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Amelioration Technology for Soil Sustainability

Ashok K. Rathoure

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Ashok K. Rathoure
Biohm Consultare Pvt Ltd, India

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Nutrients play a key role in maintaining soil fertility. Regular use of chemical fertilizers has great impact on soil infertility. Nutrient supply for soil sustainability is the most important step to maintain the fertility and integrity. The enrichment of soil with organic matter could reduce the content of bioavailable metal species as a result of complexation of free ions of heavy metals. The NPK ratio in the soil should be maintained for the good crop yield. There are various organic and inorganic materials available to mix with soil to enhance the soil fertility. Misuse of soil amendment can result not only in damage to crops but can also cause negative impact on soil fertility.

The sustainable concepts for increased crop production are immediately needed to lower pressure on soils in order to reduce or prevent the negative environmental impacts of rigorous agriculture. One efficient way to increase organic matter in soil is amelioration in soil like compost, biochar, fly ash, red mud, phosphate rock, and other rock minerals. On the one hand, growth of livestock breeding and intensification of crop production has occurred while an increasing shortage of resources can be recognized. On the other hand, urbanization and growing population interconnected with an increased amount of waste output is responsible for environmental hazards and pollution. Therefore, soil amelioration became an efficient means of agricultural crop improvement.

Soil plays a vital role in supporting the growth of crops and other vegetation, maintaining the environment, and acting as source and sink for atmospheric gases. Soils are natural bodies on which plants grow. The increasing population, industrialization, and changing lifestyle have negative effect on soil and are responsible for soil pollution. Good soil and climate for more crop production are valuable things for any nation. Soil amendments can be used to cost-effectively reduce the bio-availability and mobility of toxic metals in contaminated soils. Organic amendments considerably affect nutrient balance and interaction mobility of nutrients by influencing the chemical, physical, and biological environment in soils. Here in this chapter, the author has discussed the soil, its profile and type, analysis, and benefits on rock phosphate amendments.

Soil is an important and complex part of our environment. The agro-ecosystem is made up of many interacting components with multiple goals. Soil quality is one important part of sustainable agro-ecosystem management, analogous to water and air quality. Assessing soil quality may help managers identify practices that could be adapted to become more sustainable. Soil quality is the ability of a soil to perform functions that are essential to people and the environment. Soil quality is not limited to agricultural soils, although most soil quality work has been done in agricultural systems. Soil quality definitions emphasize several features. Dynamic properties include organic matter, soil structure, infiltration rate, bulk density, and water and nutrient holding capacity. Changes in dynamic properties depend both on land management practices and the inherent properties of the soil. Here, the author has presented for intrinsic and vigorous properties, soil structures and macrophores, soil quality management, etc.

Fly ash is one of the major global pollutants which is produced in millions of tons every year. The high content of heavy metals in fly ash categorizes them as hazardous materials. The presence of ferrous, alumina, and silica along with numerous macro- and micro-nutrients make them a suitable candidate for applications in agriculture, forestry, wasteland reclamation, soil stabilizer, etc. Fly ash has positive effects on the plant growth and crop yield. A numerous literature has reported the applications of fly ash as pesticides, herbicides, and insecticides. It has both alkaline and acidic pH which helps in maintaining the pH of the infertile soil. All these applications are cited with the previous work carried out by the investigators.

Soil amendments can be used to cost-effectively reduce the bioavailability and mobility of toxic metals in contaminated soils. Phosphate amendments effectively can be transformed to soil from the non-residual (sum of exchangeable, carbonate, Fe/Mn, and organic) to the residual fraction. Metal immobilization can be attributed to the metal-induced formation of chloropyromorphite which can be identified in the surface soil, subsurface soil, and plant rhizosphere soil. Phosphate treatments can significantly reduce metal translocation from the roots to the shoots in the plants/crops possibly via the formation of chloropyromorphite on the cell walls of roots. Application of combined H3PO4 with phosphate rock can be provided an effective alternative to the current phosphate remediation technologies for contaminated soils.

Soil mitigation is an approach to reduce the soil degradation occurring in all aspects. Soil contamination mainly happens due to release of varieties of inorganic and organic constituents into soil. Presence of highly poisonous contaminants into soil in high concentrations is enough to cause a threat to ecosystem and on human health. Sustainable approaches can be designed by the direct and indirect utilization of microbes and plants to reduce the soil pollution load. The utilization of microbes with plants in "synergy" is considered as one of the most fruitful approaches for the

promote vegetation growth.

The area in question has diversified relief and amount of rainfall and soil types. It is dry region lies in east, irrigated region in north and tribal-dominant population dominant in the west. Ahmednagar district is situated partly in the upper Godavari basin and partly in the Bhīma basin occupying a somewhat central position in Maharashtra state. The climate of the district is characterized by a hot summer and general dryness throughout the year except during the southwest monsoon season (i.e., June to September). Physiographically the district forms part of Deccan Plateau. Part of Sahayadri hill ranges fall in the district. Here in this chapter, the author has elaborated about soil quality and ground water quality near IOCL Terminal Ahmednagar, Maharashtra, India.

The study area considered for environment impact assessment (EIA) studies is an area covering 5 kms radial distance from proposed plant site in the foothills of Himalaya at Nganglam, Pemagatshel, Bhutan. Analyzing the soil samples collected from six locations in the study area has assessed the soil characteristics in the study area, especially the extent of pollution undergone by the soils due to various sources and reasons. Sampling locations were chosen to represent the soil quality of the study area. A preliminary reconnaissance survey was made to get a general picture of the area's land use. The activities around the sampling sites were also taken into consideration to learn the sources of pollution if any or factors governing the physico-chemical properties of the soil. To analyze the soil quality of the area and to assess the impact of industrial or urban activities on land environment with respect to any specific contamination, soil quality studies were carried out under EIA study.

Soil quality can be defined as the fitness of a specific kind of soil to function within its capacity and within natural or managed ecosystem boundaries to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. Soil is one of the common factors that bring all agriculture together. It can also be used to describe more complex soil characteristics such as soil organic matter, nutrient amounts, soil structure, etc. The soil quality of Tripura state where ONGC has established numerous exploratory and development wells for exploration of natural gas has been studied and presented in this chapter.

Foreword

Plants need nutrients to grow from soil, but there's a limited amount of nutrients they can actually use. Although plants are able to absorb some of the nutrients provided by synthetic fertilizers or manure, excess nutrients remain in the soil when too much is applied. These nutrients are eventually washed out of the soil and into ground and surface waters. The two major nutrient pollutants released by synthetic fertilizers and manure are nitrogen (N) and phosphorus (P). Sustainable nutrient management techniques allow farmers to maintain healthy, productive soil for crops without degrading the environment. There is an urgent need to make a plan and do necessary amendments like biochar etc. to restore the soil quality.

The process of modifying soils to improve their quality is known as soil amelioration. Soil amelioration and fertilization was by force of circumstance biological, i.e. done with substances taken from nature prior to the discovery of plant nutrients. After the discovery of plant nutrients, the chemical concept of fertility displaced the biological one. The defects of chemical cultivation—inefficiency, deterioration in product quality, diminishing soil productivity and impacts on the environment—have created an urgent need for the study of fertility as a result of the activity of the biological cycles of the ecosystem. With the aid of the advances of modern science, we can understand the defects and deficiencies of the chemical concept of fertility and return the biological concept of fertility to its proper place. This in turn is a good starting point for productive research and developmental work towards an ecologically sustainable agriculture.

In order to write a forward to the present book focused on this technology, I would like to appreciate the sincere efforts of my colleague Dr. Ashok Kumar Rathoure, Environmental Scientist to publish this book which contains latest information on the various aspects of soil sustainability and environmental management.

I hope this book will serve as a strong reference material and milestone to the new and current researcher and also help the scientist working in identifying and discovering the gaps in this research area. I consider this book a value addition to the scientific knowledge on remediation technologies focusing on amelioration and soil sustainability.

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Preface

Soil erosion is a complex process that depends on soil properties, ground slope, vegetation & rainfall amount and intensity. Erosion can be significantly reduced through sustainable agricultural practices. The most effective way to prevent erosion is to protect soil from rain and wind by covering it with plants and/or decaying organic matter. Plants need more than just sunlight and water. In order to grow, they require a variety of different nutrients. In natural environments such as prairies and forests, plants obtain most necessary nutrients from minerals found within the soil. When these plants die, they fall to the ground, decompose, and release nutrients back into the soil, making them available for new plants. In this way, nutrients are recycled with each generation.

Soil improvement influencing the substantial properties of soils is summarized under the term chemical soil amelioration. Plants need nutrients to grow from soil, but there's a limited amount of nutrients they can actually use. Although plants are able to absorb some of the nutrients provided by synthetic fertilizers or manure, excess nutrients remain in the soil when too much is applied. These nutrients are eventually washed out of the soil and into ground and surface waters. The two major nutrient pollutants released by synthetic fertilizers and manure are nitrogen (N) and phosphorus (P). Sustainable nutrient management techniques allow farmers to maintain healthy, productive soil for crops without degrading the environment. There is an urgent need to make a plan and do necessary amendments like biochar etc. to restore the soil quality.

ORGANIZATION OF THE BOOK

The book is organized into 12 chapters. A brief description of each of the chapters follows:

Chapter 1 is about the characteristics of various soil amendments. The nutrient plays a key role to maintain the soil fertility. Regular use of chemical fertilizer has great impact on soil infertility. The nutrient supply for soil sustainability is most important step to maintain the fertility and integrity. The enrichment of soil with organic matter could reduce the content of bioavailable metal species as a result of complexation of free ions of heavy metal. The NPK ratio in the soil should maintain for the good crop yield. There is various organic and inorganic materials available to mix with soil for amendment to enhance the soil fertility. Misuse of soil amendment can result not only in damage to crops but can also cause negative impact on soil fertility.

Chapter 2 is about the biochar and compost amendments for soil sustainability. The sustainable concepts for increased crop production are immediately needed to lower pressure on soils, in order to reduce or prevent the negative environmental impacts of rigorous agriculture. One efficient way to increase organic matter in soil is amelioration in soil like compost, biochar, fly ash, red mud, phosphate rock and other rock minerals, etc. On the one hand, growth of livestock breeding and intensification of crop production has occurred while an increasing shortage of resources can be recognized. On the other hand, urbanization and growing population interconnected with an increased amount of waste output is responsible for environmental hazards and pollution. Therefore, soil amelioration became an efficient means of agricultural crop improvement.

Chapter 3 presents good practices for soil sustainability. Soil plays a vital role in supporting the growth of crops and other vegetation maintaining the environment clean and act as source and sink for atmospheric gases. Soils are natural bodies on which plant grow. The increasing population, industrialization and changing life style have negative effect on soil and responsible for soil pollution. Good soil and climate for more crop production are valuable things for any nation. Soil amendments can be used to cost-effectively reduce the bio-availability and mobility of toxic metals in contaminated soils. Organic amendments considerably affect nutrient balance and interaction mobility of nutrients by influencing the chemical, physical, and biological environment in soils.

Chapter 4 shows the sustainable agro-ecosystem management. Soil is an important and complex part of our environment. The agro-ecosystem is made up of many interacting components with multiple goals. Soil quality is one important part of sustainable agro-ecosystem management, analogous to water and air quality. Assessing soil quality may help managers identify practices that could be adapted to become more sustainable. Soil quality is the ability of a soil to perform functions that are essential to people and the environment. Soil quality is not limited to agricultural soils, although most soil quality work has been done in agricultural systems. Soil quality definitions emphasize several features. Dynamic properties include organic matter, soil structure, infiltration rate, bulk density, and water and nutrient holding capacity. Changes in dynamic properties depend both on land management practices and the inherent properties of the soil.

Chapter 5 speaks about fly ash properties and their applications as a soil ameliorant. Fly ash is one of the major global pollutants which are produced in million tonnes every year. The high content of heavy metals in fly ash categorizes them in the hazardous materials. The presence of ferrous, alumina and silica along with numerous macro and micronutrients make them a suitable candidate for applications in agriculture, forestry, wasteland reclamation, soil stabilizer etc. Fly ash has positive effects on the plant growth and crop yield. A numerous literature has reported the applications of fly ash as pesticides, herbicides and insecticides. it has both alkaline and acidic pH which helps in maintaining the pH of the infertile soil.

Chapter 6 demonstrates the impacts of phosphate amendments in soil. Soil amendments can be used to cost-effectively reduce the bioavailability and mobility of toxic metals in contaminated soils. Phosphate amendments effectively can transformed to soil from the non-residual (sum of exchangeable, carbonate, Fe/Mn, and organic) to the residual fraction. Metal immobilization can be attributed to the metal-induced formation of chloropyromorphite which can be identified in the surface soil, subsurface soil, and plant rhizosphere soil. Phosphate treatments can significantly reduce metal translocation from the roots to the shoots in the plants/crops possibly via the formation of chloropyromorphite on the cell walls of roots. Application of combined H3PO4 with phosphate rock can be provided an effective alternative to the current phosphate remediation technologies for contaminated soils.

Chapter 7 speaks about the synergism between microbes and plants. The soil mitigation is an approach to reduce the soil degradation occurring in all aspects. Soil contamination mainly happens due to release of varieties of inorganic and organic constituents into soil. Presence of highly poisonous contaminants into soil, in high concentrations is enough to cause a threat to ecosystem and on human health. Sustainable approaches can be designed by the direct and indirect utilization of microbes and plants to reduce the soil pollution load. The utilization of microbes with plants in synergy is considered as one of the most fruitful approaches for the removal of soil pollutants. It is well known that plant host a variety of microbes in their roots, rizosphere, and shoot by giving them essential environment to flourish and colonize. Similarly microbes benefit, by making available certain soil nutrients to plants and also help in maintaining the overall health of soil.

Chapter 8 introduce about impact analysis of amendment application under diversified agro-ecological system. In alternative agricultural systems such as organic or low-input farming, farmers can build particular forms of relationships that help sustain ecosystem services and social infrastructure more effectively. We discuss many of these relationships, including direct marketing, fair trade certification, and food justice movements. An agroecological approach to improve tropical small farming systems must ensure that promoted systems and technologies are suited to the specific environmental and socio-economic conditions of small farmers, without increasing risk or dependence on external inputs.

Chapter 9 is about red mud and its properties to mix with soil. Rapid growth in industrialization which is necessary and inevitable for society progress had also created negative encroachment. Red mud produced during alumina production has strong alkanity in a pH range of 10-13%because of the sodium hydroxide solution used in the refining process. The base is strong enough to kill plant and animal life and due to finer particle and trace metal content it create soil contamination, ground water pollution and suspension in ocean. Red mud occupy large area or its deposition in it. Red mud have property similar to sandy clay .Red mud have property similar to clay and sand, even if it does not contain quartz or clay mineral. Bauxite residue can be mixed with variant type of, saline soils, acid soils organic rich material and silicate soil suitable pH conditions were achieved to promote vegetation growth.

Chapter 10 is about Soil Quality near Indian Oil Corporation Limited Pol Depot Ahmednagar, Maharashtra, State of India. The said area has diversified relief and amount of rainfall and soil types. It is dry region lies in east, irrigated region in north and tribal dominant population dominant in west. Ahmednagar district is situated partly in the upper Godavari basin and partly in the Bhīma basin occupying a somewhat central position in Maharashtra state. The climate of the district is characterized by a hot summer and general dryness throughout the year except during the southwest monsoon season, *i.e.* June to September. Physiographically, the district forms part of Deccan Plateau. Part of Sahayadri hill ranges fall in the district

Chapter 11 speaks about soil quality at Nganglam, Bhutan. The study area considered for environment impact assessment (EIA) studies is an area covering 5 kms radial distance from proposed plant site in the foothills of Himalaya at Nganglam, Pemagatshel, Bhutan. Analyzing the soil samples collected from 6 locations in the study area has assessed the soil characteristics in the study area, especially the extent of pollution undergone by the soils due to various sources and reasons. Sampling locations were chosen to represent the soil quality of the study area. A preliminary reconnaissance survey was made to get a general picture of the area's land use. The activities around the sampling sites were also taken into consideration to learn the sources of pollution if any or factors governing the Physico-chemical properties of the soil. To analyse the soil quality of the area and to assess the impact of industrial or urban activities on land environment with respect to any specific contamination, soil quality studies were carried out under EIA study.

Chapter 12 is about soil quality of Tripura State of India. Soil quality can be defined as the fitness of a specific kind of soil, to function within its capacity and within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. Soil is one of the common factors that bring all agriculture together.

It can also be used to describe more complex soil characteristics such as soil organic matter, nutrient amounts, soil structure, etc. The soil quality of Tripura state where ONGC has established numerous exploratory and development wells for exploration of natural gas has been studied.

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Generous participation of faculties and students to eliminate errors in the text and to eliminate errors in the text and to refine the presentation will be greatly acknowledged.

Last and not least, we beg forgiveness of all those who have been with us over the course of the years and whose names we have failed to mention.

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Chapter 1
Characteristics of Various Soil Amendments:
Soil Sustainability

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ABSTRACT

Nutrients play a key role in maintaining soil fertility. Regular use of chemical fertilizers has great impact on soil infertility. Nutrient supply for soil sustainability is the most important step to maintain the fertility and integrity. The enrichment of soil with organic matter could reduce the content of bioavailable metal species as a result of complexation of free ions of heavy metals. The NPK ratio in the soil should be maintained for the good crop yield. There are various organic and inorganic materials available to mix with soil to enhance the soil fertility. Misuse of soil amendment can result not only in damage to crops but can also cause negative impact on soil fertility.

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BACKGROUND

The primary role of soil amendments is to provide nutrients for crop growth or to provide materials for soil improvement. Misuse of soil amendments can result not only in damage to crops but can also cause negative impacts on the receiving soil, water, air or habitat environment. A soil amendment is any material added to a soil to improve its physical properties, such as water retention, permeability, water infiltration, drainage, aeration and structure. The goal is to provide a better environment for roots. To do its work, an amendment must be thoroughly mixed into the soil. If it is merely buried, its effectiveness is reduced, and it will interfere with water and air movement and root growth. Amending a soil is not the same thing as mulching, although many types of mulch also are used as amendments. Mulch is left on the soil surface. Its purpose is to reduce evaporation and runoff, inhibit weed growth, and create an attractive appearance. Mulches also moderate soil temperature. Organic mulches may be incorporated into the soil as amendments after they have decomposed to the point that they no longer serve their purpose. Common sources of micronutrients and metals are manure and chemical fertilizer. Some metals are plant micronutrients while some can become contaminants (toxic to soil microorganisms or plants). The availability of these elements varies, depending on soil type and soil pH. The major micronutrients and metals found in manure are iron, manganese, boron, chlorine, zinc, copper and molybdenum. Under both neutral soil pH and average organic matter conditions, most micronutrients in manure are available to the crop.

AMENDMENTS IN SOIL

Organic vs. Inorganic Amendments

There are two broad categories of soil amendments: organic and inorganic. Organic amendments come from something that was alive. Inorganic amendments, on the other hand, are either mined or man-made. Organic amendments include sphagnum peat, wood chips, grass clippings, straw, compost, manure, bio-solids, sawdust and wood ash. Inorganic amendments include vermiculite, perlite, tire chunks, pea gravel and sand. Wood ash, an organic amendment, is high in both pH and salt. It can magnify common soil problems and should not be used as a soil amendment. Organic amendments increase soil organic matter content and offer many benefits. The organic matter improves soil aeration, water infiltration, and both water- and nutrient-holding capacity. Many organic amendments contain plant nutrients and act as organic fertilizers. Organic matter also is an important energy source for bacteria, fungi and earthworms that live in the soil. The landscape and garden soils are improved to 4-5% organic matter. At this level, the mineralization (release) of nitrogen from the organic matter will be adequate for most plants without additional fertilizers. Many cities now require that the landscape soils be brought up to this level in new developments as a water conservation technique. With the improved aeration and deeper rooting, plants are more efficient in capturing rain events. Where the soil amendments may be high in salts, the rate is limited due to the salt problem. Salt burn of roots and death of landscape and garden plants is common from over application of salty soil amendments.

Wood Products

Wood products can tie up nitrogen in the soil and cause nitrogen deficiency in plants. Microorganisms in the soil use nitrogen to break down the wood. Over several months to years, as microorganisms complete the rapid decomposition process, the nitrogen is released and again becomes available to plants. This hazard is greatest with sawdust, because it has a greater surface area than wood chips. Compost wood products, before using them as soil amendments. For these products to decompose rapidly, add a nitrogen source to the compost pile. This could be plant residues high in nitrogen (such as grass clippings or manure), or a nitrogen fertilizer. The un-composted wood products or sawdust as a soil amendment should not be used. It is slow to break down, ties up nitrogen, interferes with seedbed preparation, and interferes with soil and water movement through the soil profile.

Sphagnum Peat vs. Mountain Peat

Sphagnum peat is an excellent soil amendment, especially for sandy soils, which will retain more water after sphagnum peat application. Sphagnum peat is generally acid (i.e., low pH) and can help gardeners grow plants that require a more acidic soil. The bogs can be re-vegetated after harvest in this moist environment. However, the harvest rate greatly exceeds the vegetation rate of the peat bogs, so it is considered a semi-renewal resource. The mountain peat is not a good soil amendment. It often is too fine in texture and generally has a higher pH. Mountain peat is mined from highaltitude wetlands that will take hundreds of years to rejuvenate, if ever. This mining is extremely disruptive to hydrologic cycles and mountain ecosystems.

Biosolids

Biosolids are byproducts of sewage treatment. They may be found alone or composted with leaves or other organic materials. The primary concerns about bio-solids are heavy metal content, pathogen levels and salts. Class A bio-solidshave been treated to reduce the bacterial content. Class A bio-solids are approved for use in production agriculture. However, it is advisable to avoid application to vegetable gardens due to the potential for heavy metals (such as cadmium and lead). Application of bio-solids is a cost-effective method to boost soil quality and plant growth and for the disposal of treated sludge. Although, bio-solids are a valuable source of nutrients, they contain lower N, P, and K contents compared to commercial fertilizers. Besides, sewage sludge also contains undesirable HMs, organic chemicals, and pathogens. Sewage sludge-amended soils irrigated with high rates of water causes leaching of nutrients and their further transport through the soil column to potential shallow aquifers. The nutrients and HMs through runoff and sediments enter water bodies and promote growth of algae and cause a wide array of water quality problems. HMs from soil, in diluted form and adhering to clay and organic matter colloidal particles, are transported to surface water bodies through runoff and sediments.

Manure

Fresh manure can harm plants due to elevated ammonia levels. To avoid this problem, use only aged or composted manure. Human pathogens, including *E. coli*, are another potential problem with fresh manure, especially on vegetable gardens. For vegetables with direct contact with the soil, fresh manure must be applied at least four months prior to harvest. For other fruits and vegetables, fresh manure must be applied at least three month prior to harvest. Aged manure refers to manure that has been piled for at least six months. Excessive ammonia will have escaped. Salt levels may be higher as the salts concentrate in the decomposing material, or may be leach out with high rainfall. Weed seeds will be viable. Composted manure technically refers to manure that has been through multiple active heating cycles and turned in between. If heated above 145 degrees F, it will kill pathogens and weed seeds. In composted manure, the organic matter is stabilized (through the rapid decomposition process) making it an ideal soil amendment. Salt level may be concentrated or may be leach out with high rainfall. As a point of clarification, composts and manures are not regulated. Many commercially available products are labeled as composted. However, this does not mean that it has been through the active decomposition process.

The use of animal manures as soil amendments must be done in a comprehensive manner to maximize their agricultural value and minimize their potential impacts on environmental quality and human health. There is no doubt that animal manures are valuable natural resources, particularly in countries where the availability of inorganic fertilizers is limited. When managed properly, manures provide plant nutrients, build soil organic matter, and improve soil physical properties, all of which are vitally important for soil quality and crop production. At the same time, the growing global trend toward intensification of animal production is gradually concentrating manure generation on smaller amounts of land. Transportation costs and the lack of an organized, efficient manure processing and distribution infrastructure are the major limitations to relocation of manures from areas where they are in surplus to areas where they are badly needed. When an adequate land base is not available to recycle manure nutrients in a balanced manner, over-application of nutrients such as N and P, which can negatively affect air, soil, and water quality, becomes a potential problem. Regional- and/or national-scale planning is required to develop and implement programs that can sustain modern animal production and use animal manures in an environmentally sound manner.

Compost

Compost refers to decomposed organic matter. It is not regulated, so there is no standard about the state of decomposition. In commercially available products the term compost is often used generically, and does not infer that the product has been through the actively heating, decomposition process. The combination of plant-based compost, manure-based composts, bio-solids, and other agriculture by-products (such as chicken feathers) are widely available. Compost made solely from plant-based products (such as wood chips and yard wastes) are low in salts. These are preferred over manure based composts which are often higher in salts.

Fertilizers

These are defined as any organic material such as manure or inorganic material of natural or synthetic origin such as granular ammonium nitrate that is added to a soil to significantly supply one or more nutrients essential for plant growth. The primary goal of fertilizer application is to provide sufficient nutrients in a balance suitable for crop use. Fertilizers counteract imbalances in the soil and replace nutrients removed by crop harvest. Organic materials that are classified as fertilizers have a carbon to nitrogen ratio of less than 30 to 1.

Soil amendments can have a profound effect on the physiological condition of a crop plant. Consequences of these changes for pest management depend on soil variability; the growth, developmental, and biochemical responses of the plant; the direct effects of these changes on herbivores; and the secondary impact on natural enemies. A considerable amount of work has been done on herbivore response to fertilizers that increase nitrogen (N) levels in plants. Mattson (1980) suggests that foliage N level is a major regulator of herbivory rate. Although increased plant quality (higher N) commonly leads to improved performance by individual insects (e.g., growth rates, survival, and fecundity), general statements on the direct responses of herbivores to N fertilizer are not possible due to the array of responses by different species. Other experiments on links between soil amendments and pest management concern effects on the pest via their response to resistant and susceptible varieties under conditions of different sources or levels of calcium, magnesium, nitrogen, phosphorus (P), potassium (K), or sulfur. The environment of a natural enemy is affected by soil amendments through changes in plant quality, as well as by concomitant changes in the herbivores.

