are in some way related to a romantic obsession.) The Center for Disease Control (1996) has classified Workplace Violence as a National Disease Epidemic.

Environmental conditions associated with workplace assaults have been identified and control strategies implemented in a number of work settings. OSHA has developed guidelines and recommendations to reduce worker exposure to this hazard, but is not initiating rulemaking at this time.

Worm: A computer program that can run independently, propagating a complete working version of itself onto other hosts on a network, and consuming computer resources destructively.

Worms: In stream ecology, the presence of certain species of worms in bottom sediment indicates stream pollution.

Wrap: Using cryptography to provide data confidentiality service for a data object.

X

Xenobiota: Any biotum displaced from its normal habitat; a chemical foreign to a biological system.

Xenobiotics: Any chemical present in a natural environment that does not normally occur in nature; for example, pesticides and/or industrial pollutants.

Xeriscaping: A method of landscaping that uses plants that are well adapted to the local area and are drought-resistant. Xeriscaping is becoming more popular as a way of saving water at home.

Xerostomia: Abnormal dryness of the mouth.

X-ray: Penetrating type of photon radiation emitted from outside the nucleus of a target atom during bombardment of a metal with fast electrons.

Y

Yard Waste: The part of solid waste composed of grass clippings, leaves, twigs, branches, and other garden refuse.

Yellow-Boy: Iron oxide flocculant (clumps of solids in waste or water); usually observed as orange-yellow deposits in surface streams with excess iron content. A classic example of Yellow Boy can be seen in following example:

When the Animas River Became a Yellow Boy[1]
The Day: Wednesday
The Date: August 5, 2015
The Place: Near Silverton, Colorado
The Event: Gold King Mine Spill
Surface Water Body Affected: Cement Creek, Animas, San Juan and Colorado River
Watershed: Includes Six U.S. States (Colorado, Utah, New Mexico, Arizona, Nevada, California)
Sources and References: US EPA(a), 2015. United States Environmental Protection Agency, Frequent Questions Related to Gold King Mine Response. http://www2.epa.gov/goldkingmine/frequent-questions-related-gold-king-mine-response. Accessed January 2, 2016; US EPA(b), 2015. United States Environmental Protection Agency, Gold King Mine Incident: Preliminary Analytical Data Upper Animas River (page 6), 15 August 2015. http://www2.epa.gov/sites/production/fiels/2015:08/documents/preliminarydata_08092015.pdf. Accessed January 1, 2016.

THE 411 ON THE GOLD KING MINE SPILL

During a United States Environmental Protection Agency (US EPA) mine site investigation of the abandoned Gold King Mine above the old adit (a mine tunnel), to:

- assess the on-going water releases from the mine
- treat mine water
- assess the feasibility of further mine remediation

Heavy equipment disturbed loose material around a soil "plug" at the mine entrance, spilling about three million gallons of pressurized water stored behind the collapsed material into Cement Creek, a tributary of the Animas River.

The spill volume associated with the release on August 5 is calculated to be approximately three million gallons based on flow rates. Current discharge rates (November 5, 2015) from the mine are averaging around 600 gallons per minute. It is important to point out, for context, there are multiple mines along the upper Animas, and historically there has been considerable discharge at each mine site. The Red and Bonita Mine, just below Gold King Mine, are currently discharging about 300 gallons per minute.

One of the results and striking features (quite apparent to all who witnessed it) of the Gold King Mine spill was the color change to Cement Creek and Animas River and to a lesser degree downstream almost to the San Juan River. The iron from the red-orange acid mine drainage settled into the water, turning it yellow. Old-time goldpanners and other sluice miners referred to this as "yellow boy." As more water is mixed in (dilution is the solution to pollution, according that mythical hero Hercules, who I argue might have been the world's first environmental engineer), iron and other metals become even more dilute and/or get attached to solids (sediments), causing them to drop out of the water (sink) and settle into river bottom sediments, and the water color returns to normal.

But, and this is the gist of this text, what appears normal in surface water bodies (or any environmental medium) may not be normal because, as in the case of the Animas River and thousands of other polluted streams,

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[1] From F.R. Spellman (2017). *Contaminated Sediments in Fresh Water Systems*. Boca Raton, FL: CRC Press.

what we are able to see at the surface does not in any way certify the quality of the water contained within the water body.

Yellow Zone: Areas where contamination with chemical, biological, radiological, or nuclear (CBRN) agent is possible but active release has ended and initial monitoring exists.

Yellowcake: A natural uranium concentrate that takes its name from its color and texture. Yellowcake typically contains 70 to 90 percent U_3O_8 by weight. It is used as feedstock for uranium fuel enrichment and fuel pellet fabrication.

Yield: 1. Mass per unit time per unit area. 2.The quantity of water (expressed as a rate of flow or total quantity per year) that can be collected for a given use from surface or groundwater sources.