Direct effects of fertilizer on biological control are not well documented. Many herbivores exhibit marked increases in population growth on nitrogen-enriched hosts. Concern emerges for the ability of natural enemies to track their prey/hosts under these conditions, but biological control of mites was maintained among apple treated with three levels of nitrogen fertilizer. Although the fecundity of the herbivore *Panonychusulmi* (Koch) increased with N level up to a fourfold increase when *Amblyseiuspotentillae* (Garman) predators were not present, the predators were able to compensate for most of the increase in prey reproduction. In contrast, fertilized (NPK) cotton plots exhibited higher levels of *Heliothiszea* than did control plots despite significantly higher population densities of *Hippodamiaconvergens* Guérin-Méneville, *Coleomegillamaculatalangi* Timberlake, and *Oriusinsidiosus* (Say) in fertilized cotton. Chiang (1970) demonstrated that fertilized midwestern corn fields (at 50 tons of manure per acre) had significantly fewer (half) corn rootworms than did unfertilized control plots. Although ground beetles and spiders were not affected, the populations of predaceous and herbivorous mites were three times higher in manure treatment plots. Through three seasons of field and laboratory experiments, Chiang concluded that predation by mites accounted for a 20% control of corn rootworm under natural field conditions and a 63% control when manure was applied.

Other effects of fertilizers on natural enemies may be predicted based on the combined information of related studies. For example, the parasitoid *Diaretiellarapae* (McIntosh) attacks the green peach aphid *Myzuspersicae* (Sulzer) more readily when the aphid is associated with *Brassica* spp. The mustard oils in crucifers serve as attractants for the wasp. It has also been shown-demonstrated that some glucosinolates are inversely related to N fertilizer level. Therefore, soil fertility may have dramatic effects on pest control by constraining the production of semiochemicals that play an important role in mediating interactions between plants, herbivores, and natural enemies.

Soil Conditioners

These are defined as any material(s) that contain limited amounts of nutrients, but are managed primarily for their beneficial impact on the biological, physical or chemical nature of the soil. They can also be used as a plant growth medium. Soil conditioners can be organic such as compost or wood waste or inorganic such as lime or perlite. Organic soil conditioners typically have high levels of organic matter but are not an immediate or significant source of plant nutrients and have a carbon to nitrogen ratio greater than 30 to 1. Addition of soil amendments with a high C:N ratio may result in crop available nitrogen being tied up (immobilized). Nutrients will be temporarily tied up in the soil, unavailable for plant use unless nitrogen is added to the soil to decrease the C:N ratio.

Most soil amendments are added to improve the structure of the soil, to increase the organic content so that the soil is more capable of holding nutrients and moisture. When these organic materials are added to the soil, they also act in varying degrees as fertilizers, providing a mix of nutrients to plant roots.

Common Soil Amendments

Common soil amendments used to maintain high permeability in sodic soils include gypsum that provides electrolytes to prevent clay dispersion and organic polymers that stabilize soil aggregates. Phosphogypsum (PG) and flue gas desulfurization gypsum (FGDG), which are by-products of the phosphate and power generation industries, are readily available and therefore frequently used. Spreading powdered PG at rates of 5 Mg ha^{-1} on the soil surface can be effective in slowing down the rate of IR decline and maintaining a higher final IR compared with the control, even in soils of ESP < 2.5 (Figure 5), indicating that some chemical dispersion takes place even at very low ESP values, and possibly even in Ca-saturated soils. The use of PG is also very effective in maintaining high IR in soils with high ESP. The favorable effect of PG on IR should be attributed not only to its effect on the EC of the percolating water but also to: (i) the physical interference with the continuity of the seal; and (ii) the partial mulching of the soil surface which protects the soil from the beating action of the raindrops.

Table 1. Soil Amendments

S. No.	Name	Description
1.	Alfalfa Meal	Primarily a plant source of nitrogen, Alfalfa Pellets also contains trace minerals and triacontanol, a plant growth promoter.
2.	Azomite	A natural source of minerals and trace elements! Azomite is used in gardens as a re-mineralizer for soils and an anti-caking agent in animal feeds.
3.	Blood Meal	A strong, slow release source of nitrogen, Blood Meal (13-1-0) is also chock-full of trace minerals.
4.	Bone Meal	Granulated for easy application and quick uptake by plants, Bone Meal contains 20% phosphate and up to 23% calcium.
5.	Chicken Manure	Composted Chicken Manure (3-2-2) provides a well-balanced supply of nutrients and is excellent for mulching and moisture retention.
6.	Coconut Coir	Made from compressed coconut fiber, coir is an eco-friendly peat alternative! Works anywhere you would normally use peat moss, rockwool, vermiculite, perlite or pumice.
7.	Compost	No amount of organic fertilizer can make up for poor soil. Compost provides a microbially active source of organic matter and other important soil builders required by plants.
8.	Greensand	Contains about 7% total potash, along with iron, magnesium, silica and as many as 30 other trace minerals. May also be used to loosen heavy, clay soils.
9.	Gypsum	Used to loosen heavy clay soils, Agricultural Gypsum contains about 23% available calcium and 18% sulfur.
10.	Kelp Meal	A great source of micronutrients and beneficial plant growth promoters. Kelp Meal also encourages tolerance to stresses such as pests, disease, frost and drought.
11.	Dolomite Lime	Sweetens soil (raises pH in acidic soils) and is a quality source of calcium (Ca) and magnesium (Mg). Promotes healthy plant growth.
12.	Rock Dust	Improves soil vitality and plant health. Rock Dust contains a broad range of trace minerals, many of which have been lost through the ages, by erosion, leaching and farming.
13.	Rock Phosphate	Provides up to a 10 year reserve of phosphorous! Contains 27% total phosphate, 33% elemental calcium and many other trace minerals. Great for flowering plants.
14.	Shellfish Meal	A source of calcium (23%), nitrogen, phosphorus and trace minerals. Contains chitin, which stimulates the growth of soil microbes that inhibit root-knot nematodes.
15.	Sulfur	Lowers pH in alkaline soils. Elemental Sulfur contains 90% sulfur with 10% bentonite as a binder. Great around acid loving plants such as blueberry, azalea and rhododendron.
16.	Sul-Po-Mag	Also known as sulfate of potash-magnesia, Sul-Po-Mag is a quick release source of potassium and contains 22% soluble potash, 22% sulfur and 11% magnesium.
17.	Worm Castings	Gardeners know Worm Castings to be the most nutrient dense organic compost available. In soil, they retain water and release nutrients in a form that is easily used by plants.

Organic polymers used for improving aggregate stability, maintaining high IR, and reducing seal formation are mainly polysaccharides (PSD) and polyacrylamides (PAM). The addition of small amounts of these polymers (10–20 kg ha^{-1}), either sprayed directly on to the soil surface or added to the applied water, was noted to be effective in stabilizing and cementing aggregates together at the soil surface, and hence maintaining high IR values in soils with ESP < 5. On the other hand, when added to soils with high ESP (>20), polymers were ineffective in controlling seal formation and maintaining high IR values; in soils with moderate ESP (10–15) the effects of polymers were inconsistent and depended on water quality and the amount of polymer added. The efficacy of anionic polymers in preventing seal formation is enhanced when the soil clay is maintained in a flocculated state and the resulting final IR could be 10 times higher than the control. It is therefore recommended that in soils exposed to rain, polymer application should be accompanied by spreading a source of electrolytes (e.g., gypsum) at the soil surface. Of the polymers currently available and under study, anionic polyacrylamide with high molecular weight ($>10^6$ Da) has been found to be the most effective in controlling seal formation and maintaining high IR.

Organic Fertilizers and Water Quality

Organic fertilizers are extensively used as a soil amendment and fulfill the nutrient requirement of crops (Brady, 1974). In addition to providing nutrients, organic fertilizers maintain soil aeration, moisture, and nurture the growth of soil microorganisms. On the other hand, organic manure contains fecal coliforms, HMs, nutrients that enter water bodies and degrade water quality and pose serious threats to the environment and public health (Jenkins et al., 1998; 2002). Most of the organic agricultural systems use compost or manures as N source and the rates of manure application are based on crop N requirements. Therefore, a farmland with successive years of manure or compost application will generally accumulate excess P. In contrast, other studies show a decrease in P concentration in organic production systems. Generally, N and P present in the manure, accumulate in the soil and may contribute to increased NO_3^- levels in groundwater and eutrophication of surface waters. Therefore, agriculture fields, supplemented with manures, also act as potential nonpoint source of water pollution.

Successive applications of high rates of dairy manure or sewage sludge can increase the risk of surface and groundwater pollution (Mohammadi et al., 2009; Rees et al., 2011). Various studies have been conducted to test the harmful effects of various types of manure on water quality parameters. Investigators observed that application of organic manure did not increase N recovery by crops; organic manure reduced NO_3^--N accumulation in the soil profile, but the total NO_3^- leaching was larger. Researcher analyzed groundwater samples collected near a pig farming operation; they contained about tenfold higher NO_3^--N and NH_4^+-N concentrations than the permissible limits. They also observed that river water showed a significant degradation in water purity. Hill et al. (2005) studied the effect of animal waste application on biological and physicochemical characteristics of runoff water using simulated rainfall events. They observed a significant increase in bacterial and nutrient concentrations after the simulated rainfall events which could contribute to water pollution. Mishra et al. (2006) observed that the application of manure causes significant edge-of-field nutrient losses, if rainfall occurs soon after application. Poultry manure is considered to be one of the sources that enhances SOM and improves soil fertility. On the other hand, poultry manure may act as a serious contaminant and pose potential risks to surface water quality. Mohammadi et al. (2009) reported that organic fertilizer increased the water extractable and bioavailable P content of soil. Rees et al. (2011) studied the effects of time of poultry manure application on soil erosion and runoff water quality. They applied manure in late fall, pre-planting, and pre-hilling on 11% and 8% slope plots. Their results showed that fresh poultry manure applications at the rate of 4 Mg ha^{-1} had no effect on annual runoff, but significantly reduced the May to October runoff when manure was applied in PH stage on 11% slope compared to the F stage on 8% slope. Fall manure applications significantly increased flow-weighted yearly runoff concentrations of nutrients, whereas, PH treatment lowered nutrient losses, runoff, and soil loss. They also reported increased concentrations of *Escherichia coli* in runoff after manure application. Rainfall events play a significant role in transporting human pathogens through water runoff from bio-solids-applied fields to surface water supplies and shallow groundwater (Sinton et al., 1999).

Salt Content and pH of the Amendment

High salt content and high pH are common problems in the soils. Therefore, avoid amendments that are high in salts or that have a high pH. Amendments frequently high in salts and/or pH include wood ash, the mountain peat and manures, and manurebased compost, bio-solids, and bio-solidbased compost. An amendment with up to 10 mmhos/ cm total salts is acceptable if mixed well into low-salt soils (less than 1 mmhos/cm). Amendments with a salt content greater than 10 mmhos/ cm are questionable. A low-salt amendment for soils testing high in salts should be chosen. Sphagnum peat and compost made from purely plant sources are low in salts and are good choices for amending the soils.

CONCLUSION

Soil amendment includes all inorganic and organic substances mixed into the soil for achieving a better soil constitution regarding plant productivity. Soil amendment does not include mulching, which includes substances lying on top of the soil. There are different substances for different soils and plants to optimize the soil conditions. A very common amendment is the addition of organic matter like compost, due to its low production costs.Soil amendments improve the physical properties resulting in better conditions for water storage, root development and soil ecosystems. Soil amendments can be produced locally, especially organic amendments, which are cheap to produce. The incorporation of the soil amendment (especially of organic amendments) can be time consuming. If too many nutrients or organic matter are put into the soil, they can be released and cause an outflow of nutrients into the groundwater and sur-rounding rivers and lakes, which can result in water pollution. Soil amendments can be applied almost everywhere by almost anybody.

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Chapter 2
Amelioration Technology for Agricultural Efficiency:
Biochar and Compost Amendments for Soil sustainability

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ABSTRACT

The sustainable concepts for increased crop production are immediately needed to lower pressure on soils in order to reduce or prevent the negative environmental impacts of rigorous agriculture. One efficient way to increase organic matter in soil is amelioration in soil like compost, biochar, fly ash, red mud, phosphate rock, and other rock minerals. On the one hand, growth of livestock breeding and intensification of crop production has occurred while an increasing shortage of resources can be recognized. On the other hand, urbanization and growing population interconnected with an increased amount of waste output is responsible for environmental hazards and pollution. Therefore, soil amelioration became an efficient means of agricultural crop improvement.

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INTRODUCTION

Agricultural efficiency depends significantly on the quality of soils, the main source of agricultural productivity. Land improvement (amelioration) became the most important component of peasant labor at the dawn of agricultural development. Amelioration differs from the common annual agricultural practices in that the effects on the soil can be radical and long lasting. It can be defined as a system of measures for radical improvement of unfavorable hydrologic, soil, and agro-climatic conditions, with a view to the most efficient use of land resources. Along with the effect on land productivity, amelioration allows us to bring poor and unused land into agricultural production, to improve the sanitary state of soils and the environment, and, hence, to raise the living standards and quality of life for people. The main amelioration practices are engineering reclamation (irrigation, drainage, filling up, flood walls, etc.), chemical, anti-erosion, and agronomic amelioration. Specific methods of land reclamation include the agricultural use of sea and lake bottoms, the development of desert soils, and the improvement of the heat regime of soils (thermal amelioration). Soil amelioration was indispensable over vast areas, with agriculturally unfavorable conditions found in almost all countries. Over thousands of years of the history of land amelioration, experience has been accumulated, the theory of amelioration has been developed, and its methods have been improved. Today, all developed countries have special laws regulating land reclamation policy. The efficiency of amelioration depends on the level of field management.

Efficient and sustainable agriculture is impossible without special measures aimed at improving land quality. Historically, the most significant and wide-scale measures for creation of sustainable agricultural systems were related to irrigation and drainage practices. It is interesting to trace the progress of irrigation and drainage technologies from earth to stone and then to high ferroconcrete dams; from a water bucket to windmills and electric pump stations; from spades to powerful machines and sprinklers; from open ditches to closed tile and plastic pipe drainage systems. The problems of ecological safety of land amelioration and the creation of highly productive and sustainable agro-landscapes, ensuring the sustainable development of modern civilization, are the focus of attention of scientists and specialists in agriculture and land management. There is no doubt that their significance in the twenty-first century will increase even more.

BACKGROUND

Soil amendment with biochar can be proposed as a means to sequester C and improve soil fertility. Application of charcoal to soils is hypothesized to increase bio-available water, build soil organic matter, enhance nutrient cycling, lower bulk density, act as a liming agent and reduce leaching of pesticides and nutrients to surface and ground water. Leach et al. (2010) also documented that application of biochar to the soil enabling increases in agricultural productivity without, or with much reduced, applications of inorganic fertilizer. Furthermore, Harley (2010) indicted that biochar is a promising amendment for ameliorating drastically disturbed soils due to its microchemical, nutrient, and biological properties. Biochar-based strategies are thus being seen to offer valuable routes to building sustainable agricultural futures, particularly for resource poor farmers for whom soil fertility and water availability are seen as key constraints on crop production and food security. The extent of the effect of biochar on crop productivity and soil carbon sequestration is, however, variable due mainly to the different biophysical interactions and processes that occur when biochar is applied to soil, which are not yet fully understood (Sohi et al.,2009). For instance, in nitrogen limited soils, application of high rates of biochar may affect growth negatively due to immobilization effect (Lehmann et al., 2006). Moreover, feedstock and pyrolysis conditions (temperature, holding time, etc.) may affect both stability and nutrient content and availability of biochar (Novak et al., 2009).

NEED OF AMELIORATION TECHNOLOGY

Driven by climate change and population growth, increasing human pressure on land forces conversion of natural landscapes to agricultural fields and pastures while simultaneously depleting land currently under agricultural use (Lal, 2009). Consequently, a vicious circle develops; further aggravating climate change, soil degradation, erosion, loss of soil organic matter (SOM) and leaching of nutrients. Therefore, sustainable concepts for increased food production are urgently needed to lower pressure on soils, in order to reduce or prevent the negative environmental impacts of intensive agriculture. A key for such strategies is the maintenance or increase of SOM level inducing positive ecosystem services such as increased productivity, nutrient and water storage, intact filter capacity, rooting, aeration and habitat for soil organism etc.One efficient way to increase SOM level is compost application, produced especially from biomass wastes. During the last decades, attention was paid at the professionalization of composting due to several trends in today's society. On the one hand, growth of livestock breeding and intensification of crop production has occurred while an increasing shortage of other hand, urbanization and growing population interconnected with an increased amount of waste output is responsible for environmental hazards and pollution. Therefore, composting became an efficient means of waste processing, soil amelioration and general environmental improvement. However, up to now reported C sequestration potential due to compost management is limited in terms of C use efficiency and long-term C preservation even combined with organic farming and no till management. Therefore, new concepts for C sequestration combating against further raise of atmospheric CO_2 emissions are urgently needed.

COMPOST

Composting is the biological de-composition and stabilization of organic matter derived from plants, animals or humans through the action of diverse microorganisms under aerobic conditions (Smith & Collins, 2007). The final product of this biological process is a humus-like, stable substrate, being free of pathogens and plant seeds which can be beneficially applied to land as an agent for soil amelioration or as an organic fertilizer. Although historical traditions such as those of Ancient Egyptians or Pre-Columbian Indians of Amazonia suggest that composting is an ancient method for soil amelioration, fundamental scientific studies of this biological process were published only in the past four decades. Process engineering and the knowledge about the dependence and interaction of numerous competing forces and factors within a composting matrix have been just recently established. Multiple composting methods and systems have been developed, varying from small, home-made reactors used by individual households, over medium-sized, on-site reactors operated by farmers, to large, high-tech reactors used by professional compost producers. In spite of different process techniques, the fundamental biological, chemical and physical aspects of composting remain always the same. This concerns for example the suitability of different input materials and amendments as well as their appropriate composition, substrate degradability, moisture control, porosity, free air space, energy balance as well as decomposition and stabilization (Bidlingmaier et al., 2000).

All proper composting processes go through four stages:

1. Mesophilic,
2. Thermophilic,
3. Cooling,
4. Compost maturation.

The duration of each stage depends on the initial composition of the mixture, its water content, aeration and quantity and composition of microbial populations (Neklyudov et al., 2006; Smith & Collins, 2007).

Numerous publications provide evidence on the multiple benefits of compost application topsoil. Effects range from soil stabilization and amelioration to phyto-sanitary impacts of mature compost. Feedstock, compost maturity and compost quality can influence intensity and degree of effects on soil physical, chemical and biological properties. Application may trigger short-term improvements such as increasing microbial activity. Long-term effects on soil properties could be achieved by preservation and increase of the stable SOM pool (Amlinger et al., 2007).Soil organic matter is of essential importance for maintaining soil quality by improving biological, physical and chemical soil conditions. It consists of a variety of simple and complex carbon compounds. While the stable SOM pool is characterized by hardly decomposable organic compounds with several beneficial, long-term effects for soil amelioration and conservation, the labile pool of SOM provides easily accessible food for soil organisms and nutrients for plant growth (Termorshuizen et al., 2005). Soil fauna, notably earthworms (*Lumbricidae*), in turn, positively influence a wide variety of different physico-chemical properties. These positive effects are especially caused by their feeding behaviour, bioturbation and the production of droppings consisting of organo-mineral complexes. The latter is of main importance for the formation of stable SOM pools in soils.

Impact on Soil

Reduction of Bulk Density

Compost application generally influences soil structure in beneficial way by lowering soil density due to the admixture of low-density OM into the mineral soil fraction. This positive effect has been detected in most cases and it is typically associated with an increase in porosity because of the interactions between organic and inorganic fractions (Amlinger et al., 2007).

Increase of Aggregate Stability

In general, soil structure is defined by size and spatial distributions of particles, aggregates and pores in soils. The volume of solid soil particles and the pore volume influences air balance and root penetration ability. As a general fact the more soil structure is compacted, the more unfavorable are the soil conditions for plant growth. By incorporation of compost into the soil, aggregate stability increases most effectively in clayey and sandy soils. Positive effects can be expected by well humified, as well as fresh, low-molecular OM. Macro-aggregates are mainly stabilized by fungal hyphen, fine roots, root hair and microorganisms with a high portion of easily degradable polysaccharides. Subsequently, the importance of stronger degraded organic compounds for the stabilization of smaller aggregates increases with time of transformation periods ranging from some few to several thousand years. In this respect, the aromatic structure of inert organic compounds seems to play an important role in stabilizing micro-aggregates in the range of 2-20 μm as well as 20-250 μm by polyvalent cation bridges with clay minerals. Besides clay minerals and oxides, fine roots, hyphen networks as well as glue-like polysaccharides originated from root and microbial exudates significantly contribute to the formation of micro-aggregates. Furthermore, aggregate and pore properties of soils are associated with specific active surface area influencing several storage and exchange processes in soil. The higher the specific surface area, the more intensive interactions can occur between soil fauna, microorganisms and root hairs under optimum conditions e.g. sufficient humidity.

Improvement of Pore Volume and Hydraulic Conductivity

Hydraulic conductivity is the percolation rate in soils per area and time unit depending on

- Actual soil moisture tension,
- Number, size and form of soil pores (pore size distribution).

Organic matter applied by compost improves water conductivity of soils by providing a food source for soil organisms which contribute to the formation of macro-pores, in turn. Additionally, it has a direct structure-stabilizing effect for soil. A resulting increase of hydraulic conductivity is of main importance, especially for clayey soils.

Increase of Field Capacity, Secondary Pore Structures and Improved Water Retention

Field capacity (FC) is defined as the amount of water which a water-saturated soil can retain against gravity after 2-3 days. It is mainly influenced by pore volume and pore size distribution because only pores below a pore diameter of 50 μm can retain water against gravity due to higher capillary force. However, adhesive force of pores with a diameter below 0.2 μm is so high that this water is not available for plants. Field capacity and available water holding capacity are generally influenced by the particle size, structure and content of OM. Several studies confirm a significant, positive impact of OMamendment to soils on FC. Amongst others, this effect results from the improved formation of secondary porestructures which can be mainly ascribed to root and animal tubes. This is important for soils with low portions of primary meso-pores. In this respect, compost increases the portion of meso and macro-pores because of an improved aggregation and stabilization of soil significantly initiated by various soil organisms.

Improved Air Balance

The portion of air in soils results from the difference between total pore volume and the pores filled with water. Air permeability and air exchange in soils predominantly depends on pores > 50 μm. While sandy soils are characterized by a high portion of primary macro pores resulting in a proper aeration, clayey or compacted soils have few macro pores which may cause lack of oxygen availability. For these latter soils, OM applied by compost has a significant ameliorating effect by improving porous soil structure and its stabilization, stimulating the formation of secondary macro pores especially by roots and animals tubes.

Reduction of Soil Erosion and Run-Off

Reduced erosion is mainly related to the improved soil structure by the addition of compost which, in turn, is pointed out by better infiltration rate, pore volume and enhanced stability through aggregation. According to Amlinger et al. (2007), experimental trials showed a clear correlation between increases of SOM, reductions of soil density, soil loss and water run-off. Five years long compost application resulted in 67% reduced soil erosion, 60% reduced run-off, 8% lower bulk density and 21% higher OM content compared to control plots.

Improved Heat Balance of Soils

Soil temperature influences the reaction rate of chemical, metabolic and biological growth processes of organisms. While temperature fluctuations mainly depend on climate, radiation absorption can be influenced by color. Composts are dark-colored resulting in higher light absorption and thus reflection rate of light from a light source. Therefore, higher light absorption will warm up soils supplied with compost faster than light-colored soils. It will promote germination of seeds, especially during spring. However, as temperature increases in summer, uncovered dark soils can heat up extremely. As a result, soil can dry out due to higher evaporation which, in turn, affects plant growth and soil biology negatively. In such case, compost mulching systems offer a good solution because they obtain reduced fluctuations of soil temperature which results from the shading effect of mulch loosely covering the soil surface.

Enhancement of Nutrient Level

Compost contains significant amounts of valuable plant nutrients including N, P, K, Ca, Mg and S as well as a variety of essential trace elements (Smith & Collins, 2007). Thus, compost can be defined as an organic multi nutrient fertilizer. Its nutrient content as well as other important chemical properties like C/N ratio, pH and electrical conductivity (EC) depends on the used organic feed-stocks and compost processing conditions. By an appropriate mixture of these organic input materials humus and nutrient-rich compost substrates can be produced serving as a substitute for commercial mineral fertilizers in agriculture. However, their diverse beneficial properties for amelioration outreach their nutrient content.

Increase of Cation Exchange Capacity (CEC)

The CEC is one of the most important indicators for evaluating soil fertility, more specifically for nutrient retention and thus it prevents cations from leaching into the groundwater. According to Amlinger et al. (2007), SOM contributes about 20 – 70% to the CEC of many soils.

Increase of pH Value, Liming Effect and Improved Buffering Capacity

Soil pH is an indicator for soil acidity or soil alkalinity and is defined as the negative logarithm of hydrogen ions activity in a soil suspension. It is important for crop cultivation because many plants and soil organisms have a preference for slight alkaline or acidic conditions and thus it influences their vitality. In addition, pH affects availability of nutrients in the soil. Compost application has a liming effect due to its richness in alkaline cations such as Ca, Mg and K which were liberated from OM due to mineralization. Consequently, regularly applied compost material maintains or enhances soil pH. Only in some few cases a pH decrease was observed after compost application.

Reduction and Immobilization of Pesticides and Persistent Organic Pollutants (POPs)

The contamination of soils or composts with pesticides and POPs can occur in consequence of environmental pollution, conventional farming practice by using chemicals and pesticides and by incorporation of contaminated materials into compost or soil. Therefore, unpolluted feed-stocks should be generally preferred for composting in order to avoid critical concentrations of pollutants. However, pesticides and POPs can be degraded or immobilized during compost processing or by the properties of the final compost product. Based on temperature and oxidative microbial and biochemical processes, composting contributes to an effective reduction of organic pollutants. Polychlorinatedbiphenyls (PCB) were degraded up to 45% during composting. Linear alkyl benzene sulphonates (LAS), Nonylphenols (NPE) and Di (2-ethylhexyl) phthalate (DEHP) which are mainly found in sewage sludge are degraded almost completely under oxidative conditions. Additionally, the degradation rate of halogenated organic compounds and pesticides is much higher than in soils, especially during the thermophilic stage. Mineralization rate of pollutants is reported to be more effective in compost soil mixtures if mature compost is applied. This concerns especially the degradation of polycyclic aromatic hydrocarbons (PAH) and other hydrocarbons. Due to the high level of humified OM, particularly mature composts contribute to sorption and immobilization of POPs resulting in a lower availability of POPs and reduced toxicity.

Immobilization of Heavy Metals

Similar to pesticides and POPs, there are several sources for heavy metal input. To a limited extent, heavy metals or trace elements serve as plant nutrients while their accumulation can cause toxicity. In this respect, OM applied by compost is able to adsorb heavy metals and reduce their solubility resulting in immobilization. Apart from some non-crystalline minerals with very high surface areas SOM has probably the greatest capacity to bond most heavy metals. The sorption strength of heavy metals to SOM generally decrease in the following order:Cr(III) > Pb(II) > Cu(II) > Ag (I) > Cd (II) = Co(II) = Li(II). On the other hand, significant correlations between the solubility of Cd, Cu, Zn, Pb and Ni and SOM content have been reported by Holmgren et al. (1993) for a range of soils from the USA. Organic matter applied by compost even effectively prevents mobilization of heavy metals for a long time after the cessation of compost addition. In order to guarantee the lowest possible pollutant input over time, raw materials for composting have to be separated and preferably unpolluted feedstock should be used. However, the prevention of environmental pollution and thus the contamination with heavy metals is basically a general matter for the society and for politics.

Biological Soil Properties

One of the most important effects of compost use is the promotion of soil biology. In this respect, the following three aspects seem essential:

1. Food supply for soil heterotrophic organisms by adding degradable carbon compounds with OM,
2. Optimization of habitat and niche properties in soil *e.g.* water and air balances, increase of specific surfaces, retreat areas etc.,
3. Introducing compost biota into soil as an inoculant.

Compost has a stimulation effect on both the microbial community in the compost substrate as well as the soil-born microbiota of soils.

Two fractions of OM are responsible for the level of microbial activity in general:

1. Easily degradable organic compounds may increase microbial activity and biomass temporarily while
2. A persisting increase of microbial biomass depends on a constant enhancement of stable OM which is particularly promoted by mature compost addition.

Microorganisms perform several ecological and environmental functions. With regard to compost, the following microbial effects seem of main importance:

- **Degradation and Humification:** A gradual breakdown of organic compounds is performed by a succession of different soil organisms over time. While at the beginning easily degradable organic substances are decomposed, further decomposition and transformation of the remaining by-products occur, finally resulting in a stable humus like compost product which is subjected to only slow decomposition rates.
- **Mineralization, Biological Immobilization and Nutrient Cycling:** On the one hand, microorganisms convert complex organic substances to low-molecular, inorganic substance. By this mineralization process, nutrients are released for plant growth so thatthe plant nutrients can cycle within the ecosystem. On the other hand, soil organisms immobilize nutrients into their own biomass. By this way, e. g. N is protected from leaching.

- **Aggregation:** Microorganisms contribute to the formation and stabilization of aggregates by the synthesis of biofilms and exudates as well as by their living or dead biomass.
- **Degradation or Reduction of Pesticides, POPs and Phytotoxic Compounds:** By microbial metabolism, several chemical compounds which are harmful for plants, can be decomposed, transformed or immobilized.
- **Suppression of Pathogens and Diseases:** The diversity of microorganisms in mature composts exhibit suppressive effects on several pathogens and diseases which could harm plant life or human health.

Growth and Health of Plant

The compost creates a favorable environment for plant and root growth especially by

1. Promoting a porous soil structure for optimized root penetration,
2. Decreasing soil erodibility due to the formation of stable aggregates. Consequently, plant roots are less exposed to direct damage caused by eroded topsoil and water can better infiltrate into soil.
3. Intensifying essential interactions between root hairs, soil fauna and microorganisms due to an enhancement of specific surface area,
4. Improving percolation,
5. Enhancing water storage capacity and improving water retention which helps plants better overcome critical climate conditions like droughts,
6. Providing valuable macro- and micro-nutrients in the long term due to slow mineralization rates, better nutrient adsorption as well as enhanced storage capacity which prevents from leaching,
7. Improving buffering capacity which helps to maintain uniform reactions and conditions for better plant growth,
8. Promoting the degradation, reduction or immobilization of harmful substances like pesticides, POPs, heavy metals and phyto-toxic compounds which can interfere plant life and health,
9. Providing microbial symbionts and beneficial soil organisms a habitat which has a positive influence on vitality and growth of plants,
10. Protecting plants from pathogens and diseases due to anti-phyto-pathogenic potential of compost.

Due to its multiple positive effects on the physical, chemical and biological soil properties, compost contributes to the stabilization and increase of crop productivity and crop quality. Long-term field trials proved that compost has an equalizing effect of annual/seasonal fluctuations regarding water, air and heat balance of soils, the availability of plant nutrients and thus the final crop yields. For that reason, a higher yield safety can be expected compared to pure mineral fertilization. Better crop results were often obtained if during the first years higher amounts of compost were applied every $2^{nd}$to 3^{rd}year than by applying compost in lower quantities of < 10 Mg(DM) ha^{-1} every year. However, crop yields after pure compost application were mostly lower when compared to mineral fertilization (Amlinger et al.,2007), at least during the first years. This can be explained by the slow release of nutrients (especially nitrogen) during mineralization of compost.

Compost use does not only improve the growth and productivity of crops in terms of quantity but it could be also proved that quality of agricultural products is influenced in a positive way. By examination of several crops in situ, an increase of beneficial and healthy ingredients and a decrease of harmful substances in the final crop product after compost use compared to a treatment with mineral fertilizer application can be observed.

BIOCHAR

Biochar has a high specific surface area (400-800 m^2 g^{-1}), it provides habitat for soil microorganisms which can degrade more labile SOM. In addition, higher microbial activity accelerates soil stabilization as outlined in the previous section. Furthermore, higher mineralization of labile SOM and biochar itself provided important nutrients for plant growth. Biochar is produced by thermal treatment at oxygen deficiency *e.g.* by pyrolysis or gasification, resulting in three products: char, gas and tarry oils. The relative amounts and characteristics of each are controlled by the process conditions such as temperature, residence time, pressure, and feedstock type. Biochar production can be chemically described by water elimination followed by increasing aromatic condensation, which can be expressed as decreasing atomic ratios of O/C and H/C along the combustion continuum. However, biochar is no clearly defined chemical compound. Instead, it is a class of compounds along the combustion continuum and we need to define thresholds for materials which are claimed to be biochar. Recently, on the basis of about 100biochar samples differing in feedstock and production process, the following elemental ratio thresholds were suggested for biochar, $O/C<0.4$ and $H/C<0.6$ (Schimmelpfennig & Glaser, 2012). The second important ecological property of biochar is presence of functional groups on the edges of the polyaromatic backbone which are formed by partial oxidation.

Due to its recalcitrance against microbial degradation, biochar is very stable in soil compared to other OM additions, making its application to soils a suitable approach for the build-up of SOM and thus, for C sequestration. The prevailing scientific understanding of biochar degradation in soil is that some portions of it are quite readily decomposable (labile), while the core structure of the material is highly resistant to degradation. C sequestration with biochar addition to soils could be quite significant since the technology could potentially be applied in many areas including croplands, grasslands and also a fraction of forestlands. The maximum capacity of carbon sequestration through biochar soil amendment in croplands alone was estimated to be about 428 Gt C for the world. This capacity is estimated according to the maximal biochar amount that could be cumulatively placed into soil while still beneficial to soil properties and plant growth; and the arable land area that the technology could potentially be applied through biochar agricultural practice. If using also grassland soils and 30% of forest soils, a worldwide biochar sequestration potential of 1,126 Gt C would be possible.

CLIMATE CHANGE

Photosynthesis captures more CO_2 from the atmosphere than any other process on Earth. Each year, terrestrial plants photo-synthetically fix about 440 Gt CO_2 being equivalent to 120 Gt C per year from the atmosphere into biomass. This corresponds to about one-seventh of the CO_2 stock in the atmosphere (820 Gt C). However, biomass is not as table form of carbon material with nearly all returning to the atmosphere in a relatively short time as CO2 because of respiration and biomass decomposition. As a result, using biomass for carbon sequestration is no good option. Any technology that could significantly prolong the lifetime of biomass materials would be helpful to global carbon sequestration. A conversion of only about 7% of the annual terrestrial gross photosynthetic products into a stable biomass carbon material such as biochar would be sufficient to offset the entire amount (nearly 9.7 Gt Ca^{-1}) of CO_2 emitted into the atmosphere annually from the use of fossil fuels. More realistic estimates are that annual net CO_2, CH_4 and N_2O emissions could be reduced by a maximum of 1.8 Pg C a^{-1} without endangering world food security and soil fertility (Woolf et al., 2010) corresponding to 16% of current anthropogenic CO_2 emissions. Therefore, biochar can significantly contribute to climate change mitigation but additional technologies are required to quantitatively offset fossil fuel-derived CO_2 emissions. The substitution of fossil fuels by developing and extending renewable energies is another essential key factor for greenhouse gas emission reduction or avoidance while still meeting the basic requirements of electrical or thermic energy consumption demands of society.

SOIL FERTILITY

Biochar application to soil influences various soil physico-chemical properties. Due to the high specific surface area of biochar and because of direct nutrient additions via ash or organic fertilizer amendments, nutrient retention and nutrient availability were reported being enhanced after biochar application. Higher nutrient retention ability, in turn, improves fertilizer use efficiency and reduces leaching. Most benefits for soil fertility were obtained in highly weathered tropical soils but also higher crop yields of about 30% were obtained upon biochar addition in temperate soils. Furthermore, enhanced water-holding capacity can also cause a higher nutrient retention because of a reduced percolation of water and the herein dissolved nutrients. However, since biochar has only low nutrients contents in general, plant nutrients must be supplied externally (Glaser & Birk, 2011). With respect to potential nutrient sources, only C and N can be produced in situ via photosynthetic organisms and biological N fixation, respectively. All other elements, such as P, K, Ca and Mg must be added for nutrient accumulation which can be best achieved by add ingorganic fertilizers such as manure or compost.

COMBINED EFFECT OF COMPOST AND BIOCHAR

Compared to compost and biochar mixing, an increased decomposition of biochar can be expected during composting although biochar is much more stable than other organic materials. As observed by Kuzyakov et al. (2009), biochar decomposition rates increase as long as easily degradable C-rich substrate is available. Additionally, Nguyen et al. (2010) reported that higher temperature increased biochar oxidation and thus decomposition. However, these effects are much lower for biochar than for compost feedstock. On the other hand, surface oxidation will enhance the capacity of biochar to chemisorb nutrients, minerals and dissolved OM. The overall reactivity of biochar surfaces therefore probably increases with composting. From the compost point of view, there is evidence that biochar as bulking agent improves oxygen availability and hence stimulates microbial growth and respiration rates. Pyrolysis condensates adsorbed to biochar initially provoked increased respiration rates in soils which most likely occur also during composting. Biochar in compost provides habitats for microbes, thereby enhancing microbial activity. Steiner et al. (2011) reported increased moisture absorption of biochar-amended composts with beneficial effects on the composting process.

Biochar could cause a positive priming effect due to its high surface area providing habitat for microorganisms and due to input of partly labile C substrate. On the other hand, biochar is a stable compound which could stabilize labile compost OM thus providing negative priming effect. Composting of biochar could be successfully conducted over a wide biochar/organic material ratio covering up to 50% biochar by weight. During composting, a relative enrichment of biochar was observed which is obvious as biochar is much more stable than organic waste materials (Erben, 2011). However, biochar caused a significant positive priming effect on non-biochar composting materials at low (1%) biochar concentrations while at high (50%) biochar concentrations a significantly negative priming effect could be observed. Therefore, a synergistic benefit for overall C sequestration could be observed when biochar was composted together with organic waste material. Further co-benefits might arise for soil microbial biomass and community structure composition and for biochar surface oxidation which still has to be proven scientifically. Combining biochar addition and fermentation resulted in negative priming, but the effect was weaker here than that of non-fermented treatments and hence ascribed rather to biochar alone than to its reinforcement of fermentation-induced negative priming.

Agricultural Efficiency

Combination of biochar with inorganic and organic fertilizers is clearly advantageous over the sole biochar or fertilizer amendments. Plant growth significantly increased after biochar addition. Although pure compost application showed highest absolute yield during two growth periods, biochar compost mixture revealed highest relative performance. It should be mentioned here that biochar compost mixture received only 50% of pure biochar and 50% of pure compost treatments, thus providing evidence for biochar compost synergism. In addition, it can be expected that in the long-term, compost will be mineralized more quickly than biochar or compost biochar mixtures. Mineral fertilizer retention was significantly more efficient when biochar was present although biochar did not increase cation exchange capacity at least after the first harvest. In comparison to mere mineral fertilizer there were clear advantages of plant growth and soil quality of the biochar-amended soils, especially when combining fertilizer (bothinorganic and organic) with biochar. The importance of biochar incorporation, additional amendments like clay minerals can add further value to the final compost product *e.g.* by promoting an enhanced CEC due to their high adsorption or swelling capacity. Their incorporation into organic substrates promotes the formation of organo-mineral complexes initiated by the biological activity of soil fauna after subsequent soil application. Other amendments like ash, excrements or urine contribute to the nutrients stock of the final composting product and can enhance microbial activity by their nutrient supply. Moreover, for providing adequate moisture conditions during composting urine can be added instead of water for preventing the dehydration of composting piles while adding nutrients at the same time. After compost maturation, the final compost substrate can be beneficially applied to soils. In this respect, the soil biota contribute to a further transformation of the applied material and provide essential ecological services, for instance by promoting aggregation and further OM stabilization. By enhancing the specific biological, physical and chemical properties of soils amended with the biochar composting substrates, plant growth is generally promoted.

CONCLUSION

The agriculture is the most important economic activity in the world which provides the food as raw material essential to human life. Soil, as a control on the biogeochemical and hydrological cycles of the Earth system and a provider of vital goods and services to sustain life, is one of our most important natural resources. Access, efficiency and affordability of agricultural information continue to be a major impediment for raising agricultural productivity. The amelioration technology is in its early stages of development, there are many concerns about the applicability of the technology in the tropics. Efficient and sustainable agriculture is impossible without special measures aimed at improving land quality. It is recommended to amend the soil for better agricultural efficiency and sustainability.

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Chapter 3
Soil Sampling, Analysis, and Rock Phosphate Amendments:
Good Practices for Soil Sustainability

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ABSTRACT

Soil plays a vital role in supporting the growth of crops and other vegetation, maintaining the environment, and acting as source and sink for atmospheric gases. Soils are natural bodies on which plants grow. The increasing population, industrialization, and changing lifestyle have negative effect on soil and are responsible for soil pollution. Good soil and climate for more crop production are valuable things for any nation. Soil amendments can be used to cost-effectively reduce the bio-availability and mobility of toxic metals in contaminated soils. Organic amendments considerably affect nutrient balance and interaction mobility of nutrients by influencing the chemical, physical, and biological environment in soils. Here in this chapter, the author has discussed the soil, its profile and type, analysis, and benefits on rock phosphate amendments.

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INTRODUCTION

Soil is the summation of natural bodies in the earth's surface, which contain living matter and supports or capable of supporting plants out-of-doors. To sum it up, it can be understood as a layer of earth crust that is thin and serves as a natural nutrient medium for the plant growth. One should study soil as it is being used as a rich medium responsible for the growth of plants and trees that provides a niche for biotic as well as abiotic interaction. Such study of soil profile from silvi-culture and crop husbandry point of view is important as, it reveals the characteristics of surface and sub-surface as also different qualities of soil namely, depth, texture, structure, drainage conditions and soil moisture relationship directly affecting the plant growth. Soil is also an unconsolidated mineral matter that is inveigled by genetic and environmental factors like-parent material, climate, organisms and topography all acting over a period of time. Soil properties differ in various ways such as physical, chemical, biological and morphological properties from the parent material. Based on the differences in genetic and environmental factors, there are different types of modified soils present such as red, black, deep shallow, coarse textured and fine textured. Soil provides water as well as a reservoir of nutrients in variety of crops, which are helpful in providing mechanical anchorage and favorable tilt. The different components of soils such as matrix of mineral, water, organic matter and air, vary in proportions for the growth of plant.

SOIL PROFILE AND CLASSIFICATION

Soil profile can be studied vertically through the soil area. It is normally regarded as a plane at right angles to the surface. In practice, a description of a soil profile comprises soil properties that can be determined only by examining volumes of soil. A description of a pedon is normally based on examination of a profile, and the properties of the pedon are expected from the properties of the profile. The width of a profile ranges from a few decimeters to several meters or more. It shall be adequate to include the largest structural units. A soil horizon is a parallel layer to the soil surface which can be distinguished by the adjacent layers through a characteristic set of properties, which is produced by the processes of soil formation.

Soil texture act as an important part in management of nutrients because it impacts retention of nutrient, for example, soils with fine texture tend to have greater ability to store soil nutrients. The simplest method of determining the type of soil is by simply feeling it to determine texture and predicting about primary makeup of the soil is. To perform the task, a baseball size portion of the soil is grabbed in hands and wetted with water, while working the moist soil with hands. The stickier it is, the more clay there is. The soapier the soil feels, the higher the silt content. Grittiness is representative of sand. Particle size distribution has an important impact on permeability of soil or water intake rate, water storage capacity ability to aggregate, crushing and the chemical makeup of the soil. The value of land, land use capability and soil management practices are largely determined by the texture.

Salinity and alkalinity in soil happens in arid and semi-arid regions, where precipitation is inadequate to meet evapo-transpiration needs of plants, and the salts move up to the surface. Salt affected soils are present inside irrigated lands. Salt accumulation happens through irrigation water and over-irrigation. The salt content in soil is measured in terms of electrical conductivity.

The classification of soil as per colour and texture is as follows:

- **Red Soil:** Red colour is due to presence of various oxides of iron. The soils are poor in nitrogen, phosphorus and potassium and with pH of 7 to 7.5. The red color is due to the diffusion of iron in soil profile. These soils are light textured with porous structure. Lime is absent with low soluble salts *e.g.* a*lfisol, inceptisol* and *ultisol.*
- **Lateritic Soil:** This type of soil is seen in those areas which have high rainfall. Under high rainfall conditions silica is released and leached downwards and the upper horizons of soils become rich in oxides of iron and aluminum. It is comprised of a mixture of hydrated oxides of aluminum and iron with small amounts of manganese oxide. The texture is light with free drainage structure. Clay is predominant and lime is deficient. The pH ranges from 5 to 6 with low in base exchange capacity, contained more humus and are well drained *e.g.* a*lfisol, ultisol* and *oxisol.*
- **Black Soil:** Black soil is characterized by dark grey to black colour with high clay content; the soils are neutral to slightly alkaline in reaction. It has a high proportion of calcium and magnesium carbonates and has a high degree of fertility. There are occurrences of deep cracks, which are developed during summer; the depth of the soil varies from less than a meter to several meters. This type of soil is rich in lime and potash and hence has high pH, examples are v*ertisol, inceptiso l*and *entisol.*
- **Alluvial Soil:** This type of soil is considered as the most important soil from the agriculture point of view. The soils range from sandy loam to clay loam with light grey colour to dark colour; structure is loose and more fertile. But the soils are low in Nitrogen, Phosphorus, Potassium and Humus. Alluvial

soil is considered as the largest and the most important group of soils.The soil is well supplied with lime and pH ranges from 7 to 8, examples include e*ntesol, inceptisol* and *alfisol.*

- **Desert Soil:** The soils are mostly sandy to loamy fine sand with brown to yellow colour; it contains large amounts of soluble salts and lime with pH ranging 8.0 to 8.5. Nitrogen content is very low. The presence of Phosphate and Nitrate make the desert soils fertile and productive under supply of water. They occur mostly in dry areas and their important content is quartz *e.g.* entisol and aridisol.
- **Forest and Hill Soils:** Soils are dark brown with more sub-soil humus content. They are more acidic. It has high organic matter *e.g*. alfisol.
- **Problem Soils:** The soils which owe characteristics that they cannot be economically used for the cultivation of crops without adopting proper reclamation measures are known as problem soils.

SAMPLING TECHNIQUES

The soil sampling techniques of soil would vary depending on the soil type and their characteristics. Proper location of sampling points and auxiliary equipment is thus very important. Sampling strategies are developed by the project team to satisfy project-specific data needs that are identified in the technical planning process. Sampling strategies may also be significantly influenced by factors such as matrix and contaminant characteristics, physical site constraints, safety, and cost. Soil sampling poses a variety of challenges due to the natural variability of the media, and the logistical problems of sampling at increased depths. Additionally, the particle size distribution of the soils must be evaluated. The technical planning process that results in the development of the sampling strategy is critical because of difficulties in acquiring representative samples, the reduction of action levels, and the problems associated with trace level cross-contamination. Development of a sampling scheme to characterize a study area should follow the successful sampling scheme. It requires a logical design to allow an evaluation of potential constituents in relation to background conditions, vertical extent, horizontal extent, and mobility in various media.

Sampling procedures for soil has different methods as follows.

Collection of Soil Samples With Trier

1. The Trier should edge into the material to be sampled at a 0 to 45 angle from horizontal. This coordination reduces the spillage of sample.
2. The Trier should be rotate once or twice to cut a core of material.
3. The Trier is gradually removed such that the slot is facing upward.
4. When there is a requirement of Volatile Organic analyses, the sample is transferred into a suitable, labeled sample container with a stainless steel lab spoon or equivalent and tightly secures the cap. The remainder of the sample is placed into a stainless steel, plastic, or other appropriate homogenization container, and mixed thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, the sample are placed into appropriate, labeled containers and the caps are tightly secured; or, if composite samples are to be accumulated then a sample is placed from another sampling interval into the homogenization container and mixed thoroughly. When compositing is complete, the sample is placed into appropriate, labeled containers and the caps are tightly secured.

Collection of Samples With Auger

1. The auger must be attached to a drill rod extension, and the T handle to the drill rod.
2. The area to be sampled is first cleaned and made free from surface debris such as twigs, rocks, and litter.
3. It is recommended to remove the surface soil for an area around six inches in radius around the drillinglocation.
4. The auguring is started, and then intermittently removed and accumulated soils are deposited on top ofplastic sheet spread near the hole. This avoids accidental brushing of loose material back down the borehole when removing the auger or adding drill rods.
5. The Auger is removed with care from the hole after achieving desired depth. When sampled directly from the auger, the sample is collected after the auger is removed from the hole.
6. The auger tip is then taken away and replaced with a pre-cleaned thin wall tube sampler. Proper cuttingtip is installed.

7. It is then lowered into the tube sampler and progressively forced into the soil. The scrapping of boreholesides must be avoided. Hammering threads are avoided as the vibrations may cause the boring walls tocollapse.
8. The tube sampler is then removed and the drill rods unscrewed.
9. The cutting tip and also the core are removed from the device.
10. The top of the core (~ 1 inch) is discarded as this represents material collected before penetration of the concerned layer. The rest of the core is placed into the appropriate labeled sample container. Sample homogenization is not necessary here.
11. If volatile organic analysis is to be performed, the sample is transferred into an appropriate, labeledsample container with a stainless steel lab spoon or equivalent and the cap is tightly secured. The rest ofthe sample is placed into a stainless steel, plastic, or another appropriate homogenization container andmixed thoroughly to gain a homogenous sample representative of the entire sampling interval. Thesample is then placed into appropriate, labeled containers and the caps tightly secured.
12. The hole is refilled depending upon its depth. Generally, shallow holes can simply be backfilled with theremoved soil material.

Collection of Samples With Scoops and Shovels

1. Vegetation and the top layer of soil can be removed by using pre-cleaned stainless steel scoop or trowel.
2. The soil is further loosened to the required volume.
3. The distinct grab sample is then transferred into container.
4. For composite sample, sole stainless steel or glass mixing or any other appropriate container must be used and tools such as stainless steel spoon, trowel, or pestle must be used for collection.
5. The sample containers must be marked while soil sample data sheets mentioning depth, location, color other observations, are filled up.
6. The glass sample containers must be placed in sealed plastic bags and packed into an iced shipping container. Samples must be compulsorily cooled and maintained at 4°C as soon as possible.
7. The cycle of custody and shipping must be finish as fast as possible to reduce its holding time. When the sample arrives at laboratory, it should be within the holding time.

Collection of Samples With Split Spoon (Barrel) Sampler

1. The sampler is assembled by aligning both the sides of barrel and screwing the drive shoe to the bottom and the head piece on top.
2. The sampler is then placed in a perpendicular position to the sample material.
3. The well ring should be good to drive the tube. However, it should not drive past the bottom of the head piece; otherwise it may result in compression of the sample.
4. The length of the tube is then penetrated into the material to be sampled, and the number of blows recorded to get to this depth.
5. The sampler is then withdrawn and opened by unscrewing the bit and head and splitting the barrel. The amount of recovery and soil type is recorded on the boring log. In case a split sample is required, cleaned, stainless steel knife is used to divide the tube contents in half, longitudinally.
6. The core is transferred without disturbing to an appropriate labeled sample container(s) and sealed tightly.

Sampling at Depth With Augers and Thin Wall Tube Samplers

1. It employs use of an auger, or a thin-wall tube sampler, a series of extensions, and “T” handles. The auger is used to bore a hole to a desired sampling depth, and then withdrawn. The sample can be collected directly from the auger.
2. The core of sample can be collected by replacing the auger tip with a thin wall tube sampler. It is then lowered down the system into the borehole, and driven into the soil to the completion depth.
3. There are several types of augers available; which includes bucket type, continuous flight (screw), and post-hole augers. Bucket type augers are better for direct sample recovery as they provide a large volume of sample in lesser time.
4. The continuous flight augers are useful in collecting the sample directly from the flights. Their use is satisfactory when a composite of the complete soil column is required. Post-hole augers have limited utility for sample collection as they are designed to cut through fibrous, rooted, swampy soil and cannot be used below a depth of approximately three feet.

Sampling Pattern

The sampling pattern should be selected to best represent the field, accounting for known sources of variability such as major soil type changes, past cropping patterns, etc. A grid pattern is usually the best way to be sure the entire field is represented, but with the possibility of patterns developing from past nutrient applications, cropping effects and other uniform patterns, it is advisable to use a sampling scheme that avoids arranging sampling points in a straight line. For conventional sampling, a common approach is to divide the field into cells of about 2 ½ to 5 acres, and collect 5 cores in a zigzag pattern within each cell to make up the sample. This area sampling method provides for fairly complete sampling of the field and a good estimate of the needs for a single uniform application rate to be applied to the entire field.

Sediment Collection Procedure

Grab samplers/Dredges are used for the collection of bottom sediment deposits, which are designed to recover sediment material from the top few centimeters of the lake/river bed. Grab samplers consist of either a set of jaws which are lowered to the surface of the bottom sediment or contain a bucket which rotates into the sediment upon reaching the bottom. The dredges usually have beveled lips to scrap upper layers of the sediments. For special cases, the dredges may have teeth to plough the bottom and stir out burrowing molluscs, worms etc. The fine-grained bottom sediments are collected with Van Veen type of the sediment sampler. This device consists of two bowl-clamp shaped sections, which are held open by a catch. When the sampler touches the sediment, the catch is released and the bowl shape sections close together, trapping sediment from a penetration depth of about 20 cm. For general operational suitability of Grab samplers, there are some properties needed for it, such as stability and capability to prevent sample loss from washout. Also sample volume must be considered while choosing a surface sediment sampler. The bottom sediment sampler devices are widely used variety which is designed for biological and geological studies mainly in marine environment. Other than this, they can also be used in pollution studies in the marine and freshwater environment.