Yield Point: The intensity of stress beyond which the change in length increases rapidly with little (if any) increase in stress.

Yield, Optimal: An optimal amount of groundwater, by virtue of its use, that should be withdrawn from an aquifer system or groundwater basin each year. It is a dynamic quantity that must be determined from a set of alternative groundwater management decisions subject to goals, objectives, and constraints of the management plan.

Yield, Perennial: The amount of usable water from an aquifer than can be economically consumed each year for an indefinite period of time. It is a specified amount that is commonly specified equal to the mean annual recharge to the aquifer system, which thereby limits the amount of groundwater that can be pumped for beneficial use.

Yield, Safe: The amount of groundwater that can be safely withdrawn from a groundwater basin annually, without producing an undesirable result. Undesirable results include but are not limited to depletion of groundwater storage, the intrusion of water of undesirable quality, the contraventions of existing water rights, the deterioration of the economic advantages of pumping (such as excessively lower water level sand the attendant increased pumping lifts and associated energy costs), excessive depletion of stream flow by induced infiltration, and land subsidence.

Z

Zero Air: Atmospheric air purified to contain less than 0.1 ppm total hydrocarbons.

Zero Energy State Energy: The state of equipment in which every power source that can produce movement of a part of the equipment, or the release of energy, has been rendered inactive.

Zeta Potential: The electrokinetic potential in colloidal dispersions.

Zinc (Zn): A metal that is found naturally in air, soil, water, and foods. It is used in brass alloys, bronze, die-casting alloys, galvanizing iron, fungicides, smoke bombs, pharmaceuticals, pennies, and as a protective coating for other metals.

Zirconium (Zr): A transition metal with atomic number 40; atomic weight 91.22; density 6.49 g/cc; melting point 1852° C and boiling point 3580°C.

Zonal Isolation: Various methods to selectively partition portions of the wellbore for stimulation, testing, flow restriction, or other purpose.

Zone: An area within the interior space of a building, such as an individual room(s), to be cooled, heated, or ventilated. A zone has its own thermostat to control the flow of conditioned air into the space.

Zone of Aeration: The zone above the water table. Water in the zone of aeration does not flow into a well.

Zone of Capillarity: The area above a water table where some or all of the interstices (pores) are filled with water that is held by capillarity.

Zone of Initial Dilution (ZID): The region of initial mixing surrounding or adjacent to the end of the outfall pipe or diffuser ports, provided that the ZID may not be larger than allowed by mixing zone restriction in applicable water quality standards.

Zone of Recent Pollution In streams or rivers, the point of pollution discharge.

Zone of Saturation The layer beneath the surface of the land containing openings that my fill with water.

Zone of Sedimentation: The zone with settled solids in a sedimentation or clarifier tank.

Zooglea: Bacteria embedded in a jelly-like matrix formed as the result of metabolic activities.

Zoogleal Film: A jelly-like matrix developed by bacteria formed in treatment devices. For example, in wastewater treatment unit operations a Rotating Biological Contactor (RBC) may be used. As the RBC rotates, the attached biomass film (zoogleal slime) that grows on the surface of the disks moves into and out of the wastewater. While submerged in the wastewater, the microorganisms absorb organics; while they are rotated out of the wastewater, they are supplied with needed oxygen for aerobic decomposition. As the zoogleal slime re-enters the wastewater, excess solids and waste products are stripped off the media as *sloughings.* These sloughings are transported with the wastewater flow to a settling tank for removal.

Zooplankton: Small (often microscopic) free-floating aquatic plants or animals.

Zooxanthllae: Very small yellow-green algae.

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About the Author

Frank R. Spellman, PhD, is a retired assistant professor of environmental health at Old Dominion University, Norfolk, Virginia, and the author of more than 155 books, with two more in the works, covering topics ranging from concentrated animal feeding operations (CAFOs) to all areas of environmental science and occupational health. Many of his texts are readily available online, and several have been adopted for classroom use at major universities throughout the United States, Canada, Europe, and Russia; two have been translated into Spanish for South American markets. Dr. Spellman has been cited in more than 850- publications. He serves as a professional expert witness for three law groups and as an incident/accident investigator for the U.S. Department of Justice and a northern Virginia law firm. In addition, he consults on homeland security vulnerability assessments for critical infrastructures including water/wastewater facilities nationwide and conducts pre-Occupational Safety and Health Administration (OSHA)/Environmental Protection Agency audits throughout the country. Dr. Spellman receives frequent requests to co-author with well-recognized experts in several scientific fields; for example, he is a contributing author of the prestigious text *The Engineering Handbook,* 2nd ed. (CRC Press). Dr. Spellman lectures on sewage treatment, water treatment, biosolids and homeland security and safety topics throughout the country and teaches water/wastewater operator short courses at Virginia Tech (Blacksburg, Virginia). He holds a BA in public administration, a BS in business management, an MBA, and an MS and PhD in environmental engineering.