SOIL ANALYSIS

Parameters for Soil Analysis

Primary Nutrients

The primary nutrients, Nitrogen (N), Phosphorous (P) and Potassium (K) are essential elements for crop growth. The application of commercial N, P and K fertilizers has contributed to a tremendous increase in yields of agricultural crops that feed the world's population. However, excessive use of these fertilizers has been cited as a source of contamination of surface and ground water. Ideally, application rates should be adjusted based on estimates of the requirements for optimum production at each location because there is high spatial variability of N, P and K within individual agricultural fields. A healthy soil produces healthy crops. Maintaining a healthy soil demands care and effort from farmers. Nitrogen is an important for a growth because it is a major part of all amino acids, which are the building blocks of all proteins, including the enzymes which control virtually all biological processes. A good supply of nitrogen stimulates root growth and development, as well as the uptake of other nutrients. Phosphorous enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting and maturation. In plant, it is present mainly as a structural component of the nucleic acid, deoxyribonucleic acid (DNA) and ribose nucleic acid (RNA). It is present in both organic and inorganic forms, both of which are readily translocated within the plant. All energy transfers in the cell are critically dependent on phosphorous. Phosphorous is concentrated at the most actively growing points of a plant and stored within seeds in anticipation of their germination. Phosphorous is available to plants in limited quantities in most soils because it is released very slowly from insoluble phosphates and is rapidly fixed once again. Potassium occurs in all parts of plants in substantial amounts. Potassium is important in leaves and at growing points. It is outstanding among the nutrient elements for its mobility and solubility within plant tissue. Potassium regulates the opening and closing of the stomata by a potassium ion pump.

Secondary Nutrients

Secondary and micronutrients are important in enhancing crop productivity. Calcium (Ca), Magnesium (Mg) and Sulphur (S) are secondary macro nutrients. The measure source for supplementing the soil with calcium is dolometic lime (aglime). Calcium is also available from variety of fertilizer source *i.e.* Gypsum (Calcium Sulphate$CaSO_4$, 22.5%Ca). It is used as secondary nutrients. Calcium is component of plant cell wall and regulates the cell wall construction. Calcium deficiency is uncommon in monotona and Wyoming areas due to presence of Calcium carbonate and gypsum in most agriculture soil. In sufficient Ca cause young leaves to become distorted and turn abnormally dark green. Leaf tips often become dry or brittle and will eventually wither and die. Stems are weak and germination is poor. The predominant role of Mg is as a major constituent of the chlorophyll molecule and it is therefore actively involved in photosynthesis and it also assists the movement of sugars within a plant. Sulphur is the secondary nutrients it requires in the smaller amount than the primary nutrient. It is essential constituents of certain amino acids and proteins. It is available in fertilizers such as potassium and magnesium sulphate, Gypsum (Calcium sulphate) and elemental sulphur. The deficiency symptoms initially occur in younger leaves, causing them to turn light green to yellow (chlorosis). In later growth the entire plant may be pale green. Characteristic spot or strips are generally not displayed. Additionally plant deficient in sulphur tends to be spindly, small and stems are often thin.

Micro Nutrients

The micro nutrients are Boron (B), Chlorine (Cl), Copper(Cu), Iron(Fe), Molybdenum and Zinc (Zn).These plant food elements are used in very small amounts, but they are just as important to plant development. Boron is essential for the movement and metabolism of sugar in the plant and synthesis of plant harmonic and nucleic acids. It also functions in the lignin formation of cell walls. Chlorine is necessary for osmosis and ionic balance; it also plays a role in photosynthesis. Copper is a formation of cell walls involved in the photosynthesis respiration and processes within the plant involving nitrogen. Iron is involved in photosynthesis, respiration and chlorophyll formation and many enzymatic reactions. Molybdenum is involved in nitrogen fixation and nitrification. Zinc is a component of organic complexes and DNA proteins. It is an important enzyme for protein synthesis. Zinc is evolved in the growth of harmonic production and seed development. Manganese is a component of enzymes and is also involved in photosynthesis and root growth. It is also involved in nitrogen fixation (Ashvini et al., 2016).

ROCK PHOSPHATE AMENDMENTS

Rock phosphate, a naturally occurring mineral source of phosphate, could serve as an alternative source of phosphorus in developing countries. It has been found to be much less expensive than soluble phosphorus fertilizers (Lorion, 2004). However, rock phosphate material has poor solubility when used as a fertilizer in soils. The rock phosphate can be finding in three forms viz. colloidal phosphate, soft rock phosphate and hard rock phosphate. These minerals release a small percentage of their phosphorus each year, the colloidal phosphate a bit faster than the others. These rocks also contain micronutrients. Treating rock phosphate with organic materials is found to be a technique for enhancing the solubility and the subsequent availability to plants of phosphorus (Zapata & Roy, 2004). Several studies have been conducted on amending rock phosphates to enhance their rate of dissolution after application to soils. The incorporation of agricultural wastes like poultry manure and cow dung with rock phosphate significantly improved the release of P and performance of crops (Singh & Amberger, 1990; Akande et al., 2005; Akande et al., 2008).

Compositing of rock phosphates with agricultural wastes is known to increase solubility of rock phosphates (Bangar et al., 1985; Mey et al., 1986; Mishra et al., 1984; Mishra & Bangar, 1986; Kothandaraman, 1987; Singh & Amberger, 1990; Akande et al., 1998). The content of P solubility of a given rock phosphate varies with the kind of organic material and the rate of decomposition (Banger et al., 1985). Akande et al. (2003) reported that okra growth and yield were significantly increased by the combined used of rock phosphate with either poultry manure and to a lesser degree urea compared to sole used of the materials. They also reported an increase in soil available P of between 112 and 115%, and 144 and 153%, respectively for a two year field trials (Morra et al., 1991; Ben-Dor & Banin, 1995; Brunet et al., 2007).

The immediate or short-term effects of applied fertilizers are often emphasized to the neglect of residual effects. Yet when farming is continued on the same site for several years, residual effects of fertilizer treatments may considerably affect the soil chemical properties and consequently crop yield (Enwezor et al., 1989). Reviewing residual effect of rock phosphates, Khasawneh and Doll (1978) did not confirm the common assumption that rock phosphates have greater residual effect than soluble phosphorus fertilizer. On the contrary, it appeared that the residual effects of soluble phosphorus fertilizer were greater than those of rock phosphate in the first 3 or 4 years after application.

Phosphorus-containing amendments were greatly concerned amendments on in situ remediation of metal contaminated soils. Rock phosphate can remove Pb, Zn, Cu and other heavy metals from aqueous solutions (Xu et al., 1994; Brown et al., 2005; Ma et al., 1997; Hettiarachchi & Pierzynski, 2002; Cao et al., 2004; Ownby et al., 2005; Chen et al., 2006; 2007; 2009).

CONCLUSION

Growing concern about environmental pollution by excessive use of fertilizers lead to increases in needs to monitor soil nutrients required for crop growth. The sensor network technology will help the farmers to know the soil requirements which will help them take better decisions and preventive measures at the right time. To maintain the soil sustainability, it is urgently needed to popularize the amelioration techniques for soil amendments.

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Chapter 4
Soil Quality and Soil Sustainability:
Sustainable Agro-Ecosystem Management

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ABSTRACT

Soil is an important and complex part of our environment. The agro-ecosystem is made up of many interacting components with multiple goals. Soil quality is one important part of sustainable agro-ecosystem management, analogous to water and air quality. Assessing soil quality may help managers identify practices that could be adapted to become more sustainable. Soil quality is the ability of a soil to perform functions that are essential to people and the environment. Soil quality is not limited to agricultural soils, although most soil quality work has been done in agricultural systems. Soil quality definitions emphasize several features. Dynamic properties include organic matter, soil structure, infiltration rate, bulk density, and water and nutrient holding capacity. Changes in dynamic properties depend both on land management practices and the inherent properties of the soil. Here, the author has presented for intrinsic and vigorous properties, soil structures and macrophores, soil quality management, etc.

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INTRODUCTION

Soil is an important and complex part of our environment. As per Miller and Wali (1995), sustainability lies in the dynamic nature of its fundamental components: ecological (spatial and temporal relations, diversity, stability and resilience; economic (resource distribution and allocation); and social (equity, access, stewardship and institutions). The agro-ecosystem is made up of many interacting components with multiple goals. Soil quality is one important part of sustainable agro-ecosystem management, analogous to water and air quality. Assessing soil quality may help managers identify practices that could be adapted to become more sustainable. Soil quality is one aspect of sustainable agro-ecosystem management. Soil quality is the ability of a soil to perform functions that are essential to people and the environment. Soil quality is not limited to agricultural soils, although most soil quality work has been done in agricultural systems.

BACKGROUND

Soil quality assessments focus on the dynamic, or management-affected, properties of soil, such as nutrient status, salinity and water-holding capacity. These properties are assessed in the context of the inherent capability of a particular soil. Soils support plant growth, recycle dead material, regulate and filter water flows, support buildings and roads and provide habitat for many plants and animals. Depending on the land use, many of these functions occur simultaneously. Soil quality assessments go beyond measuring degradation (erosion, compaction or contamination) to focus on these soil functions and the processes that create them. Soil functions provide private benefits such as crop production or structural support for buildings (Karlen, 2001). Simultaneously, the same soil may provide societal benefits such as carbon sequestration, water quality protection, or preservation of soil productivity for future generations. Evaluating soil quality requires that we identify and prioritize these benefits and pay attention to the interactions and tradeoffs among them. The ability to continue providing essential services in the face of disturbance, whether natural or human induced, is essential to maintain or improve soil quality over time. A soil is not considered healthy if it is managed for short term productivity at the expense of future degradation (Doran et al., 1994).

Soil quality cannot be measured directly because it is a broad, integrative, context-dependent concept. Indicators of soil quality may include characteristics of soil solids, soil solutions, soil atmospheres, vegetation and other soil biota and possibly even economic analyses of land-uses or ecosystem services. Although the quantity and quality of data may differ, the process of soil quality evaluation follows the same basic steps regardless of the method used: identification of soil use issues followed by indicator selection and interpretation. More specifically, in order to select appropriate indicators, one must first determine the land-use objectives and then indicators must be proposed, measured and assessed across a representative set of lands and management practices.

INTRINSIC AND VIGOROUS PROPERTIES OF SOIL

The quality of a soil is a combination of intrinsic and vigorous soil properties. The focus of most soil quality work is vigorous soil properties and how they change in relation to the intrinsic features of the soil. Inherent or use-invariant properties change little, if at all, with land use or management practices. They may include soil texture, depth to bedrock, type of clay, CEC and drainage class. These properties were established as soil formed over millennia. The soil form depends on the five soil-forming factors (Jenny, 1941):

- Climate (precipitation and temperature),
- Topography (shape of the land),
- Biota (native vegetation, animals and microbes),
- Parent material (geologic and organic precursors to the soil),
- Time (time that parent material is subject to soil formation processes).

Dynamic properties or use-dependent properties can change over the course of months and years in response to land use or management practice changes. Dynamic properties include organic matter, soil structure, infiltration rate, bulk density and water and nutrient holding capacity. Changes in dynamic properties depend both on land management practices and the inherent properties of the soil. For example, the organic matter levels in soil depend on tillage practices and the types of plants growing (management), but the total amount of organic matter is constrained by soil texture and climate (inherent features).

Value of Soil

Nutrient cycling, water regulation and other soil functions are normal processes occurring in all ecosystems. From these functions come many benefits to humans, such as food production, water quality and flood control, which have value economically or in improved quality of life. People can increase or decrease the value of soil benefits because land-management choices affect soil functions. Thus, it is important to understand what benefits we derive from soil and their value so we can appreciate the importance of managing land in a way that maintains soil functions. People tend to emphasize benefits with the most direct, private economic value. In rural areas, this is usually plant growth especially as crops and rangeland, but also as recreation areas. In urban/suburban areas, the most direct economic benefits of soil relate to structural support for buildings, roads and parking. Landscaping, gardening and parklands may also be valued economically. Those are all on-site, short-term benefits. That is, the landowner who decides how to manage the soil also reaps the benefits of those management decisions. In contrast, many important benefits are long-term or go beyond the land being managed.

Aggregate Stability

Soil aggregates are groups of soil particles that bind to each other more strongly than to adjacent particles. Aggregate stability refers to the ability of soil aggregates to resist disintegration when disruptive forces associated with tillage and water or wind erosion are applied. Wet aggregate stability suggests how well a soil can resist raindrop impact and water erosion, while size distribution of dry aggregates can be used to predict resistance to abrasion and wind erosion.

Changes in aggregate stability may serve as early indicators of recovery or degradation of soils. Aggregate stability is an indicator of organic matter content, biological activity and nutrient cycling in soil. Generally, the particles in small aggregates (< 0.25 mm) are bound by older and more stable forms of organic matter. Microbial decomposition of fresh organic matter releases products that bind small aggregates into large aggregates (> 2-5 mm). These large aggregates are more sensitive to management effects on organic matter, serving as a better indicator of changes in soil quality. Greater amounts of stable aggregates suggest better soil quality. When the proportion of large to small aggregates increases, soil quality generally increases. Stable aggregates can also provide a large range in pore space, including small pores within and large pores between aggregates. Pore space is essential for air and water entry into soil and for air, water, nutrient and biota movement within soil. Large pores associated with large, stable aggregates favor high infiltration rates and appropriate aeration for plant growth. Pore space also provides zones of weakness for root growth and penetration. Surface crusts and filled pores occur in weakly aggregated soils. Surface crusts prevent infiltration and promote erosion; filled pores lower water-holding and air-exchange capacity and increase bulk density, diminishing the conditions for root growth. Aggregate stability is critical for infiltration, root growth and resistance to water and wind erosion. Unstable aggregates disintegrate during rainstorms. Dispersed soil particles fill surface pores and a hard physical crust can develop when the soil dries. Infiltration is reduced, which can result in increased runoff and water erosion and reduced water available in the soil for plant growth. A physical crust can also restrict seedling emergence. Wind normally detaches only loosely held particles on the soil surface, but as blowing soil particles are accelerated by the wind they hit bare soil with sufficient energy to break additional particles loose from weakly aggregated soil.

Practices that lead to poor aggregate stability include:

- Tillage methods and soil disturbance activities that breakdown plant organic matter, prevent
- Accumulation of soil organic matter and disrupt existing aggregates,
- Cropping, grazing, or other production systems that leave soil bare and expose it to the physical impact of raindrops or wind-blown soil particles,
- Removing sources of organic matter and surface roughness by burning, harvesting or otherwise removing crop residues,
- Using pesticides harmful to beneficial soil microorganisms.

Conservation practices resulting in aggregate stability favorable to soil function include:

- Conservation Crop Rotation,
- Cover Crop,
- Pest Management,
- Prescribed Grazing,
- Residue and Tillage Management,
- Salinity and Sodic Soil Management,
- Surface Roughening.

Loss of Organic Matter

The plow is a potent tool of agriculture for the same reason that it has degraded productivity. Plowing turns over soil, mixes it with air and stimulates the decomposition of organic matter. The rapid decomposition of organic matter releases a flush of nutrients that stimulates crop growth. But over time, plowing diminishes the supply of soil organic matter and associated soil properties, including water holding capacity, nutrient holding capacity, mellow tilth, resistance to erosion and a diverse biological community. After several decades of farming using intense tillage and much lower inputs of new organic matter, much of that land lost up to half of its original organic matter. Sandy lands that once contained 2% organic matter are now below 1%. Rich prairie loam that carried 8% or more is now at 4%. The initial rise in atmospheric CO_2 levels can be explained largely by the conversion of soil organic matter into CO_2 and by the conversion of forests to other land uses. Soil organic matter in some regions began to stabilize or rise slightly as farmers began to use higher yielding varieties, apply fertilizers and remove less straw at harvest (Cole et al., 1990). Improved yields have been important in improving soil organic matter levels over the past few decades (Allmaras et al., 1998, 2000).

Soil Enzymes

Soil enzymes increase the reaction rate at which plant residues decompose and release plant available nutrients. The substance acted upon by a soil enzyme is called the substrate. For example, glucosidase (soil enzyme) cleaves glucose from glucoside (substrate), a compound common in plants. Enzymes are specific to a substrate and have active sites that bind with the substrate to form a temporary complex. The enzymatic reaction releases a product, which can be a nutrient contained in the substrate. Sources of soil enzymes include living and dead microbes, plant roots and residues and soil animals. Enzymes stabilized in the soil matrix accumulate or form complexes with organic matter (humus), clay and humus-clay complexes, but are no longer associated with viable cells. It is thought that 40 to 60% of enzyme activity can come from stabilized enzymes, so activity does not necessarily correlate highly with microbial biomass or respiration. Therefore, enzyme activity is the cumulative effect of long-term microbial activity and activity of the viable population at sampling. However, an example of an enzyme that only reflects activity of viable cells is dehydrogenase, which in theory can only occur in viable cells and not in stabilized soil complexes. Enzymes respond to soil management changes long before other soil quality indicator changes are detectable. Soil enzymes play an important role in organic matter decomposition and nutrient cycling. Some enzymes only facilitate the breakdown of organic matter *e.g.* hydrolase, glucosidase, while others are involved in nutrient mineralization *e.g.* amidase, urease, phosphatase, sulfates. With the exception of phosphatase activity, there is no strong evidence that directly relates enzyme activity to nutrient availability or crop production. The relationship may be indirect considering nutrient mineralization to plant available forms is accomplished with the contribution of enzyme activity. Absence or suppression of soil enzymes prevents or reduces processes that can affect plant nutrition. Poor enzyme activity *e.g.* pesticide degrading enzymes can result in an accumulation of chemicals that are harmful to the environment; some of these chemicals may further inhibit soil enzyme activity. Organic amendment applications, crop rotation and cover crops have been shown to enhance enzyme activity. The positive effect of pasture is associated with the input of animal manure and less soil disturbance. Agricultural methods that modify soil pH can also change enzyme activity.

SOIL STRUCTURE AND MACROPORES

Sand, silt and clay particles are the primary mineral building blocks of soil. Soil structure is the combination or arrangement of primary soil particles into aggregates. Using aggregate size, shape and distinctness as the basis for classes, types and grades, respectively, soil structure describes the manner in which soil particles are aggregated. Soil structure affects water and air movement through soil, greatly influencing soil's ability to sustain life and perform other vital soil functions. Soil pores exist between and within aggregates and are occupied by water and air. Macro-pores are large soil pores, usually between aggregates, that are generally greater than 0.08 mm in diameter. Macro-pores drain freely by gravity and allow easy movement of water and air. They provide habitat for soil organisms and plant roots can grow into them. With diameters less than 0.08 mm, micro-pores are small soil pores usually found within structural aggregates. Suction is required to remove water from micro-pores. Important soil functions related to soil structure are: sustaining biological productivity, regulating and partitioning water and solute flow and cycling and storing nutrients. Soil structure and macro-pores are vital to each of these functions based on their influence on water and air exchange, plant root exploration and habitat for soil organisms. Granular structure is typically associated with surface soils, particularly those with high organic matter. Granular structure is characterized by loosely packed, crumbly soil aggregates and an interconnected network of macro-pores that allow rapid infiltration and promote biological productivity. Structure and pore space of subsurface layers affects drainage, aeration and root penetration.

Clay soils with poor structure and reduced infiltration may experience runoff, erosion and surface crusting. On-site impacts include erosion-induced nutrient and soil loss and poor germination and seedling emergence due to crusted soil. Off-site impacts include reduced quality of receiving waters due to turbidity, sedimentation and nutrient enrichment. Water entry into a sandy soil can be rapid, but subsurface drainage of sandy soils with poor structure can also be rapid such that the soil cannot hold water needed for plant growth or biological habitat.

Practices that lead to poor soil structure include:

- Disturbance that exposes soil to the adverse effects of higher than normal soil drying, raindrop and rill erosion and wind erosion.

- Conventional tillage and soil disturbance that accelerates organic matter decomposition.
- Residue harvest, burning or other removal methods that prevent accumulation of soil organic matter.
- Overgrazing that weakens range and forage plants and leads to declining root systems, poor growth and bare soil.
- Equipment or livestock traffic on wet soils.
- Production and irrigation methods that lead to salt or sodium accumulation in surface soils.

Practices that provide soil cover, protect or result in accumulation of organic matter, maintain healthy plants and avoid compaction improve soil structure and increase macro-pores.Practices resulting in improved soil structure and greater occurrence of macro-pores favorable to soil function include:

- Cover Crop,
- Conservation Crop Rotation,
- Irrigation Water Management,
- Prescribed Grazing,
- Residue and Tillage Management,
- Salinity and Sodic Soil Management.

Total Organic Carbon

Total organic carbon (TOC) is the carbon (C) stored in soil organic matter (SOM). Organic carbon (OC) enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms and soil biota. SOM is the organic fraction of soil exclusive of non-decomposed plant and animal residues. Nevertheless, most analytical methods do not distinguish between decomposed and non-decomposed residues. SOM is a heterogeneous, dynamic substance that varies in particle size, C content, decomposition rate and turnover time.

Soil Organic Carbon

Soil Organic Carbon (SOC) is the main source of energy for soil microorganisms. The ease and speed with which SOC becomes available is related to the SOM fraction in which it resides. In this respect, SOC can be partitioned into fractions based on the size and breakdown rates of the SOM in which it is contained. The first three fractions listed are part of the active pool of SOM. Carbon sources in the active pool are relatively easy to break down. SOM contains approximately 58% C; therefore, a factor of 1.72 can be used to convert OC to SOM. There is more inorganic C than TOC in calcareous soils. TOC is expressed as percent C per 100 g of soil. SOC is one of the most important constituents of the soil due to its capacity to affect plant growth as both a source of energy and a trigger for nutrient availability through mineralization. SOC fractions in the active pool, previously described, are the main source of energy and nutrients for soil microorganisms. Humus participates in aggregate stability and nutrient and water holding capacity. OC compounds, such as polysaccharides bind mineral particles together into micro-aggregates. Glomalin, a SOM substance that may account for 20% of soil carbon, glues aggregates together and stabilizes soil structure making soil resistant to erosion, but porous enough to allow air, water and plant roots to move through the soil. Organic acids *e.g.* oxalic acid, commonly released from decomposing organic residues and manures, prevents phosphorus fixation by clay minerals and improve its plant availability, especially in subtropical and tropical soils. An increase in SOM and therefore total C, leads to greater biological diversity in the soil, thus increasing biological control of plant diseases and pests. Data also reveals that interaction between dissolved OC released from manure with pesticides may increase or decrease pesticide movement through soil into groundwater. A direct effect of poor SOC is reduced microbial biomass, activity and nutrient mineralization due to a shortage of energy sources. In non-calcareous soils, aggregate stability, infiltration, drainage and airflow are reduced. Scarce SOC results in less diversity in soil biota with a risk of the food chain equilibrium being disrupted, which can cause disturbance in the soil environment.

SOIL QUALITY MANAGEMENT

An important function of soil is to buffer and detoxify chemicals, but soil's capacity for detoxification is limited. Pesticides and chemical fertilizers have valuable benefits, but they also can harm non-target organisms and pollute water and air if they are mismanaged. Nutrients from organic sources also can pollute when misapplied or over-applied. Efficient pest and nutrient management means testing and monitoring soil and pests; applying only the necessary chemicals, at the right time and place to get the job done; and taking advantage of non-chemical approaches to pest and nutrient management such as crop rotations, cover crops and manure management. Regular additions of organic matter improve soil structure, enhance water and nutrient holding capacity, protect soil from erosion and compaction and support a healthy community of soil organisms (Lal et al., 1998). Practices that increase organic matter include: leaving crop residues in the field, choosing crop rotations that include high residue plants, using optimal nutrient and water management practices to grow healthy plants with large amounts of roots and residue, growing cover crops, applying manure or compost, using low or no tillage systems, using sod-based rotations, growing perennial forage crops and mulching (Ditzler, 2002).

Compaction reduces the amount of air, water and space available to roots and soil organisms. Compaction is caused by repeated traffic, heavy traffic, or traveling on wet soil. Deep compaction by heavy equipment is difficult or impossible to remedy, so prevention is essential. Subsoil tillage is only effective on soils with a clearly defined root-restricting plow pan. In the absence of a plow pan, subsoil tillage to eliminate compaction can reduce yield. Prevention, not tillage, is the way to manage compaction (Moebius, 2007).

Bare soil is susceptible to wind and water erosion and to drying and crusting. Ground cover protects soil, provides habitats for larger soil organisms, such as insects and earthworms and can improve water availability. Ground can be covered by leaving crop residue on the surface or by planting cover crops. In addition to ground cover, living cover crops provide additional organic matter and continuous cover and food for soil organisms. Ground cover must be managed to prevent problems with delayed soil warming in spring, diseases and excessive build-up of phosphorus at the surface (Pankhurst, 1997).

Diversity is beneficial for several reasons. Each plant contributes a unique root structure and type of residue to the soil. A diversity of soil organisms can help control pest populations and a diversity of cultural practices can reduce weed and disease pressures. Diversity across the landscape can be increased by using buffer strips, small fields, or contour strip cropping. Diversity over time can be increased by using long crop rotations. Changing vegetation across the landscape or over time not only increases plant diversity, but also the types of insects, microorganisms and wildlife (Pankhurst et al., 1997; Magdoff, 1992; Coleman & Crossley, 1996; Lal, 1998).

CONCLUSION

Both soil and water are crucial natural resources which are essential for life on earth. Because of the position soils occupy at the surface of the earth and the fact that they receive huge quantities of water which they then help to re-distribute, there is an important relationship between soils and water. The soil health is the capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health. Anthropogenic reductions in soil health, and of individual components of soil quality, are a pressing ecological concern. The soil can only be assessed for the particular purposes for which it is to be used, such as suitability of soils for a particular crop or a particular program. Properties of soils ideal for one use may not be the ones useful for another use. There are several fundamental properties of soils that influence soil quality. A well-balanced healthy soil is one that is likely to be the most robust and capable of meeting the requirements for a wide range of uses. Some properties, such as texture, are static and cannot be changed readily. Others are more sensitive to change and it is these that we need to monitor carefully to maintain optimum levels. One of the most important is organic matter because it contributes to many functions, such as stability of soil structure, water holding capacity, nutrient-supplying power, and is the food for the huge numbers of organisms that live in the soil. Hence it is usually the number one selection in any monitoring of soils, now particularly because of it large potential impact on climate change. Soil acidity or pH, is another usually essential indicator to be monitored particularly because of the sensitivity of some plants to changes in pH. The agro-ecosystem is made up of many interacting components with multiple goals. Soil quality is one important part of sustainable agro-ecosystem management, analogous to water and air quality. Assessing soil quality may help agronomist to identify practices that could be adapted to become more sustainable.

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Chapter 5
Fly Ash Properties and Their Applications as a Soil Ameliorant

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ABSTRACT

Fly ash is one of the major global pollutants which is produced in millions of tons every year. The high content of heavy metals in fly ash categorizes them as hazardous materials. The presence of ferrous, alumina, and silica along with numerous macro- and micro-nutrients make them a suitable candidate for applications in agriculture, forestry, wasteland reclamation, soil stabilizer, etc. Fly ash has positive effects on the plant growth and crop yield. A numerous literature has reported the applications of fly ash as pesticides, herbicides, and insecticides. It has both alkaline and acidic pH which helps in maintaining the pH of the infertile soil. All these applications are cited with the previous work carried out by the investigators.

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BACKGROUND

Fly ash is produced in huge million tonnes around the globe, which are used for tiles, bricks, cements, road construction and agriculture. Though it has numerous micro and macronutrients which are very important for the plant growth, so it was huge scope in agriculture. It is used as an amendment with soil in different proportions for different plants. Besides this it has also high content of silica and ferrous which are required by the plants. Silica is one of the major elements for the growth of several plants, and forms a hard structure in sugarcane and grass family. Here role of fly ash as an amendment with soil has been discussed, for plant growth, crop yield, and waste land reclamation, as an insecticide, pesticide and herbicide.

INTRODUCTION

Fly Ash

Fly ash is a fine-glass like, spherical shaped heterogeneous in nature whose size varies 0.01-100μ recovered from the gases of burning coal during the production of electricity in thermal power plants. Fly ash commonly resembles to volcanic ashes which were used for the production of earliest known hydraulic cements about 2,300 years ago. Fly ash is the best known, and one of the most commonly used, pozzolans, in the world.

Fly Ash Mineralogy and Composition

These micron-sized earth elements primarily consists of silica, alumina and ferrous. The mineralogy and composition of fly ash varies from one sample to next depending on the source of the coal; degree of coal preparation, cleaning and pulverization; design, type and operation of the power plant boiler unit; conditions during combustion; additives used to assist combustion or improve precipitation performance; efficiency of emission control devices; storage and handling of the by-products; and the prevailing climate (Adriano *et al*, 1988). The mineralogical characteristics determine the crystalline phases of the fly ash which is about 15-45% in the fly ash. The high calcium fly ash i.e. class C have larger amounts of crystalline contents i.e. 25-45% (ACI committee 226, 1987).

Different Classes of Fly Ash

There are two classes of fly ash namely: class C and class F depending on the source of coal used and compositions of fly ash. The primary difference between class C and class F fly ash is the amount of calcium, silica, alumina, and iron content in the ash. Besides these, the two types vary in their applications, mineralogy and content which have been summarized in the Table 1.

Chemical and Material Properties of Fly Ash

The pH of the fly ash varies depending on the source of the coal. Fly ash is known to be both acidic and alkaline in nature. Fly ashes with pH ranging from 4.5 to 12.0 have been identified due to differences in particle size and subsequent concentration of trace metals. Similarly, EC, which reflects the quantitative estimate of soluble cations and anions, varies between 0.177 to 14 mmhos/cm. Ashes from bituminous coal, although higher in S, are mostly acidic, whereas sub-bituminous coal gives rise to alkaline ash with a lower content of S, but a higher content of Ca and Mg than the bituminous coal (Fulekar & Dave, 1990). Fly ash varies in its chemical composition depending on the parent coal and the operating conditions of the furnace. While the physical and mineralogical properties of fly ash vary depending on the source

Table 1. Major differences between class F and class C types of fly ash

S. No.	Class F- Fly Ash	Class C-Fly Ash
1.	Produced from burning harder, older anthracite and bituminous coal	Produced from burning younger lignite and sub-bituminous coal
2.	Contains less than 20% lime	Contains more than 20% lime
3.	Calcium ranges from 1-12%, in the form of calcium hydroxide, calcium sulfate and glassy components	Calcium content: 30-40%
4.	Higher amount of alkali and sulfate	Less amount of alkali and sulfate
5.	Requires cementing agent like PC, quick lime, hydrated lime	Self-cementing properties
6.	Addition of air entrainer needed	Does not require activator & air entrainer
7.	Used in high sulfate exposure conditions	Can't be used in high sulfate conditions
8.	Useful in high fly ash content concrete mixes	Limited to low fly ash content concrete mixes
9.	Used for structural concretes, HP concretes, high sulfate exposure concretes	Primarily residential construction

Table 2. Size distribution in fly ash particles

Category Based on Grain Size	Size (mm)	U.S. Fly Ash (%)
Very coarse sand	2.00-1.00	0.2
Coarse sand	1.00-0.50	0.9
Medium sand	0.50-0.25	3.4
Fine sand	0.25-0.10	14.8
Very fine sand	0.10-0.05	13.1
Silt	0.05-0.002	63.2
Clay	< 0.002	4.3

of coal. In general, approximately 95-99% of fly ash consists of oxides of Si, Al, Fe, Ca and Ti and about 0.5% to 3.5% consists of Na, P, K, Mg, Mn and S (ACI committee 226, 1987). The remainder of the fly ash is composed of trace elements.

Physical Characteristics of Fly Ash

The color of fly ash varies from tan to gray to black, depending on the concentration of unburned carbon in the ash. Lighter the color of fly ash, the lower the carbon content. Lignite or sub-bituminous fly ashes are typically light tan to buff in color, signifying relatively low amounts of carbon, and presence of some amount of lime or calcium. While, bituminous coal derived fly ashes is usually some shade of gray, due to higher carbon content with the lighter shades of gray generally indicating a higher quality of ash. About 98% fractions of fly ash smaller than 75µ; 70% - 80% smaller than 45µ. The specific surface area of fly ash varies between 2,000 to 6,800 cm^2/gram. The specific gravity of fly ash usually ranges from 2.1 to 3.0 g/cm^3, while its specific surface area (measured by the Blaine air permeability method) may range from 170 to 1000 m^2/kg. The particle size of U.S. and Indian fly ash is given in the Table 2.

The major chemical and elemental compositions of fly ash are given in the form of oxides and tabulated in Table 3. Here the total ferro-alumino-silicate (FAS) composition is 88.46% along with traces of Ca, Mg, Na, Mn, K and P oxides. Silica was present 56.989%, alumina 26.072% and iron oxides is 5.401%. Besides this fly ash is rich in rutile phases also which was about 2.901%. It is class F fly ash, as it was high in FAS and low in CaO% content i.e. greater than 70% and CaO less than 5% (Dogan et al., 2001).

APPLICATIONS OF FLY ASH AS A SOIL AMELIORANT

Soil Conditioner

Soil amendments are materials which are mixed with the soil to improve its physical or chemical properties. The exact compositions of soil amendments may vary which depends on the application required. Such amendments can be used to either increase the fertility, soil quality, crops yield, water holding capacity, porosity or several other parameters. Most of the soil amendments acts as a soil conditioner also which have positive impact on the soil health. A soil conditioner is a product which is added to soil to improve the soil's physical qualities, usually its fertility (ability to provide nutrition for plants) and sometimes its mechanics. Soil conditioners can be used to improve the quality of poor soils, or to reconstitute soils which have been spoiled by improper soil management. They can make poor soils more useful for agriculture and can be used to maintain soils in peak condition. The products which are more commonly used as soil conditioners are fly ash, clay, red mud, sewage or sludge waste or agricultural waste. Such soil conditioners are cheaper in cost, easily available and by-product of the industries.

Table 3. Elemental composition of fly ash

Elements	Wt %
SiO_2	56.989
Al_2O_3	26.072
P_2O_5	1.956
SO_3	0.045
Na_2O	4.259
MgO	0.00
K_2O	1.169
CaO	1.096
TiO_2	2.901
MnO_2	0.066
Fe_2O_3	5.401
CuO	0.020
SrO	0.025
Total	**99.999**

One such industrial by product is fly ash which is used nowadays very frequently as soil conditioners due to their high elemental values. Fly ash is a resourceful material which is extensively used as a soil modifier in large quantity and micro fertilizer in converting wasteland into agriculturally productive land. The water retaining property of fly ash in ground facilitates bacteria to perform actions for the cultivation of good quality of crops or vegetables. When fly ash is added to the soil, it generally acts as a soil conditioner by altering the soil texture, nutrients, cation exchange, water retention and many other properties. Fly ash have more than 45 elements including micro and macronutrients in it depending on the source and type of coal.Some of the elements have direct beneficial effect on the soil and plant growth while few in the form of oxides have positive effects on the soil. While the size, shape, texture and other physical properties also have positive effect on the soil and plant growth. The impact of fly-ash on soil largely depends upon the properties of the original coal and the soil examined.

Major Roles of Fly Ash as Soil Conditioners

1. Figure 1 shows the role of fly ash as soil conditioners-acts as a biofertilizer, soil conditioner, etc. It also acts as a source of micro and macro nutrients, as a source of lime for the reclamation of acidic soils.
2. Hydraulic conductivity- increases with small amount of addition, but decreases with higher doses. There is enhanced organic carbon content and moisture availability to plants roots through improved moisture retention characteristics due to the modifications in both micro and macro pores size distribution in the soil. Porosity is the air space between soil particles, which is usually occupied by water when available. So, the increase in water holding capacity is due to greater space between the soil particles. Electrical conductivity is positively correlated with pH and reflects the total concentration of soluble cations and anions (Elseewi et al., 1978). Normal values of electrical conductivity for vegetable crops range between 3 and 4 mmhos/cm, and higher values have adverse effects on crop production (Hodgson & Holliday, 1966). Addition of fly ash to soil significantly increases the electrical conductivity of the soil mixture by increasing the levels of soluble major and minor inorganic constituents (Sudha & Dinesh, 2006; Eary et al., 1990). The initial increase in soil pH after alkaline fly-ash amendment is explained by the rapid release of Ca, Na, Al and OH ions from fly-ash (Hodgson et al. 1982; Wong & Wong, 1990). Excessive Fe and Al convert soluble P to insoluble P compounds, which are not readily available to plants.

Figure 1. Roles of fly ash as soil amendments

Fly Ash: An Alternative Source of Gypsum

Gypsum is a source of calcium which is a major constituent that binds soil organic matter to clay in soil and provides stability to soil aggregates. Gypsum complements the beneficial effects of water-soluble polymers used as amendments to improve soil structure. Fly ash $CaCO_3$ reduces the acidity of the soil and also acts as source of Ca. Fly ash amended soils tends to have lower bulk density, lower hydraulic conductivity, lower moduli of rupture and higher water holding capacity.

Fly Ash-Soil Amendment as a pH Balancer

Fly ash has both acidic and alkaline pH depending on the presence of Na_2O and CaO, which are used to buffer the pH of the soil (Elseewi et al., 1987a). The CaO and Na_2O both are responsible for basic nature and fly ash having alkaline pH can be added to acidic soil to maintain the pH. While the acidic fly ash can be added to the alkaline soil to bring the pH of the soil to neutral. The lime (CaO) or Ca $(OH)_2$ present in fly ash easily reacts with the acidic components present in the soil and releases S, B, Mo in the form of nutrients beneficial to the crop plants. Several investigators have worked in this field and reported the effect of increasing pH of the acidic soil, nutrient status of the soil, and improving soil texture for the agronomic plants. (Sudha & Dinesh, 2006; El-Mogazi et al., 1988) and improving the nutrient status of soil (Doran & Martens, 1972; Schnappinger et al., 1975; Wallace et al., 1980; Rautaray et al., 2003). Soil health is one of the major factors for the soil quality and crop yield. Further a work reported by (Fail & Wochok, 1977), in which fly ash was applied on the acidic strip mine spoils at different places which increased the yield of many crops which was attributed to the increased availability of Ca^{2+} and Mg^{2+}in soil and preventing toxic effects of $Al^{3+}$and other metallic ions by neutralizing the soil acidity. While phosphorus present in fly ash don't have direct role but has been reported that P can accelerate the uptake of Ca^{2+} and Mg^{2+} by leguminous plants (Adriano et al., 1978).

Effect of Soil Amendment on the Physical Properties of the Soil

In general, fly ash is effective in enhancing growth performance and yield of the crops in majority by alone at lower doses and combination treatments at a wider range of fly ash levels. The effect is rather relatively better in case of weathered fly ash applications. Fly ash acts as a potential source of fertilizer or bio-fertilizr due to the richness in C, Si, N, P and K. As fly ash are rich in numerous metals, which on addition into soil not only enhances the metallic content but also increases the electrical conductivity of the soil. It has been observed that the addition of fly ash to the soil results in multi-beneficial effects including (i) improvement in the available N, available P_2O_5 and available K_2O, as also in the contents of available secondary nutrients like Ca^{2+} and $Mg^{2+}$and available micronutrients such as Zn, Mn, Cu, in soil, and (ii) significant improvement in the physico-chemical properties (like bulk density, maximum water holding capacity, pH, electrical conductivity, etc.) of various kind of soils resulting in better soil health (Vimal Kumar & Gopal Krishna Jha., 2014).

In one of the experiments conducted between control soil and fly ash admixed soil at different treatment level varied markedly. Addition of fly ash in lateritic soil resulted in improvement of soil physical properties like texture, bulk density (B.D.), water holding capacity (W.H.C.) and porosity. The concentration of major nutrients such as nitrogen, phosphorus and potassium are slightly increased in treated soils as compared to control. Soil quality, which determines the soil health, manifests into soil productivity and has far reaching effect on the soil ecosystem. While the health of soil depends on inorganic and organic matter content and processes like erosion, salinization and chemical contamination has a direct bearing on ground water contamination, land use and management practices. Work carried out by Fail and Wochok, (1977) and Capp, (1978), where fly ash was added at 70 t/ha, and found that it has altered the texture of sandy and clay soils to loamy soils. Fly ash addition generally decreased the bulk density of soils, which in turn improved soil porosity and workability and enhanced water retention capacity (Page et al., 1979). Because of the addition of fly ash the water holding capacity of sandy/loamy soils increased by 8% and accompanied increase in hydraulic conductivity helped in reducing surface encrustation. Similarly, addition of fly ash to calcareous and acidic soils have showed higher yield in several agronomic crops, due to the enhanced availability of sulphur to plants (Page et al.,1979).

Singh and Siddiqui (2003) conducted a 120-day greenhouse experiment and investigated the effects of various fly ash soil application rates on the growth and yield of three cultivars of rice, *Oryza sativa*. They found that the application rates of 20% and 40% fly ash resulted in major increases in plant growth and yield of all three rice cultivars. Sinha and Gupta (2005) studied the effects of various levels of CFA (10, 25, 50, 75 and 100%, w/w) on plant growth in a fly ash amended soil, seeded with *Sesbaniacannabina*. After 90 days, they found that shoot length and biomass increased up to the 25% fly ash application rate as compared to the untreated control soil.

A field experiment was conducted by Tripathi et al. (2009) to assess the effect of fly ash application on the yield and nutrient composition of wheat, maize and eggplant crops grown in sequence on a previously uncultivated land. The ash was mixed with soil at 100 t ha^{-1}. In the case of first crop (wheat), the increase in yield of grain and straw was 29.4% and 26.6%, respectively, over the untreated control. The residual effect of fly ash was also observed with increase in the yield of maize grain (33.1% e 2^{nd} crops) and eggplant (18.4% e 3rd crops). This clearly demonstrates that when applied in appropriate amounts fly ash as a soil amendment can help in the increase and sustain crop productivity.

Kumar and Patra (2012) performed studies on *Mentha piperita* plant and their findings conclude that application of agronomic doses of fly ash improves soil properties and fertility as well as enhances growth and yield of crops. However, fly ash when applied in larger amounts than site-specific requirements adverse effects are inevitable. In such situations, retardation of plant growth could result from metal toxicity and low availability of nitrogen and phosphorus. Furthermore, given the variability in the nature and composition of fly ash (pH, major- and micro-nutrients) and that of soil (pH, texture, and fertility), a specific fly ash application rate cannot be recommended. For example, an already fertile soil may not show any positive effect, and if the fly ash application significantly raises its pH it may even have negative effects on plant growth due to reduced supply of soil nutrients. Clearly all these factors should be taken into consideration in order to work out appropriate rates of fly ash application for soil site-specific improvements. Increase in the yield has been reported for all crops with application of fly ash. The crops include cereals, pulses, oil seeds, cotton, sugarcane, fodder crops, horticultural crops, ornamental & medicinal plants. The increase in yield of cereal crops have been reported 10-15%, in case of pulses and oil seeds 20-25% and in vegetable as well as in other crops up to 40%. Texture being sandy silt to silty loam improves water holding capacity and percolation in sandy as well as clay soils for beneficial effects.

Role of Fly Ash-Soil Amendment in Agriculture

Use of fly ash as a soil-amending agent has been investigated for a numerous types of crops (Wallace & Wallace, 1986; Elseewi et al.,1978a,b; Tolle et al., 1983; Adriano et al., 1980; Mittra et al., 2003). The crop response appeared to depend on a combination of factors such as method of application, physicochemical properties of soil, precipitation and plant species. Inconsistencies have been reported in the uptake of K, Ca, Mg due to the interaction among these element species in theroot–soil solution interface and within the plant system. Ca and Mg reduced K uptake by plants grown in fly ash treated soils (Martens et al., 1970b; Adriano et al., 1978). An increase in the yield of alfalfa and Bermuda grass was reported on fly ash application (Elseewi et al., 1978a,b). The S content of Swiss chard (*Beta vulgaris*), corn (*Zea mays*) and beans also increased in presence of fly ash irrespective of the soil type and fly ash source (Elseewi et al., 1978a,b; Adriano et al., 1978).

Fly ash amendment in soil substantially improves water holding capacity and plant available water without adversely affecting the growth and marketability of the turf species, centipede grass. The 40% fly ash along with soil was found to have nematicidal effect and was suggested for the management of root knot disease in tomato caused by *Meloidogyne sp*. and providing nutrients (Khan et al., 1997). The cultivars of tomato grown on the fly ash amended soils had higher tolerance to wilt fungus *Fusarium oxysporum* (Khan & Singh, 2001).

Role of Fly Ash-Soil Amendment in Forestry

The concept of fly ash application in agriculture and forestry is not new. Because of its useful physico-chemical properties including the considerable content of macro-nutrients (P, K, Ca, Mg, and S) and micro-nutrients (Cu, Zn, Mn, and Fe), the use of fly ash has been advocated over the last three decades (Page et al., 1979; Adriano et al., 1980; El-Mogazi et al., 1988; Yunusa et al., 2006). The presence of almost all essential plant nutrients in fly ash (Table 1) and its ameliorating effects on physical and chemical nature of the soil thus makes fly ash a useful amendment for crop production especially for degraded soils and wastelands (Ram et al., 2006b; Ukwattage et al., 2013).The use of fly ash on acidic soils can improve their chemical, physical and biological properties (Pandey & Singh, 2010). Coal fly ash depending on its characteristics, and its acidity/alkalinity could be used as an ameliorating agent for sodic soils (Kumar & Singh, 2003), acidic (Ram et al., 2007) and as a safe and effective fertilizer (Gupta et al., 2004). It can also be used to convert the problematic soils including wasteland into agricultural land or for re-vegetation purposes (Shukla & Mishra, 1986; Bhumbla et al., 1991). One foremost beneficial use of fly ash land application could be as an amendment to mitigate problems associated with low soil pH. Some deleterious effects of soil acidity are greater solubility of many TEs (toxic elements) which may become phytotoxic and detrimental to animals/humans when sufficient quantities of these elements accumulate in plant tissues consumed by organisms (Kabata-Pendias, 2011; Hooda, 2010).

Coal fly ash through its influence on soil biological physical & chemical properties and processes is likely to affect the growth and development of the plants (Ukwattage et al., 2013; Singh et al., 2010). Research has demonstrated positive benefits of fly ash land application for improving soil properties and crop productivity (Skousen et al., 2013). Many workers (e.g., Ciravolo and Adriano, 1979; Elfving et al., 1981; Aitken et al., 1984; Khan and Khan, 1996; Singh et al., 1997; Matsi & Keramidas, 1999; Dwivedi et al., 2007; Tripathi et al., 2009) have reported that fly ash addition generally increases plant growth. It has been noticed from the earlier studies and work done, that the amendment of fly ash with soil has significantly increased the yield of agricultural and forest tree species. Fly ash amended soil was attributed to increased availability of major plant nutrients (Asokan et al., 1995). Gratima et al. (2005) found a gradual increase in the yield of succeeding crops after fly ash application, and suggested that the effect was probably due to the residual plant-availability of fly ash borne nutrients in the soil. When weathered fly ash was used there was beneficial effects on the plant growth and productivity of the crop (Ukwattage et al., 2013). Soils generally have inherent structural and nutritional limitations, and the fly ash amendment can improve crop yields and enhance food security (Ukwattage et al.,

Table 4. Fly ash amendment effect on the yield of crops

Plants	References
Lettuce	Lau and Wong, 2001
Zea mays,	Lau and Wong, 2001
Medicago sativa	Lau and Wong, 2001
Lotus corniculatus	Lau and Wong, 2001
Phaseolus vulgaris	Mgagwu, 1983; Wong and Wong, 1989
Brassica parachinensis	Wong and Wong, 1990
Brassica chinensis species	Wong and Wong, 1990
Hordeumvulgare	Sale'etal.,1996
Clover	Summers et al., 1998
forage crops	Gutenmann et al., 1979
Brassica oleracea	Kim et al., 1997
Brassica campestris	Jayasinghe and Tokashiki, 2012
Cotton	Dunn and Stevens, 2000
Cyanodondactylon	Adriano and Weber, 2001; Pathan et al., 2003
Zea. Mays	Tarkalson et al., 2005
Secalecereale	(Matsi and Keramidas, 1999
Oryza sativa	Lee et al., 2006
Solanummelongena	Gond et al., 2013
Biofuel feedstock	Dzantor et al., 2013

2013). The yield increase due to FA application has been extensively reviewed by Basu et al., (2009) and several others. Earlier studies and reviews showed significant increase in the yield was observed for a variety of crops (Table 4).

Fly Ash-Soil Amendment: As a Source of Micronutrients

Fly ash have more than 50-60 elements reported from the different fly ash samples around the various parts of the globe. It has elements essential for plants, it has heavy metals, radioactive elements etc. Elements like, Boron, Cu, Co, Mn, Mg, Na, P, K, Ni, S, C acts as a micronutrients for most of the plants required for growth and vital mechanism. Fly ash are rich source of secondary elements like Ca, Mg and S. Si is one of the major requirement of plants like grass family which have silica depositions in the form of stones.

Table 5. Major source of organic manures

Organic manures				
Cattle shed wastes	**Human habitation wastes**	**Slaughterhouse wastes**	**By-products of agro industries**	**Crop wastes**
Dung, Urine Slurry from biogas plants Poultry Jitter, droppings of sheep and goat	Night soil, Human urine, Town refuse, Sewage, Sludge Sullage	Bone meal Meat meal, Blood meal, Horn and hoof meal, Fish wastes	Oil cakes, Bagasse Press mud, Fruit and vegetable processing wastes	Sugarcane trash, Stubbles and other related material Water hycnith Weeds Green manure crops Green leaf manuring

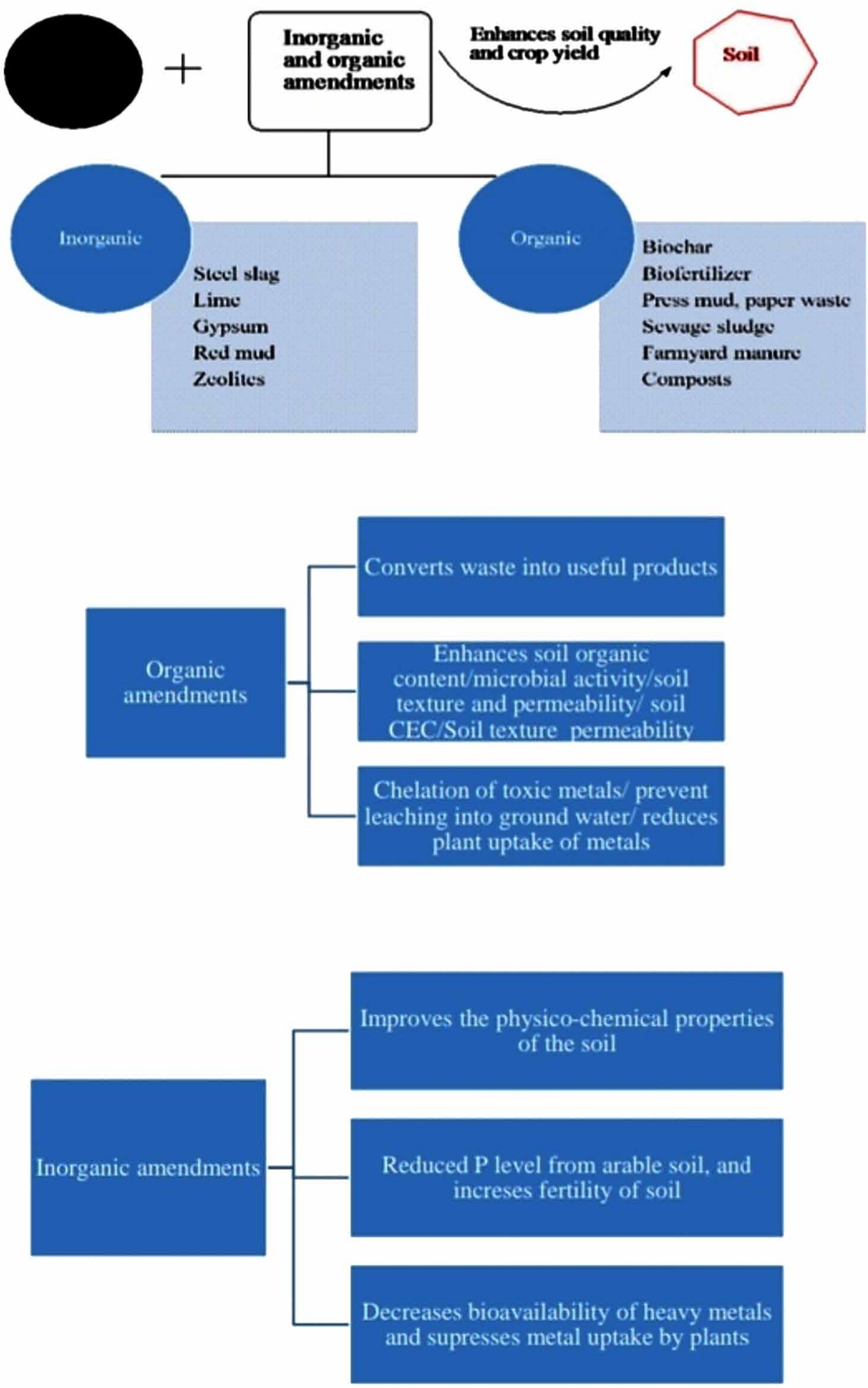
Fly Ash as a Source of Silicon

Fly ash generally reacts with soil and releases silicon which can be effectively used as a source of nutrient for crops. The benefit of Si was highlighted by scientists as spotlight wherever the Si sources of material viz., rice straw, rice hull ash, sugarcane bagasse ash and other available industrial bye products. In recent years the importance of Si fertilization has been realized in view of intensive cultivation of crops where depletion of Si occurs in rice soils which responded to Si sources.

Fly Ash-Organic Manure Amendment

Fly ash is generally rich in inorganic minerals which can be mixed with organic manures and can be proved to be valuable materials for the growth of the plants. Fly-ash is an inorganic substrate that is rich in electrolytes and does not contain significant organic matter; therefore, its addition to soil results in increased hydraulic activity limited at lower application doses (Dharmendra K. Gupta, et al., 2002). Organic amendments improve soil conditions by increasing the cation-exchange capacity and organic matter content of the soil, thereby resulting in increased immobilization of toxic elements, higher fertility and enhanced microbial activity. Certain inhibitory effects to soil microbes by toxic components of fly-ash may,

Figure 2. Flow chart of uses of organic and inorganic amendments



furthermore, be attenuated by the application of organic materials (Chaney and Giordano, 1977). The major sources of organic manures are tabulated in Table 5.

The organic manures are mostly derived from the animal feces, animal matter, and human excreta, vegetable matter (e.g. compost and crop residues) or from the agricultural waste.

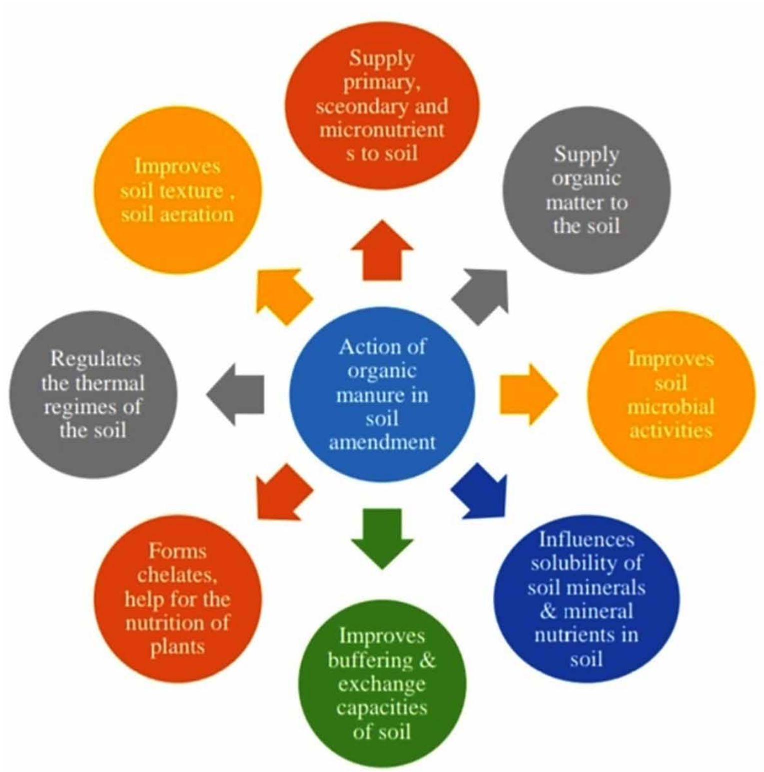
Actions of Organic Manures on the Soil

Basically organic manures have two components plant nutrients and organic matter. The organic matter from it supplies primary, secondary and micro-nutrients to the plants, which are released in the available form as mineralized by different microbes in the soil. Organic matter from organic manure improves the physical condition of the soil like soil structure, aeration, water holding capacity etc. Moreover organic manure also stimulates the activity of different soil micro-organisms through the supply of energy. It improves the buffering and exchange capacities of soil and also influences the solubility of soil minerals as well as mineral nutrients in soil. It also forms chelates which also help for the nutrition of plants and regulates the thermal regimes of the soil. The actions of organic manure are depicted in Figure 3.

Previously several investigators have worked in this field where they have mixed the fly ash with the organic manures and studied the effect of the mixtures on the yield of crop and microbial communities present in the soil. Giardini et al. (1991) mixed the alkaline fly ash with highly carbonaceous acidic material to make compost for soil treatment. They observed the effect of mixing of swine manure with fly ash and reported the increased availability of Ca and Mg balancing the ratio between monovalent and bivalent cations (Na+, K+, Ca^{2+}, Mg^{2+}), which otherwise proves detrimental to the soil.

The calcium present in the organic manure/fly ash mixture have tendency to enhance the flocculation/aggregation of soil particles, mainly clay. Such property of Ca in soil, keeps them friable, enhances water penetration and allows roots to penetrate hard/compact soil layers. Moreover Ca can easily replace the Na at clay exchange sites to enhance soil flocculation and stability. The study conducted by Hill and Lamp (1980) and Molliner and Street (1982) concluded that there was an appreciable change in physicochemical properties of the soil, increase in pH and rice crop yield after the application of fly ash and paper factory sludge and farmyard manure.

Figure 3. The actions of organic manure in soil amendment

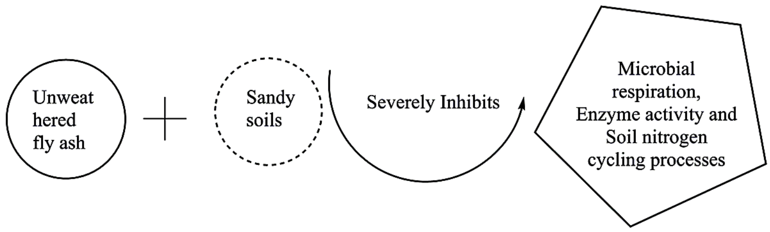


Effect of Fly Ash Amendment on the Biological Properties of Soil

Even though very little is known about the effect of fly ash on the biological properties of the soil. Several short-term laboratory incubation studies found that the addition of un-weathered fly ash to sandy soils strictly inhibited microbial respiration, enzyme activity and nitrogen cycling processes in soil such as nitrification and nitrogen mineralization (Figure 4) (Sudha & Dinesh, 2006). The essential plant nutrients found in fly ash also encourages plant growth and increases crop yield.

Fly ash composted with wheat straw and 2% rock phosphate (w/w) for 90 days enhanced the chemical and microbiological properties of the compost and fly ash up to 40–60%, and did not exert any detrimental effect on either C:N ratio or microbial population (Gaind & Gaur, 2003a,b). There was enhanced microbial activity for the fly ash-amended soils containing sewage sludge (Pitchel, 1990; Pitchel & Hayes, 1990). Moreover, the microorganisms invariably adapt to the stressed conditions and

Figure 4. The mineralization of nitrogen by un-weathered fly ash



show a gradual increase in the respiration after an initial lag. Presence of organic matter in the soil showed an additive effect as it has reduced the concentration of toxic metals through sorption, lowers the C/N ratio and provides organic compounds, which promote microbial proliferation and diversity (Wong & Wong, 1986; Pitchel & Hayes, 1990). From the various available data it was found that the microbial incidence and diversity increases as the fly ash weathers and nutrient accumulates (Rippon et al., 1975).

FLY ASH AS FERTILIZER ADDITIVE, PESTICIDE AND INSECTICIDE

As a Fertilizer

Fly ash is rich in numerous elements like P, N, K, Ca, C and S which are major parts of fertilizer. These elements are released from the amended mixture into the soil in a sustainable way. Fly-ash can be directly used as an economic fertilizer and soil amendment in the small-scale cultivation of plants that have ornamental, medicinal and agricultural or forestry potential. Its application on a large scale to field crops, vegetables and other edible plants, however, must await more extensive field experiments to establish its quality and safety. The mixture of soil and fly ash and their utilization as a fertilizer will not only reduce the cost of traditional fertilizers but also the cost of production of crops and vegetables as well. Nowadays, the cost of fertilizers is roaring continuously. A synergistic fly ash based soil conditioner cum fertilizer composition has been formulated (Singh et al., 2002). The loss of nitrogen from the soil by volatilization, leaching and de-nitrification is significantly inhibited, increasing the efficiency of nitrogenous fertilizers and reducing nitrate pollution of, surface, and water. Fly ash can help the soil to retain inorganic fertilizers for longer periods (Ram et al., 2011), leading to residual, beneficial effects from fly ash application.

As an Insecticide

The insecticidal property of ash from solid fuel in India is well known since a long time; there is tradition of using ashes from cooking biomass/wood fuel as insecticide. A team lead by P. Naranswamy et al. (2002) and scientists from various other research centers has also proved that the fly ash could be effectively used against pests of vegetables such as brinjal, bhendi, tomato and cauliflower. Serious polyphagus pests such as *Helicoverpa armigera* and *Spodoptera litura*, which are major enemies of cotton, have also been found to be controlled by the application of fly ash. It has observed that the fruit yields of bhendi, brinjal and tomato increased considerably when dusted with fly ash. A dose of 40 kg per hectare was recommended for effective control of the pests. The same dose was recommended for the vegetables such as brinjal, bhendi and tomato, but the time of application was variable with the crop. Fly ash can be used as an additive for the formulation of fungal bio-pesticides to control Brown planthopper and GLH. It has been found to induce resistance in rice against BPH and GLH. It protects stored paddy from the red flour beetle infestation, and guards the field population of friendly insects, which are natural enemies of rice pests. Fly ash works by interfering with the mouthparts and digestive system of the larvae of crop pests and help in eliminating them.

Fly Ash as an Insecticide and Pesticide Carrier

Based on all the previous studies carried out in India, have concluded that the fly ash could be a potential insecticide as well as an active carrier in chemical and herbal insecticides for use against several kinds of pests infesting different crops like, rice, vegetables, oil seeds, fruit and plants (WACAU, 2014). It can also be used as a carrier in developing insecticides to check house-hold pests i.e. cockroaches etc. Morphological analyses of the fly ash particles revealed spherical shape containing mostly of silica as silicon–di- oxide (SiO_2) which is present in two forms: amorphous which is rounded and smooth and crystalline which is sharp and pointed. The fly ash particles of different gets adhere to the body skin of the pests and insects firmly as the body morphology is contained with several structures like, scales, spine-like processes hairs, pustules, nodules, vesicles etc. When the fly ashes are sprayed in the form of dusts through mechanical dusters, they reach the targets like the foliage of the plants, cling to it and remain for considerably long time to check the pest damage. These structural features of the fly ash shown that there was better dispersion of the filler in the synthesis of herbal and chemical insecticides while incorporating carrier – value to the fly ash.

WASTELAND AND MINING SITES RECLAMATION BY FLY ASH AMENDMENT

The addition of energy-related by-products, such as fly ash to the degraded or spoiled mine soil and wasteland, can address their adverse characteristics through a variety of mechanisms. Recently the application of fly ash in reclamation of mine spoil has been reviewed. In a number of field investigations, enhancement in the biological activities of waste/degraded land, alkaline soil, and mine spoil on amendment with fly ash and pond ash alone and in combination with inorganic and organic amendments was observed.

There was enhanced productivity in the crop plants like maize, wheat, paddy and brinjal. Applying fly ash to acidic mine soils increased the yields of different cropsin several places, which were credited to increased plant nutrient availability and no toxicity effects due to trace and heavy metals and radionuclides. Re-vegetation of fly ash land-fills and ash dumps with different species has been attempted. This includes yellow sweet clover (*Melilotusofficinalis*), white sweet clover (*Melilotusalba*), and other tree species. The plant species contribute to improving the nutrient status of the reclamation site (mine spoil/ash- filled area) through littering and subsequent bio-decomposition proliferation in microbial activity (Ram et al., 2008).

Sometimes along with fly ash some amendments such as lime, gypsum and organic materials are also used for degraded land reclamation purposes. However, large-scale use of such amendments has been restricted due to economic considerations and limited availability of the materials needed. Industrial by-products, like coal and bio-fuel combustion wastes, such as alkaline fly ash can be used as a useful soil ameliorant (Sajwan et al., 2003). Coal fly ash is one of the most economical and largely available waste materials suitable for reclamation of degraded soils (Pandey et al., 2012). Results from many studies suggest enormous potential for the use of fly ash to improve cultivable, degraded/waste land and mining-affected soils for agriculture and forestry (Shaheen et al., 2014).

Acid mine drainage, mine-tailings ponds, and mineralized waste dumps are sources of toxic metal pollutants and acidity. Coal fly ash as a soil amendment has capability of restoring acid mine drainage affected land and increased metal solubility problems (Misra et al., 1996; Iyer & Scott, 2001; Xenidis et al., 2002). Studies have indicated that land application of fly ash improves the physical, chemical and biological qualities of such mining activities affected soils. The use of fly ash as a soil amendment for contaminated mine sites would solve several problems by reducing the amounts of other soil ameliorants (fertilizers, lime) required and by decreasing the mobility and bioavailability of PTEs (Mittra et al., 2005; Ciccu et al., 2003).

USE OF FLY ASH FOR CONTAMINATED LAND REMEDIATION

Fly ash can be used for the reclamation of mined area, acidic mines, or meat polluted area, as they are a good absorbent and being cheaper in cost being a waste product. Preserving soils from degradation, particularly due to pollution by toxic metals and organic pollutants is of increasing concern. Even though many of the metals are essential in trace amounts for plants, human health and other biota, at their elevated levels due to pollution they are potentially toxic and thus present a great health and environmental risk. The risk, however, can be mitigated by controlling metal soil solubility. One of the most important method to reduce the metals solubility and hence their availability to plant is liming, a method which increases the pH of the soil and enhances metals retention in the solid phase (Hooda et al., 1997; Hooda, 2010). However, liming has several limitations. For example, it is not efficient in strongly acidic soils, as large amounts of lime are not available in many regions of the world, and mining for lime has its own environmental impact.

For Acidic Soils

Coal fly ash applied on acidic mine spoil strips at various field locations reported to increase the yield of several crops which was attributed to the increased soil availability of Mg& Ca and prevention of Mn, Al and other metallic ions toxicity by neutralizing the soil acidity (Fail & Wochok, 1977). Clearly the use of fly ash for reclamation of metalliferous abandoned mining sites or sites affected by acid mine drainage can help neutralize the acidity and mitigate associated problem of metal toxicity and at the same time can supply key soil nutrients for land cover establishment.

For Reclamation of Sodic Soil

Fly ash has also been successfully utilized and recommended for reclamation of sodic soil. The effect of pond ash alone and in combination with other amendments on eradication of sodicity is found suitable a suitable substitute of gypsum at much lower cost. When fly ash was used with gypsum or along with farm yard manure, showed a synergistic positive effect in increasing the yield of paddy, wheat and mustard in highly sodic soil. Results of all the fields' experiment/trials indicate that based on the degree of alkalinity/salinity pond ash can effectively substitute 50% gypsum requirement.

FLY ASH FOR THE REMEDIATION OF METAL CONTAMINATED SOILS

The use of alkaline fly ash may offer an alternative way of metal contaminated soil remediation/management via their immobilization (Kim et al., 2012). This was demonstrated in a study where fly ash was used to stabilize a Pb- and Cu-contaminated soil (Kumpiene et al., 2007). The results showed that soil amendment with fly ash reduced the leaching of Cu and Pb by an average of 96%and 99.9% in laboratory batch experiments and by 96% and 97%, respectively during the two-year field trial period. The amendment reduced the exchangeable metal forms, as estimated by different physicochemical methods, likely resulting from the formation of new mineral Cu- and Pb-bearing phases and the enhanced metal sorption due to enhanced amount of sorptive sites.

The use of fly ash seems to offer significant metal immobilization potential. For example, a laboratory column leaching study demonstrated that relatively small additions of fly ash to contaminated soils drastically reduced the toxic metal content in the effluent (Ciccu et al., 2003). Similarly, Dermatas and Meng (2003) found that addition of fly ash to metal-contaminated soils effectively reduced metals leaching well below their nonhazardous regulatory limits. One of the criticisms of such studies is that they are often short-term and lack field testing.

Another study where fly ash was used to aid phyto-stabilisation of a site highly contaminated with PTEs showed similar results. Eight years after amending the site with fly ash and planting with trees, the findings show that soil extractable Cd, Pb and Zn were much lower than in the reference control, at least partly due to soil pH buffering effect of the fly ash (Lopareva-Pohu et al., 2011). The effect of fly ash on metal mobility via its influence on soil pH was further demonstrated by Houben et al. (2012), where the fly ash application reduced leaching and plant-availability of Cd, Zn and Pb, mainly due to increased soil pH. The mechanism of metal stabilization in a contaminated soil by silicon-rich amendments was investigated by Gu et al. (2011). XRD analysis revealed that the mobile elements were mainly transformed as their silicates, phosphates and hydroxides in the amended soil. Scotti et al. (1999) in a study with different soils amended with fly ash found that in acidic soils the ash addition decreased Zn, Cu, Cd and Ni bioavailability.

Coal fly ash can retain the metals due to their composition (alumina, silica, ferric oxide, calcium oxide, magnesium oxide and carbon, and its physical properties), even though it can be a significant source of them as well which was demonstrated by Tsadilas et al. (2009c) where they compared the influence of fly ash application (0.25% and 0.5%, w/w) on Cu and Zn sorption by an acidic soil. The distribution co-efficient (K) values for the 0.5% treatment were about 10 and 7 times greater compared to those of the control soil for Zn and Cu, respectively.

Similar influence of CFA application on Cd and Pb sorption by an acidic Alfisol was also observed (Shaheen & Tsadilas, 2010). The increase in metal sorption following fly ash application may also be attributed to its alkalinity and high contents of silica, alumina and iron oxides, which are strong metal sorbents (Adriano et al., 1980). This interpretation is consistent with the observations that the hydrous silicon oxide and aluminium oxide in fly ash can form complexes with metal ions bychemical bonding. It would, therefore, appear that fly ash enhances soil metal sorption through a combination of mechanisms, such as, raising soil pH, supplying metal sorbents (e.g. silica oxide, aluminium oxide) and by increasing soil surface area. Bertocchi et al. (2006) also confirmed the high sorption capacity of fly ash for As, Cd, Cu, Pb and Zn. The results of this investigation showed that sorption capacity is strongly influenced by pH. One of the most apparent and ubiquitous mechanisms in heavy-metal tolerance in plants is the neutralization of toxic metal ions by specific metal-binding peptides, called phytochelatin. Phytochelatins are most responsible for Cd detoxification, but are also believed to have a role in multiple species of metals (Grill et al., 1985).

VERMIN COMPOSTED FLY ASH

Among different methods of composting of organic materials, vermin composting technology is recently emerging as an important one owing to simplicity as well as high efficiency of this technology in producing better quality compost, as compared to traditional methods of composting. The utilization of fly ash with organic and mineral wastes will not only help in extraction of more amount of plant nutrients into available forms from insoluble mineral fractions in fly ash, but it will also supplement the material with organic matter for improving the health of the soil. The organic materials, excreted by the earthworms in half digested forms, contain micro-organisms and enzymes in high concentrations, which help in rapid aerobic decomposition of these excreted organic materials resulting in the production of good quality compost in lesser period of time along with multiplication of different beneficial micro-organisms. Such beneficial effects of vermin composting of fly ash have been witnessed in field levels also. Use of vermin composted fly ash resulted in significant yield rises in case of rice, potato and tomato etc.

CONCLUSION

No doubt fly ash is considered as hazardous pollutants due to their high heavy metal contents, but at the same time it finds applications in the agriculture, civil works, after slighter modification. The fly ash amended soil has positive effect on the crop yield and growth of plant. It is beneficial for cotton, brinjal, bhendi etc while it also acts as an insecticide or pesticide against several insects and pests. Fly ash have successfully used for the waste land reclamation, moreover it is cheaper and byproduct of thermal power plants. The fly ash has also used to modify the soil pH, as fly ash has both acidic and alkaline pH so it has been used to neutralize the alkaline and acidic soil. Moreover fly ash on amending with soil enhances the water holding capacity, bulk density, porosity, conductivity etc. It finds more applications in agriculture, agro-forestry in future.

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Chapter 6
Impacts of Phosphate Amendments at a Contaminated Site:
Soil Sustainability

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ABSTRACT

Soil amendments can be used to cost-effectively reduce the bioavailability and mobility of toxic metals in contaminated soils. Phosphate amendments effectively can be transformed to soil from the non-residual (sum of exchangeable, carbonate, Fe/Mn, and organic) to the residual fraction. Metal immobilization can be attributed to the metal-induced formation of chloropyromorphite which can be identified in the surface soil, subsurface soil, and plant rhizosphere soil. Phosphate treatments can significantly reduce metal translocation from the roots to the shoots in the plants/crops possibly via the formation of chloropyromorphite on the cell walls of roots. Application of combined H3PO4 with phosphate rock can be provided an effective alternative to the current phosphate remediation technologies for contaminated soils.

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INTRODUCTION

Rock phosphate is an important mineral resource with numerous uses and applications in agriculture and the environment. It is used in the manufacture of detergents, animal feed, and phosphate (PO_4^{3-}) fertilizers. Leaching or runoff losses from rock phosphate products like PO_4^{3-} fertilizers, animal feeds, and detergents could cause eutrophication of surface waters enriched in PO_4^{3-} by these losses. Although direct application of rock phosphate reduces pollution by acting as a slow-release fertilizer, its effectiveness is limited by several factors. The major limitation of rock phosphate in direct application is its low solubility, which reduces its availability for soil reactions or plant uptake. Strategies used to increase the effectiveness of directly applied rock phosphate are based on increasing acidity, as this increases rock phosphate solubility. The application of rock phosphate in agriculture may have adverse effects because it contains hazardous elements that could be transferred to the soil through the application of fertilizers, especially after long term use. Chemical analysis of Rock phosphate obtained from top rock phosphate-producing countries, however, shows that hazardous elements contained therein are below tolerable limits for PO_4^{3-} fertilizers. Studies have also reported that the radionuclides in rock phosphate do not pose any radiological risk. The presence of these elements in rock phosphate can be put to positive use if they are extracted before they are applied to farmlands. This makes rock phosphate a source of rare earth metals and radionuclides that could be used in technological development and as a future energy source. The affinity of rock phosphate for metals makes it a useful adsorbent for the removal of metals from aqueous solutions and an excellent material for metal immobilization in contaminated soils. Rock phosphate is a very important finite resource but its applications have adverse environmental implications.

SOIL AMENDMENTS

Soil amendments can be used to cost-effectively reduce the bioavailability and mobility of toxic metals in contaminated soils. One study was conducted at a Pb-contaminated site to evaluate the effectiveness of P-induced Pb immobilization by Cao et al., 2002. Phosphate was applied at a 4.0 molar ratio of P to Pb with three treatments: T1, 100% of P from H3PO4; T2, 50% P from H3PO4 + 50% P from Ca(H2PO4)2; and T3, 50% P from H3PO4 + 5% phosphate rock. Phosphate amendments effectively transformed soil Pb from the nonresidual (sum of exchangeable, carbonate, Fe/Mn, and organic) to the residual fraction, with residual Pb increase by 19−48% for T1, 22−50% for T2, and 11-55% for T3, respectively. Lead immobilization was attributed to the P-induced formation of chloropyromorphite [Pb10(PO4)6Cl2], which was identified in the surface soil, subsurface soil, and plant rhizosphere soil. Occurrence of chloropyromorphite was evident 220 days after P addition for T1 and T2 treatments and 330 days for T3. Visual MINTEQ model and activity-ratio diagram indicated that lead phosphate minerals controlled Pb2+activities in the P-treated soils. Phosphate treatments significantly reduced Pb translocation from the roots to the shoots in the St. Augustine grass (*Stenotaphrumsecundatum*), possibly via the formation of chloropyromorphite on the cell walls of roots. In this field observation, the researcher suggested that P amendments are efficient in reducing Pb mobility via in situ formation of insoluble chloropyromorphite minerals at a field setting. Lead immobilization shows a long-term stability. A mixture of H3PO4 and phosphate rock yields the best overall results for in situ Pb immobilization, with less soil pH change and less P leaching. Application of combined H3PO4 with phosphate rock may provide an effective alternative to the current phosphate remediation technologies for contaminated soils.

METAL IMMOBILIZATION

The contact of soluble metal species with microbial cells results in *in-situ* transformations of the targeted species. As a consequence, the metals are immobilized by the microbial biomass. Soluble metal and metalloid species may be sequestered from water streams via their interaction with microbial cells by active (i.e. metabolic/ energy dependent) and passive (i.e. non metabolic/energy independent) processes. Metabolically mediated immobilization of metal species by active microbial cells includes different mechanisms such as bio-precipitation and biological reduction/ oxidation. Passive metal uptake by microbial cells is described by the general term biosorption and includes different mechanisms of physico-chemical interaction between the microbial cell biopolymers and the metal species such as complexation, chelation, ion exchange and precipitation.

Both living/metabolizing and non-metabolizing microbial cells may be used in technology development for:

1. The removal of metals from aqueous industrial effluents
2. Metal recovery from industrial process streams
3. Bioremediation of contaminated surface waters and groundwater

Among the existing microorganisms in nature, bacteria, fungi, yeasts and algae are used in most cases for metal and metalloid sequestering from water streams.

Microorganisms influence the chemical state - speciation and hence the mobility of the metals by numerous and complex mechanisms ranging from direct processes like metal transformation and intracellular uptake, to more indirect processes via production of substances that render the metals more or less mobile.

Microbially-mediated metal transformations

- May involve phase changes of metals;
- Are responsible for metal cycling in ecosystems.
- Are of use in biohydrometallurgy and bioremediation
- Are much more often caused by prokaryotes than by eukaryotes

A great number of microbially-mediated metal transformations exist. The mechanism and influence on metal mobility is not clear in all cases. Many terms that are used for classification are overlapping and there is some confusion in terminology (Johnson, 2006).

- Assimilation/adsorption and mineralization
- Dissolution and precipitation
- Oxidation and reduction
- Methylation and dealkylation

Other commonly used terms describing microbially-mediated metal transformations are not always consistent with the previous classification. These terms seem often to be used to describe biotechnologies like applied microbially-mediated metal transformations within biohydrometallurgy:

- Bioleaching
- Biotransformation
- Microbiological separation processes like
  - Biosorption
  - Bioprecipitation
  - Bioaccumulation

Bioremediation

Bioremediation is one of the most promising technological approaches to the problem of hazardous waste. It is a technology for removing pollution from environment, restoring contaminated site and preventing future pollution. Bioremediation can be performed in situ or ex situ. Microorganisms directly degrade contaminants rather than merely transferring them from one medium to another, employ metabolic degradation pathways and can be used in situ to minimize disturbance of the clean-up site. Hence, microorganisms can be effective, economical and non-disruptive tools for eliminating hazardous chemicals. Its advantage generally outweigh the disadvantage, therefore may be used as management tool.The microorganisms can improve phytoextraction by increasing plant biomass or by enhancing the availability of heavy metals to the plant. However, use of microorganisms to improve plant biomass via improved N or P nutrition can have a significant positive impact on phytoextraction. Those soils, which are contaminated and possess the higher amount of toxic metal than plant tolerance, then at such sites phytoremediation through rhizobacteria is preferred and carried out. This method not only increases the plant tolerance towards metals but also stabilizes the growth of plants involving the remediation of metal polluted soil. The soil fertility which is being lost due to heavy metal accumulation has been restored through this method. As the role of plant growth-promoting rhizobacteria is known however a lot remains there to understand regarding the mechanism of phytoremediation. While on the other hand, bioremediation through rhizobacteria is an economic and ecological friendly process.In order to survive in heavy metal polluted environments, many microorganisms have developed resistance to toxic metal ions. Thesemechanisms include: metal exclusion by permeability barriers, active transport of the metalaway from the cell organism, intracellular sequestration of the metal by protein binding,extracellular sequestration, enzymatic detoxification of the metal to a less toxic form andreduction in metal sensitivity of cellular targets. The detoxification mechanisms may be directed against one metal or a group ofchemically related metals. Furthermore, the detoxification mechanisms may vary dependingon the type of microorganism. Most microorganisms are known tohave specific genes for resistance to toxic ions of heavy metals. Mostly, the resistance genesare found on plasmids or on chromosomes. Plasmid encoded metal resistancedeterminants have been reported to be inducible.

Biosorption

Among the recent studies biosorption by filamentous fungi is the most frequently used technology to treat waste water contaminated with mercury. The technology has been used to meet regulatory cleanup levels, is commercially available to treat waste water, and generates a residual that typically does not require further treatment before disposal. There is always a scope of improvement and addition of new technologies or process improvement, the intent of this chapter is to call for action with the development of sound efficient and economical methods to reduce the contamination of mercury.

CHLOROPYROMORPHITE FORMATION WITH METAL

Conversion of soil Pb to pyromorphite [Pb5(PO4)3Cl] was evaluated by Ryan et al. (2001) by reacting a Pb contaminated soil collected adjacent to a historical smelter with hydroxyapatite [Ca5(PO4)3OH]. In a dialysis experiment where the soil and hydroxyapatite solids were placed by researchers in separate dialysis bags suspended in 0.01 M NaNO3 solution a crystalline precipitate, identified as chloropyromorphite, formed on the dialysis membrane containing the soil. The aqueous composition of the solution indicated that dissolution of solid-phase soil Pb was the rate-limiting step for pyromorphite formation. Addition of hydroxyapatite to the soil caused a decrease in each of the first four fractions of sequential extractable Pb and a 35% increase in the recalcitrant extraction residue. After 240-day incubation at field-moisture content there was a further increase in the recalcitrant extraction residue fraction of the hydroxyapatite-amended soil to 45% of the total soil Pb. The increase in the extraction residue fraction in the hydroxyapatite amended 0-d incubated soil as compared to the control soil illustrates that the chemical extraction procedure itself caused changes in extractability. Therefore, the chemical extraction procedure cannot easily be utilized to confirm changes occurring in amended soils. The further increase after the 240-d incubation implies that the reaction also occurs in the soil during incubation. Extended X-ray absorption fine structure (EXAFS) spectroscopy indicated that after the 240-d incubation the hydroxyapatite treatment caused a change in the average, local molecular bonding environment of soil Pb. Low-temperature EXAFS spectra (chi data and radial structure functions – RSFs) showed a high degree of similarity between the chemical extraction residue and synthetic pyromorphite, providing additional evidence that the change of soil Pb to pyromorphite is possible by simple amendments of hydroxyapatite to soil.

IMPACT OF METAL ON SOIL

Heavy metal pollution is a serious global environmental problem as it adversely affects plant growth and genetic variation. It also alters the composition and activity of soil microbial communities. The objectives of this study were to determine the soil microbial diversity, bermudagrass genetic variation in Cd contaminated or uncontaminated soils from Hunan province of China, and to evaluate Cd-tolerance of bermudagrass at different soils. The Biolog method, hydroponic experiments and simple sequence repeat markers were used to assess the functional diversity of microorganisms, Cd-tolerance and the genetic diversity of bermudagrass, respectively. Four of the sampling sites were heavily contaminated with heavy metals. The total bioactivity, richness, and microbial diversity decreased with increasing concentration of heavy metal. The hydroponic experiment revealed that bermudagrass populations collected from polluted sites have evolved, encompassing the feature of a higher resistance to Cd toxicity. Higher genetic diversity was observed to be more in contaminated populations than in uncontaminated populations. Heavy metal pollution can result in adverse effects on plant growth, soil microbial diversity and activity, and apparently has a stronger impact on the genetic structure. The results of this study provide new insights and a background to produce a genetic description of populations in a species that is suitable for use in phytoremediation practices.

Microorganisms and plants employ different mechanisms for the bioremediation of polluted soils. Using plants for the treatment of polluted soils is a more common approach in the bioremediation of heavy metal polluted soils. Combining both microorganisms and plants is an approach to bioremediation that ensures a more efficient clean-up of heavy metal polluted soils. However, success of this approach largely depends on the species of organisms involved in the process. Plants growing on these soils show a reduction in growth, performance, and yield. Bioremediation is an effective method of treating heavy metal polluted soils. It is a widely accepted method that is mostly carried out in situ; hence it is suitable for the establishment/ reestablishment of crops on treated soils.

Soil pollution by heavy metals is a critical global environmental problem. Experts have estimated that more than 20 million hectares of farmland in China have been contaminated, accounting for 20% of the total landmass (Wei & Chen, 2001). Cd is considered to be one of the most phytotoxic metal pollutants due to its high mobility (especially in soil with low CEC and acidic pH), bioaccumulation in lower organisms and its easily being transferred to higher trophic levels in the food chain (Lin & Aarts, 2012). The toxicity of Cd pollution and its physical disturbance can influence plant survival, reproductive success and migration (Deng et al., 2007). Plants are sedentary; they lack the ability to move actively to evade contaminated environment. Therefore, their only chance to survive in unfavorable conditions is the mobilization of defense mechanisms, and evolution of tolerate genotype (Chmielowska-Bąk et al., 2014).

Soil microorganisms, both free-living and symbiotic soil microbes in the rhizosphere of plants growing on metal contaminated soils, can increase plant biomass production and enhancing phytoremediation process. However, heavy metals affect the growth, morphology, and metabolism of soil microorganisms, through functional disturbance, protein denaturation or the destruction of the integrity of cell membranes (Leita et al., 1995). Soil microorganisms are essential in the decomposition of soil organic matter; any decrease in the microbial diversity or abundance may adversely affect nutrient absorption from the soil for plant (Giller et al., 1998a). The elevated levels of heavy metals in soils had significant impacts on the population size and overall activity of the soil microbial communities. Several studies, depending on the isolation-based techniques used, have revealed that heavy metal contamination gave rise to shifts in microbial populations (Gingell et al., 1976; Barkay et al., 1985; Roane & Kellogg, 1996). However, isolation-based techniques are limited because they only represent a small component of the microbial community. This limitation could be attributable to the fact that only a small percentage of soil microbes are culturable. A relatively improved procedure that may be useful in evaluating changes in microbial community structure is the determination of the metabolic profile of a particular system via the Biolog procedure (Garland, 1997). Biolog has been effective in characterizing the functional capability of soil organisms to utilize specific carbon substrates (Garland & Mills, 1991; Garland, 1996), and also has been widely used in assessing the functional diversity, associated with the microbial community in soil samples from farmland and grassland ecosystems (Sarathchandra et al., 2001; Rutgers et al., 2016).

Bioremediation is the use of organisms (microorganisms and/or plants) for the treatment of polluted soils. It is a widely accepted method of soil remediation because it is perceived to occur via natural processes. It is equally a cost effective method of soil remediation. Blaylock et al. (1997) reported 50% to 65% saving when bioremediation was used for the treatment of 1 acre of Pb polluted soil compared with the case when a conventional method (excavation and landfill) was used for the same purpose. Although bioremediation is a non-disruptive method of soil remediation, it is usually time consuming and its use for the treatment of heavy metal polluted soils is sometimes affected by the climatic and geological conditions of the site to be remediated.

EFFECTS OF PHOSPHATE ROCK ON SEQUENTIAL CHEMICAL EXTRACTION OF LEAD IN CONTAMINATED SOILS

Lead contamination is of great concern because of its adverse effects on human health, especially children. Ma et al. (1997) evaluated the effects of phosphate rock on chemical associations of Pb in eight Pb-contaminated soils using a sequential extraction procedure. The chemical fractions are operationally defined by an extraction sequence in the order of increasing ability to dissolve Pb of lower solubilities. Additionally, more soluble forms of Pb are considered to be potentially more bioavailable than the less soluble forms. Lead in these soils was primarily associated with the carbonate and Fe-Mn oxide fractions (63–85%). Up to 21% of the Pb in these soils was associated with either the organic or the residual fraction and < 11%

was associated with the water-soluble and the exchangeable fractions. Phosphate rocks effectively converted Pb from the water soluble, exchangeable, carbonate, Fe-Mn oxide, and organic fractions (collectively the nonresidual fraction) to the residual fraction, thus reducing Pb solubility and presumably bioavailability. Lead precipitation as a fluoropyromorphite-like mineral in these contaminated soils was suggested as the primary mechanism for reduced Pb solubility and Pb reduction in the nonresidual fraction. The effective conversion of Pb from potentially available fractions to the residual fraction suggests that phosphate rock has potential for in-situ immobilization in Pb contaminated soils.

CONCLUSION

Composting with phosphate is very cheap and reliable techniques for the solid waste containing organic matter. If the compost contains contaminants such as heavy metal then it is harm to environment. Heavy metals are toxic to soil, plants, aquatic life and human health if their concentration is high in the compost. Heavy metals exhibit toxic effects towards soil biota by affecting key microbial processes and decrease the number and activity of soil microorganisms. Even low concentration of heavy metals may inhibit the physiological metabolism of plant. Uptake of heavy metals by plants and subsequent accumulation along the food chain is a potential threat to animal and human health. The amendment of soil with rock phosphate is more favorable than other chemical fertilizers at contaminated sites. Hence, the use of rock phosphate as soil amendments should be encouraged.

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Chapter 7
Synergism Between Microbes and Plants for Soil Contaminants Mitigation

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ABSTRACT

Soil mitigation is an approach to reduce the soil degradation occurring in all aspects. Soil contamination mainly happens due to release of varieties of inorganic and organic constituents into soil. Presence of highly poisonous contaminants into soil in high concentrations is enough to cause a threat to ecosystem and on human health. Sustainable approaches can be designed by the direct and indirect utilization of microbes and plants to reduce the soil pollution load. The utilization of microbes with plants in "synergy" is considered as one of the most fruitful approaches for the removal of soil pollutants. It is well known that plant host a variety of microbes in their roots, rizosphere, and shoot by giving them essential environment to flourish and colonize. Similarly, microbes benefit by making available certain soil nutrients to plants and also help in maintaining the overall health of soil. This chapter will emphasize the problems related to soil degradation by metals, pesticides, and hydrocarbons, and their remediation by the utilization of plant-microbial synergism system.

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BACKGROUND

Life-supportive and basic component of the bio-sphere is 'soil', it provides several benefits to the environment involving maintenance of biodiversity, primary production, management of biological cycles, bio-diversity and essence of life (Alexander, 1978; Kuske*et al.,* 2002). Majority of the population dating few centuries back had a belief that the resources present on this land are surplus in amount and that these will remain available to man-kind for coming future generations. But unluckily due to extensive utilization and present exploitation, about half of this naturally present wealth is either damaged or is on the edge of exhaustion (Balba*et al.,*1998; Andreoni*et al.,* 2004; Reda & Ashraf, 2010). The main factors causing depletion of healthy soil ecological system are the non-judicious application of pesticides, chemical fertilizers, hydrocarbons, petroleum compounds, metals, disposal of anthropogenic chemicals and deposition of industrial and domestic effluent into nature; each of these actions are creating a serious danger to mankind itself (Kuske*et al.,* 2002; Srogi, 2007). In relation to other prevailing contaminants – toxic as well as heavy metals,petroleum hydrocarbons, xenobiotic compounds and pesticides are of immense concern due to their toxic behavior, ability to persist for a longer duration in nature and complexity of their structures. (Tolosa*et al.,* 2004; Pinedo*et al.,* 2013; Brevik*et al.,* 2015; Fatima *et al.,* 2015; Tahseen*et al.,* 2017). Through the alliance of bio- and physio-chemical processes the soil system is able to convert, preserve, detoxify to some extent and discard contaminants (United States Environmental Protection Agency). Further it helps the microbial populations and other naturally occurring biota which are associated in the recycling of important nutrients and elements. On the other hand, it promotes the sequestration and processing of organic carbon. Besides the continuous over utilization and misuse of natural resources, population boom, and industrialization have made their way to the liberation of toxic compounds in the soil ecosystem (Mielke et al. 2004; Chen, 2007). The surrounding ecosystem can become contaminated with biodegradable and non-biodegradable chemicals as a consequence of naturally, accidental, or intended events like manufacturing industry waste, poor waste management and disposal, extraction of minerals, use of fertilizers, leaking of chemicals from underground storage sources, illegal waste dumping, and other mismanaged activities of various industries (Environment Act, 1995).

In order to categorize that soil is polluted, the current environmental behavior, strength and exposure route or a potential threat of a contaminant to health of humans or an ecological system, need to be characterized (Environment Act, 1995). Only then precise approach towards the soil mitigation can be designed effectively. Most of the contaminants enter into the environment, whether they are natural resources or man-made, leading towards the pollution of fresh water sources, deteriorating air and water quality and ultimately affects the fertility of soil (Sebiomo et al., 2010; Janbandhu & Fulekar, 2011; Prince et al., 2013; Shabir et al., 2013). Besides continuous exposure human beings even to these low strength contaminants can lead to serious genetic defects. (Aguilera et al., 2010; Ordinioha & Brisibe, 2013; Robertson & Hansen, 2015). Since the problem of soil contamination is prevailing worldwide, more precise techniques are required as compared to traditionally used ex-situ techniques which are very expensive and leave harmful residues or effects on the environment. The traditionally used techniques are usually based on physio-chemical methods are not preferable because they consume lot of time, energy, money and labor, further for their proper management skilled personnel's are required (Pandey *et al.,* 2009)

In the view of the limitations of traditional methodologies, an efficient approach is required to remove the contaminants or transform the contaminants into less toxic or non-toxic forms. This can be achieved by the utilization of efficient microbial strains in association with suitable flora i.e. plant-microbe assisted remediation (Weyens et al., 2009; Khan et al., 2013a; Ijaz et al., 2015a; Fatima et al., 2016). This approach also provides a future hope for in-situ processing of polluted land with higher efficiency, moreover, it will also help to rectify and restore the natural soil ecological system, as compared to conventionally used methods (Chaudhry et al., 2005; Company et al., 2010; Glick, 2010; Sessitsch et al., 2013; Afzal et al., 2014a; Ijaz et al., 2015b, 2016; Ahmed et al., 2017). In microbe-plant synergism system, plants provide essential environment and nutrients to their associated microbe and in return the microorganisms promote the plant development and helps in detoxification of the pollutants present in environment.

The synergic effect of plants with utilization of microbes is sufficient to promote plant development and remediation of contaminated soil. This association (synergy) could be immense value in the field of agriculture, as farmers will be able to get high crop yield and also able to re-vive their polluted and damaged soil (Abraham et al., 2002; Ramos et al., 2005; Lugtemberg & Kamilova, 2009; Bhattacharyya & Jha, 2012). The beneficial microbes have been identified, isolated and their abilities have been studied since early 19th century and till date researchers are working in identification of new microbial strains which have efficient potential for soil mitigation of harmful contaminants (Badri et al., 2009; Segura & Ramos,2013)

SOIL CONTAMINANTS

The contamination of soil can happen through various processes like improper handling of wastes and its disposal, extensive use of fertilizers and pesticides, or through different industrial and chemical procedures. Major soil contaminants are listed below-

Heavy Metals

Heavy metals are naturally present in the environment, but due to their indiscreet utilization for various needs have modified or changed their geological cycle and biological balance. This has led to the profuse discharge of heavy metals like Zn, Cu, Ni, Pb, Cd, etc. in the natural reserves. Degradation of heavy metals takes place slowly through deflation, leaching, erosion, and plant uptake. Further indiscreet discharge of heavy metals into the environment is a chief health concern around the world, because they are not easy to degrade into smaller non-toxic components, therefore have long term influence on environment. Some metals like Cd, Cu, Pb, Ni, Cr, As, Hg, Zn, Se, Ag, are poisonous, cancer causing and act as mutagens even in low concentrations (Salem et al., 2000).Heavy metals in the environment are present due to various anthropogenic and natural sources. Anthropogenic sources include use of pesticide, fertilizers, coal, combustion, core mining, smelting, insecticide, herbicide, automobile batteries, plastic stabilizers etc. whereas natural sources include biogenic sources, volcanic activities, weathering of minerals, erosion etc. (Wuana et al., 2011; Modaihsh et al., 2007; Sumner, 2000). The deposition of these heavy metals in aquatic biota and soil ecosystem above standard levels is sufficient enough to have harmful effects on flora and fauna. (D'Amore et al., 2005).

Pesticide

Pesticides are a group of chemicals that are particularly made to slay biotic individuals like rodents, insects and weeds. Further, the excessive utilization of pesticide may lead to their aggregation in the environment. They have poor biodegradability and are classified as xenobiotic or persistant toxic chemicals. Examples of pesticides include fumigants, fungicides, disinfectants, herbicides, rodenticides, insecticides, wood preservatives, nematicides and antifoliants (Tayade et al., 2013). Due to various pests and rodents, about $1/3^{rd}$ of the universal agricultural production is lost each year because of pests. India faces agricultural loss of money more than Rs 6000 Crores, of which about 26% by diseases, 33% is because of weeds, 10% because of rodents and birds, 20% because of insects and other 11% is because of other influencing factors (Rajendran, 2003).

INDIAN AND WORLD STATUS OF PESTICIDES

Around 2 million tons of pesticides are utilized every year globally. About 45% is consumed in Europe, 24% is used in USA and around 25% is utilized in the rest of the globe. The highest amount of pesticide is consumed in China, then Korea, then Japan, and India, in the Asian countries. In India, around 0.5kg/ha of pesticide is consumed, and organo-chlorine pesticides is main contributor in it (Bhat and Padmaja, 2014). Since pesticides are biologically stable and make their way into our food commodities, they cause a serious risk to human beings and animals (Tayade et al., 2013). Because of the varieties that give high crop yield, their demand is increasing, and has caused high utilization of toxic chemicals as pesticides (Rajendran, 2003). After the Green Revolution the demand of pesticides which promote high crop yields have increased drastically. Currently India has ranked highest pesticide producer in Asia, and ranks 12th worldwide in utilization and have an annual production of 90,000 tones.

Currently in India consumption of pesticides, per hectare is very low as compared to global consumption, i.e. India have 0.6 kg/ha as compared to UK, which have 5.7 kg/ha and China, which have ~13 kg/ha pesticide consumption. As pesticides are making their identity in the market, its consumption is likely to enhance in coming future. But there are some difficulties also present which needs to be tackled properly such as inefficacies in supply chains, manufacturing of non-genuine products and poor attention on R & D by the domestic producers. Further, Indian agriculture desires to concentrate on finding approaches to upgrade the crop production, in addition to usage of chemicals for crop protection. It's a very challenging issue for us to accept competent agricultural practices, improved fertilizers, and usage of biotechnology for the reduction of wastes and to achieve self-sufficiency in agricultural sector. In Indian agriculture, for the elimination of pests and diseases, Integrated Pest Management seems to be the most efficient and sustainable strategy (Abhilash & Singh 2009).

The first plant for the generation of pesticides in India was established near Calcutta, 1952, and now India, after Asia and China, has become second largest generator of pesticides, and globally holds twelfth position (Mathur, 1999). Steady improvement is seen in the manufacturing of pesticides which are of technical grade in India, i.e. production has increased from 5,000 metric tons in 1958 to 102,204 metric tons in 1998. The value of pesticides in 1996-97 with related to demand was computed to be near USD 0.5 billion which is close to 2% of the market globally (Akhtar et al., 2009).

HARMFUL EFFECTS OF PESTICIDES

Excessive use of pesticides can cause numerous environmental issues and health related concerns like miscarriages, poisoning of farmers and other people who come in contact, neurological disorders, foetal deformities, skin disorders and many more. The pesticides leave harmful residues in the soil which influence the survival of beneficial creatures like bees, spiders, earthworms, and some plants (Singh et al., 2014). The main issue related to pesticide is that they are highly stable, have high degree of toxicity and have active constituents which are less soluble (Odukkathil & Vasudevan, 2013). Pesticides like, endosulphan, chloro-organic compounds, heptachlor, DDT, aldrin are in need of immense attention because they have ability to acclimatize inside the living tissues and can cause fatal diseases, and have noxious outcome on soil ecosystem (Das et al., 2003). Some pesticides are banned such as DDT, aldrin, benzene hexa-chloride, dieldrin, lindane, but somehow they made their way into our food which can cause serious health disorders (Bhat & Padmaja, 2014).

Hydrocarbons

Hydrocarbons are basically petroleum and their products. They have high economic value. Oils contains wide range of hydrocarbons i.e. xylanes, camphor, octanes, napthalenes etc. If their concentration in surroundings increases, it can cause environmental pollution (Figure 1). It is known that components of hydrocarbons have carcinogenic and neurotoxic constituents. Due to activities like refining, exploration, transport, production and storage, accidental leaks and spills of petroleum hydrocarbon occurs (Kvenvolden &Cooper, 2003). Intentional or accidental discharge of hydrocarbons into biological system is the main reason of soil contamination and water pollution. Soil contaminated with petroleum hydrocarbons causes immense loss to naturally occurring soil ecosystem and deposition of contaminants in living tissues of flora and fauna can lead to severe mutations and even death (Holliger et al., 1997). Current oil spill accident happened in Mumbai 2010, in India, in which major regions of Arabian Sea become polluted (Alvarez and Vogel, 1991). Another such kind of incident occurred in 2014 in Sundarbans (Bangladesh) where about 350 tons of oil was accidently spilled into Sela river, and damaged the Sunder ban'smangrove forests (Jain & Bajpai, 2012).

Consequences of Hydrocarbon Pollution are as follows:

1. Greenhouse effect and global warming.
2. They have cancer causing constituents.

3. Leads to extinction of species of flora and fauna because of contaminated air, land and oceans.
4. Some aromatic hydrocarbons are found to cause cancer.
5. Fertility of agricultural soil is immensely gets effected.
6. Petroleum hydrocarbons are found to cause reduction in birth weight, some developmental defects, and prenatal disorders.
7. When inhaled they cause irritation of the respiratory tract, can lead to asthma, and person becomes susceptible to develop allergies.
8. Contamination of water resources with hydrocarbons leads to depletion of the oxygen which kills aquatic creatures present in rivers, oceans, ponds and lakes.

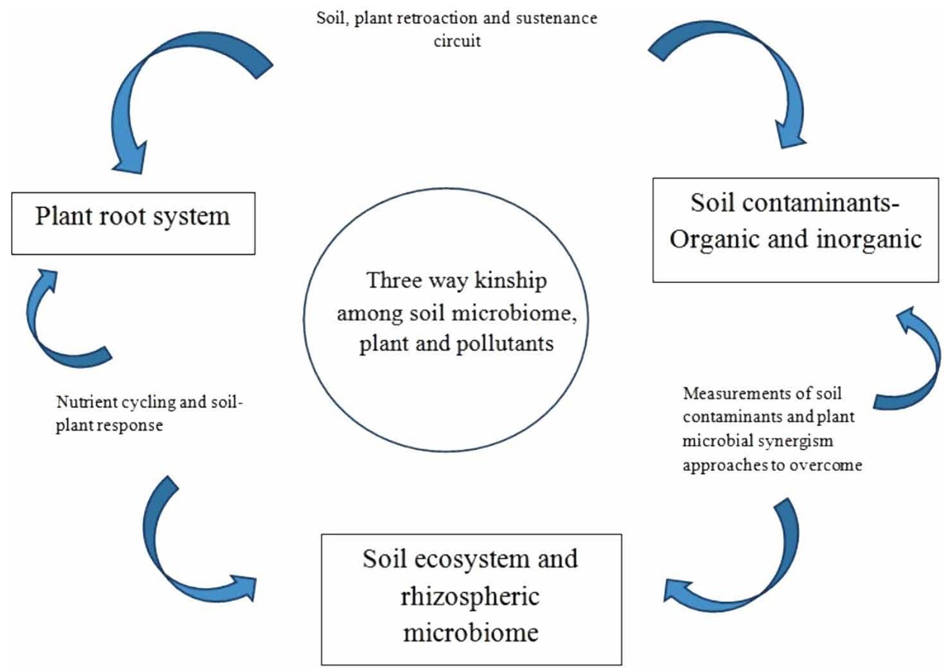
Methodologies accepted for disposal of hydrocarbons include physic-chemical, burial, incineration or landfills but then these are of not any use when concentration of contaminants is profusely high due to economic factors (Salleh et al., 2003). Chemical and mechanical methods have been devised to degrade petroleum hydrocarbons from polluted regions but these are not very effective and highly expensive, also require skilled man power and can increase the risk of spreading to other regions and aggravating the situation. Other techniques utilized include dispersion, washing, evaporation, burying etc. but these are not capable in fully degrading the constituents of petroleum compounds (Das & Chandran, 2011). Thus, a methodology which is natural but simple, cost effective is a necessity to remove hydrocarbons in current scenario.

ROLE OF MICROBES IN REMEDIATION

Metals

The polluted environment and soil system have to be treated to make them devoid of trace elements and heavy metals, as a preventive measure to make the biological system sustainable for human beings. Some of the methods like evaporation, reduction and oxidation reactions, filtration, reverse osmosis, chemical precipitation, ion-exchange, membrane technology, and electro-chemical treatment are devised for remediation of these heavy metals, but when concentration of heavy metals is less than $100mg^{L}$ majority of these methods are not much effective (Ahluwalia & Goyal, 2007). Further it is difficult to elute heavy metals from physical separation procedures because majority of the metals ions have ability to get easily dissolved in the effluents (Hussein et al., 2004). Likewise when strength of metals is low, physio-chemical methods were

Figure 1. Issues related to petroleum hydrocarbons contamination in soil



found to be costly and undesirable. An interesting alternative way to treat metals can be accomplished using biological agents or techniques like bioaccumulants or biosorption (Kapoor & Viraraghvan, 1995). Utilization of plant and microbial systems for the remediation of metals is found to be the only feasible or sustainable approach to re-vive the natural system of soil. But the inclusion of metals in soil creates some modifications in the microorganisms despite the fact that metals are required in low amounts for the microbial community to survive (Doelman et al. 1994). By blocking of some chief essential groups, inhibitory functions can be achieved which helps in transportation or rearrangement of some essential conformations of biomolecules, by this, approaches for microbial modification can be devised (Woodand Wang, 1983, Li & Tan, 1994). The behavior of microbial system to heavy metals relies upon the concentration, need of heavy metals, and it is a very complicated process which depends upon various factors. The microbial uptake of heavy metals takes place either through adsorption or bioaccumulation (Hussein et. al. 2001). Lipids, proteins and polysaccharides are the main components of the microbe cell wall, which have various kinds of functional groups attached to it that have ability to bound to heavy metal ions like phosphate group, carbohydrate, amino group and hydroxyl group (Scott & Karanjkar, 1992). Further, among various methods, biosorption phenomena are found to be highly feasible in comparison with bioaccumulation, for the application in large scale. *Aspergillus, Penicillium, Rhizopus* and various genera of fungi have been investigated and are found that they have potential to remove the heavy metals from the solutions which are aqueous (Ajmal & Rafaqat, 1996; Dilek et al., 1998). A novel technique has been reported by Xiao et al. (2010) for having exclusive biosorbents from endophytes, a hyper-accumulator, which is highly desirable rather than the commonly used methods for having biosorbants. Further, Sun et al. (2010) studied the generic variance of endophytes from the Cu tolerance species of *Elshotziaapliendes* and *Conmeliacommunis*.

Pesticides

Because of absence of ineffective and insufficient waste processing techniques including bio and physico-chemical techniques, pesticides have become a major problem. Since from numerous data it is well known that pesticides leave harmful residues in the soil which results into toxic compounds being present into water and soil and contaminating them. Trichlopyrbutonyethyl, chlorpyrifos, fenvalenate and cypermethrin are some traditionally utilized pesticides. Bioremediation is helpful because some plants and few microbes (*Pseudomonas* species, *Klebsiella*species, *Phanerochaete*, Mycobacterium species, *Bacillus* and *Chrysporium* species) have ability to detoxify these pollutants from environment (Fulekar & Geetha, 2008)

ROLE OF FUNGI

Degradation of pesticides by fungi takes place by the inclusion of minute conformational modifications to the pesticides breaking it into small, non-toxic compounds which are then released into the soil, where its further degradation takes place through microbes especially through bacteria.Pesticidal groups such as phenylamide, phenylurea, triazine, dicarboximide, organophosphorus and chlorinated compoundsare degraded by various fungi like *Avatha discolor, Agrocybesemiorbicularis, Stereumhirsutum, Coriolus versicolor, Pleurotusostreatus, Dichomitussqualens, Hypholomafasciculare,, Flammulinavelupites, and Auricularia auricular.* White rotfungi have ability to degrade few classes of pesticides like, lindane, atrazine, terbuthylazine, chlordane, diuron, heptachlor, metalaxyl, aldrin, DDT, dieldrin, gammahexachlorocyclohexane (g-HCH), mirex, etc. to different extents (Das & Chandran, 2011). From an oil spill ecosystem a fungi has been isolated that can minimize the problem of soil pollution.

ROLE OF BACTERIA

Most of the bacterial strains capable of degrading pesticides are from the genera – *Azotobacter, Pseudomonas, Flavobacterium, Burkholderia, Arthrobacter.* Type of decomposition is different it depends upon the bacterial strain and target compounds. Strains like *Klebsiella* and *Pseudomonas* having enzymes which are hydrolytic in nature, have ability to break down s-triazine herbicides like atrazine. Likewise, different enzymes including hydroxylases, isomerases, oxygenase, and hydrolases are found in Alcaligenes and Pseudomonas species have shown potential to degrade 2, 4-D herbicide. Because of limited environmental conditions and variying kind of pesticides in soil ecosystem most of the pesticides undergo incomplete decomposition which results in build-up and development of metabolites in the soil eco-system (Singh et al., 2014.). Sometimes it happens that these metabolites are poorly soluble and highly toxic than the actual parental compound which can hamper the microbial biota in soil and slows down the decomposition of pesticides which results into incomplete deteriotion of pesticide (Zhang et al., 2011). By inclusion of the microbes which have ability to decompose the pesticides fully and by streamlining the environment conditions, one can amplify the degeneration of pesticides, including its metabolites in soil. Some anions like sulphate and chloride limit the microbial degradation of many recalcitrant and xenobiotics compounds.

Petroleum Hydrocarbons

Petroleum decomposition is a very complicated procedure, and it is influenced by the nature and total amount of hydrocarbons involved. The aromatics, the saturates, the asphaltenes (phenols, ketons, fatty acids, porphyrins and esters) and the resins (quinoles, pyridines, amides, slufoxides and carbazoles) are the four different classes of petroleum hydrocarbons (Colwell et al., 1977). Degradation of hydrocarbon is effected by various factors, reported by Cooney et al. (1985) since petroleum compounds are available to microbes are limited, this hampers their degradation. Use of microbes for the degradation of petroleum hydrocarbons is one of the best natural mechanisms for their removal (Atlas, 1992). Microbes like *Rhodococcus, Arthrobacter, Sphingomonas, Burkholderia, Pseudomonas, and Mycobacterium* were likely to be responsible for degradation of alkyl aromatic compounds (Adebusoye et al., 2007). In the environment hydrocarbons are normally degraded by yeast, fungi, and bacteria. The observed and reported capability for bio-degradation ranges from 6% to 82%, in case of soil fungi, 0.13% to 50% in case of soil bacteria and 0.003% to 10.0% in case of marine bacteria (Jones et al., 1970; Pinholt et al., 1979; Hollaway et al., 1980; Mulkins Phillips & Stewart, 1974). It has been found by most of the scientists that over all enzymes activities of mixed population of microbes are able to remove complicated compounds of hydrocarbons like presence of crude oil in the surface of soil, fresh water reserves and marine systems (Floodgate, 1984). The most active creatures involved in hydrocarbon degradation are bacteria, as they are found to be effective in oil spills (Brooijmans et al., 2009) Some bacteria are also known which depend specifically on hydrocarbons. 25 generas of fungi and 25 generas of bacteria are listed down by Floodgate that is capable of hydrocarbon decomposition and these strains were screened from marine eco-system. Species of *Acinitobactor* was observed to be able in utilization of n-alkanes having chain length of C10-C40 as single reserve of carbon. Bacteria belonging to genera- *Mycobacterium, Gordonia*, *Burkholderia, Brevibacterium*, *Dietzia* and *Aeromicrobium,* were screened from soil contaminated with petroleum compounds, were confirmed as efficient creatures for the degradation of hydrocarbons (Chaillan et al., 2004). Daugulis and McCracken (2003) reported that polyaromatic hydrocarbons are degraded by *Sphingomonas. Talaromyces, Amorphoteca, Graphium, Neosartory* are generasof fungi and *Pichia, Candida, and Yarrowia*belonging to generas of yeast were screened from soil contaminated with petroleum and these generas were found to be successful in degradation of hydrocarbons (Singh.2006). For degradation of crude oil hydrocarbons several strains of fungi- *Pencillium, Cephalosporium,*and *Aspergillus* are found to be effective, reported by Singh. Several species of yeast- *Trichosporonmucoides, Rhodotorulamucilaginosa, Candida lipolytica, Geotrichum*species screened from polluted water reserves are listed down as they are able to remove petroleum compounds (Bogusławska-Was & Da¸browski, 2001).

However, there are only few reports available which highlight the role of protozoa and fungi in removal of hydrocarbons. An alage *Protothecazopfi* screened by Walker et al, was able to utilize crude oil and hydrocarbons as substrate and show exclusive decomposition of n-alkanes, aromatic compounds and isoalkanes (Walker et al., 1975). It is investigated by Cerniglia et al. (1980) that one brown algae, five green algae, one red algae, two diatoms, and nine cyanobacteria have ability to oxidize naphthalene. Moreover, it has been observed that observed that hydrocarbons are not utilized by protozoa.

Genetically Modified Bacteria

Use of microbes that are genetically engineered in remediation, have gathered a lot of consideration to enhance the degeneration of risky wastes in lab conditions. The GEM'S show high removal capabilities. But some environmental and ecological issues and regulations are main constrains in GEM field testing. These issues are need to be resolved before GEM can be utilized as efficient clean-up treatment at less expense. The utilization of genetically altered bacteria were exploited to bio-remediation process supervising, stress-response, strain monitoring, toxicity and end-point analysis. In India, 1979, Anand Mohan Chakrabarty, American scientist of Indian origin, for the 1st time screened a strain of *Pseudomonas putida*, that have NAH and XYL plasmids, but also have a hybrid plasmid which drawn by recombination of parts of OCT and CAM (these plasmids do not have ability to co-exist in a single bacterium, they are also incompatible). The strain was efficiently able to metabolize hydrocarbons; as a result it can grow vigorously on crude oil. USA government in 1990, permitted him to utilize his superbug to clean up the oil spill in water of the, State of Texas. The large scale production of superbug was done in a laboratory, and blended with straw and then dried. The bacteria amalgamated straw was stored until it was required. Whenever the straw was applied on the oil slicks, the straw soaks up oil and bacteria breaks the oil into non-contaminating, non risky products.

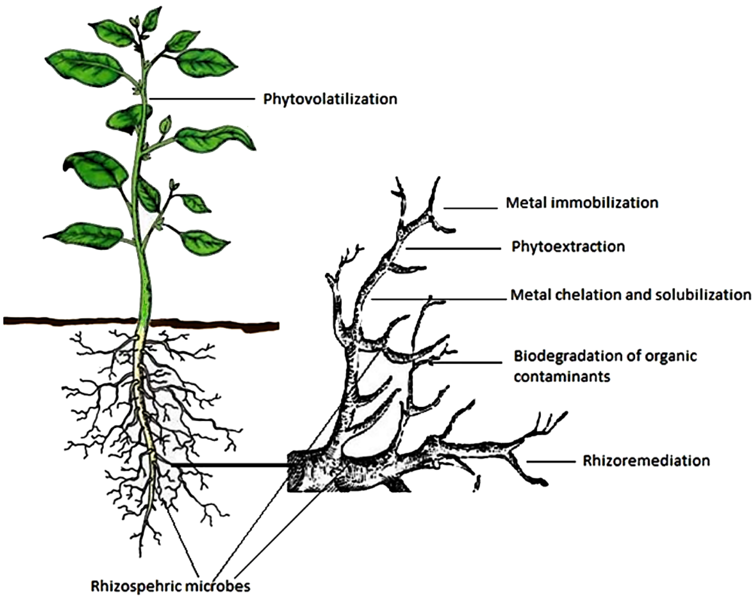
ROLE OF PLANTS IN REMEDIATION

Metals

The term Phyto-Remediation usually implies to the utilization of flora and the related microbes to completely or incompletely rectify the chosen contaminants from effluents, sub-surface water, soil, ground water, sediments and sludge. Organic pollutants, heavy metals and radionuclides also can be removed by this method (Ali et al., 2013). A variety of physical properties and plant processes are used in Phyto-Remediation for the rectification of polluted regions. Utilization of phytoremediation approach proves to be efficient means for the remediation of heavy metals (Robinson, et. al 1997, Martinez, et. al 2006). This approach can be driven by using solar energy, it is efficient, more eco-friendly and cost-effective. Phytostabilization, phytofilteration, phytodegradation, phytovolatilization, and phytoextraction are some different processes of phytoremediation (Alkorta et al., 2004). The very usual starting point of phytoremediation is by phytoextraction, it involves the imbibition of different contaminants from water resources and soil systems by the roots of the plants and then deportation to, and aggregation in shoots (Sekara et al., 2005). The displacement of heavy metals to the shoots is an essential biochemical process and it is expected in an efficient phytoextraction (Figure 2).

The next step of phytoremediation is phyto-filteration, it involves caulofilteration (utilization of shoots excised from plants), blastofilteration (involves utilization of seedlings), rhizofilteration (utilization of roots of plants) (Mesjasz-Przybylowicz et al., 2004). It involves either adsorption or absorption of metals and as a result the

Figure 2. Rhizospheric interaction of pollutants



mobility of metals in underground water is restricted (Erakhrumen, 2007). Further, phyto-immobilization and phyto-stabilization also occurs in addition, in which bioavailability and mobility of metals in the surroundings is minimized and as an outcome it forbids their relocation into the food chain or water reserves (Barceló & Poschenrieder, 2003). The confinement of heavy metals in the soil by plants is done by the complex formation, through precipitation, reduction of metal valence in rhizosphere or by roots. Oxygenase or dehalogenase are the two enzymesthat metabolize the organic pollutants in plants and theses are independent from rhizospheric microbes (Vishnoi & Srivastava, 2008). But there are some heavy metals which get absorbed by the plants and then get transformed in volatile compounds and at some point they are discharged in the ecosystem by phyto-volatilization process. Some volatile heavy metals like Se and Hg can be removed by the help of this process. But the major drawback is that these processes do not aid in removal of the metals fully, but in fact it just translocates them from one media (water or soil) to some another medium from there, they can re-invade the water and soil resources (Karami & Shamsuddin, 2010). The use of hyper-accumulators to decompose and remove toxic constituents from heavy metal contaminants has gained major attraction recently, because of its cost efficiency and efficacy.

Pesticides

Metabolic pathways of both microbes and plants (Chaudhry et al., 2001; Atterby et al., 2002) have ability to detoxify majority of the pesticidal compounds, which are discharged into surroundings (Singh et al., 1999; Aislabie & Lloyd-Jones, 1995). Since pesticides persists for a longer duration, so this limits the capability of plants and microorganisms for their degradation. Organo-chlorine compounds are specifically not metabolized easily by both plants and microbes (Shimabukuro RH et al., 1982; Chaudhry et al., 2001). Numerous enzymes such as Flavin dependent monoxygenase, peroxidases and very important cytochromes P_{450} catalyse the degradation of pesticides by oxidation (Chaudhry et al., 2001; Hodgson et al., 1995). Further, the process of oxidation is not much efficient in plants as it is in animals, but the availability of cytochrome P_{450}in plants plays very efficient role in stimulation and degeneration of various kinds of pesticides (Chaudhry et al., 2001). Another method for pesticidal decomposition by plants involves conjugation by the tripeptide glutathione, enzyme glutathione-S-transferase mediates the activity of tripeptide glutathione (Chaudhry et al., 2001). Most of the pesticides are hydrophobic in nature which hampers their withdrawal and dislocation by the plants (Shann, 1995). The phyto-remediation is the modern and ideal method for the clean-up of environment (Ziarati & Alaedini, 2014). Around 2400 plant species and more have been reported that have properties to control pests, some plants show their effects by poisonous exudates, or by repelling, by inhibiting growth or by feeding deterrence, without having bad influence on environment and on human health (Rajendran, 2003). Several products based on plants can also be used as biopesticides. PIP's (Plant Incorporated Protectants) are the compounds which are produced naturally by genetic alternations of plants. Examples include the inclusion of protease inhibitor, chitinase, Bt gene and andlectines etc. into the genome of plants, to make the plants transgenic and these transgenic plants synthesize their own compounds or substances that kill the specific pest species (Kandpal 2014). Polyamines(exogenous) which are naturally biodegradable, helps the plants to withstand the strength of contaminants higher than 500 times, than the untreated plants, and helps to uptake more contaminants (Maheshwari et al., 2014). The major merits of phyto-remediation are that it is easily accepted by public, have low disruptive impact on environment, excavation and removal of heavy traffic is not required. The process of phyto-remediation is mainly based on an accumulator which effectively uptakes the target pollutants (Emiko Matsumoto et al., 2009). Majority of genetically altered plants are used in phytoremediation – cyctochrome P_{450} enzymes, glyphosate oxidase, non- hememonoxygenase (DMO) which converts dicamba into 3, 6- dichlorosalicyslic acid, has been introduced in *A. thaliana*, tobacco, soyabean and tomato plants(Behrens et al., 2007), enzymesaryloxyalkanoate dioxygenase is introduced in corn (it is patented for degeneration of pyridyloxyacetate and 2, 4-D herbicides) (Scott et al., 2008).

Hydrocarbons

The use of plants for remediation of contaminated sites is a growing technique to handle majority of environmental problems, which include the clean-up of ground water and soil which are contaminated by hydrocarbons and other harmful materials. In the past 15 years the research has been done that have given much data to utilize and prepare and proper remediation strategies, improve the already existing approaches and to innovate something too, to utilize the approach of phyto-remediation to treat the hydrocarbon pollutants. Number of contaminated sites can be treated by the application of phyto-remediation. But not much information is available on the fate of the contaminants, transformation and translocation pathways and various metabolites involved, little information exists on rate of the removal of contaminants and efficiency.

A site in which contamination by hydrocarbon has occurred was investigated to see the potential of phyto-remediation approach. Site granted by Alabama Department of Environmental Management, which has around 1500 cubic yards of soil in which about 70% of baseline samples have above 100ppm of all over petroleum hydrocarbon. Then vegetative cover has been established on the land and after 1year, around 83% of samples contained less than 10ppm petroleum hydrocarbons (Hecht & Badiane, 1998; Nedunur et al., 2000). The eradication of TPH (Total Petroleum Hydrocarbon) at various regions polluted with petroleum refinery wastes, crude oil or diesel fuel, at initial concentrations of 1700 to 16000 mg/kg of TPH were also analyzed (Schnoor et al., 1995). Vegetation growth was found to be varied which depends upon the species of plants. Some plant species showed increased TPH removal while some had little effect in comparison to unvegetated soil. Beach naupaka (*scaevolaserica*), kou (*Codrdiasubcordata*), milo (*thespesiapopulnea*) are the coastal tress which are tested for their utilization in Pacific Islands, have shown tolerance in provided field conditions and helped in removal of diesel fuel contaminants from soil (U.S. Army Corps of Engineers, 2003). Sites contaminated with organic pollutants, planted with trees and grasses as an initial removal method. Hydrophobic pollutants like TPH, PAH, were effectively treated by the fine roots in the soil surface by binding and transforming them. Legumes like clover (*Trifoliumhybridium*), alfa alfa (*Medicago sativa*), peas (*Pisum* species) could be utilized to re-vitalize the lost nitrogen in the soils. Rye (*Elymus* species), reed canary grass (*Phalarisarundinacea*), Fescue

(*Vulpiamyuros*) were found successful in several sites contaminated by petrochemical compounds (Miya & Firestone, 2001). Once they are harvested, the grass could be disposed by burning or by composting.

SYNERGISM BETWEEN PLANTS AND MICROBES

The major demerits of a plant dependent remediation system depend upon two factors- a) because of the toxic and poisonous ability of contaminants b) soil loses its fertility because nutrients become unavailable due to which soil texture become modified. Whereas, microorganisms fail to decompose contaminants because of poor nutrient availability in soil, microbial biota does not possess efficient system for contaminant degradation, because of poor bio-availability of contaminant constituents to microbes (Noroozi et al., 2017; Patel & Patra, 2017). Due to these inefficient measures, an optimum remediation system is required to overcome these complications.

The remarkable relationship between roots of plants and microbial flora of soil has gained much attention because of the major part of bacteria in development of plants and deterioration of petroleum hydrocarbons (Kamath et al., 2004; Vaziri et al., 2013). When specific bacterial strains are inoculated, they increased the resistance mechanism in plants towards pollutants and increased the biomass of plants. To which, plants responded by their rizospheric activity, by supporting the development of pollutant decomposing microbes, as a result recalcitrant organic compounds are mineralized (Kuiper et al., 2004; Glick, 2010). Thus the combo of microbial degradation process and phyto-remediation, helps in developing the efficient approach for re-vitalization of contaminated soil (Afzal et al., 2013; Khan et al., 2013b; Arslan et al., 2014).

It is an established fact that fungi and bacteria are chiefly involved in pollutant degradation, in which bacteria found to be much versatile as compared to fungi (Weyens et al., 2009; Khan et al., 2013a; Sessitsch et al., 2013). Microbes are ubiquitous in nature, they live in rhizosphere, rhizosphereic plane or in phyllosphere, some others live in interiors of plants, and therefore they can be utilized actively in the cleaning-up approach of contaminants(Truu et al., 2015; Pandey et al., 2016a). Most of the microorganisms have dual ability – one pollutant degradation and, second, producing substances that promote the plant growth, reduce plant stress and remove contaminants of soil (Truu et al., 2015; Pandey et al., 2016a). Various bacteria promote the plant growth by different ways, like by fixing atmospheric nitrogen, phosphate solublization, increasing the plant tolerance mechanisms, helping the plant to come out of stress by producing 1-aminocyclopropane 1-carboxylate

(ACC) deaminase, by enhancing the degradation mechanism (Compant et al., 2010). An essential plant hormone ethylene plays an important role in ripening of fruit, extension and initiation of root, and cell signaling in case of stress. The growth of plant is hampered due to variety of environmental influences due to increased amount of ethylene production (Belimov et al., 2001). But the bacteria which produce the ACC deamianse can lower down the ethylene level by producing a cleavein the precursor of ethylene and to reduce the stress in growing plant (Saleem et al., 2007; Rai et al., 2016). A number of bacteria synthesize IAA, or indole-3-acetic-acid, that have an essential part in the promotion of root system and enhance the taking up of nutrient, therefore, increase the propagation of bacteria in the zones of the roots (Saleem et al., 2007). It is observed that those bacteria which produce IAA may help to prevent the harmful effects of environmental stress on the development of plants. Therefore the combined utilization of vegetative flora and microbial agents can be a helpful substitute for the remediation of contaminated soil (Benson et al., 2017; Salam et al., 2017; Spada et al., 2017). The efficiency of microbe-plant based system chiefly depends on the persistence and metabolic activity of microbes having genes for catabolizing the essential enzymatic digestion of pollutants (McGenity et al., 2012; Shankar et al., 2014). It is also very important to isolate and investigate the gene expression of specific gene in the removal of pollutants from contaminated sites of soil, to have a proof that inoculated microbes can survive and metabolize in such polluted environment (Afzal et al., 2011, 2012, 2013). Changes in the microbial population can be determined using culture-dependent methodologies. Although, mere 1% or less bacteria present in environment are cultivable, but culture-dependent techniques have made a way for deep-study of microbial ecosystem, giving useful data on the gene expression and abundance (Andria et al., 2009). The molecular nature of bacteria persisting in a definite region at a specific time can be drawn through culture-independent techniques (Yan et al., 2016; Gandolfi et al., 2017; Wang et al., 2017). Utilization of quantitative PCR or fingerprinting of essential and functional genome/gene helps to give information on the occurrence of specific strain of bacteria in a given environment (Blain et al., 2017; Li et al., 2017).

CONCLUSION

Gene modification technology may also likely to help in the engineering of "designer" microorganisms and plants which have a potential to eliminate or degrade a particular chemical complex or group of chemicals which are structurally related to each other. Gene modification approach provides great opportunities in improving the corrective or restorative techniques. Current issues for the utilization of genetically modified strains in environment are expected to avoid their large scale field testing in the coming future. Therefore, it would be more rational to highlight the target research on accomplishing such advancements by the traditional selection methodologies instead. Lot of things are still unknown about the degenerative abilities, tolerances and ecological interaction of living beings which have ability to be used in bio-remediation programs. However, there is no doubt that the combined effect of microbes and plants can help to enhance the biodegradation rate and bio-stabilization of contaminants present in the environment. Despite the emergence of genetically altered organisms has proposed a way to increase bio-remediation, we have yet to fully recognize the potential of transgenic organisms.

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Chapter 8
Impact Analysis of Amendment Application Under Diversified Agro-Ecological System:
Sustainable Environment

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ABSTRACT

In alternative agricultural systems such as organic or low-input farming, farmers can build particular forms of relationships that help sustain ecosystem services and social infrastructure more effectively. The authors discuss many of these relationships, including direct marketing, fair trade certification, and food justice movements. An agroecological approach to improve tropical small farming systems must ensure that promoted systems and technologies are suited to the specific environmental and socio-economic conditions of small farmers, without increasing risk or dependence on external inputs. Here in this chapter, the authors have focused on diversified agro-ecological systems.

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BACKGROUND

One of the major challenges of this millennium is ensuring food security in times of climate change, increasing population, environmental needs, economic and energy crisis. Agro-ecology as a science,is a set of principles and practices, and a social movement.Small scale diversified systems which rely mostly on local resources and complex crop arrangements are reasonably productive and stable, exhibiting a high return per unit of labor and energy. In many ways complex polycultures and agroforestry systems used by small tropical farmers mimic the structure and function of natural communities therefore acquiring many features typical of such communities, such as tight nutrient cycling, resistance to pest invasion, vertical structure, and high levels of biodiversity.An agro-ecological approach to improve tropical small farming systems must ensure that promoted systems and technologies are suited to the specific environmental and socio-economic conditions of small farmers, without increasing risk or dependence on external inputs. Rather, agro-ecological development projects should incorporate elements of traditional agricultural knowledge and modern agricultural science, featuring resource-conserving yet highly productive systems such as poly-cultures, agroforestry, and the integration of crops and livestock.It is ecologically futile to promote mechanized monocultures in areas of overwhelming biotic intricacy where pests flourish year-round and nutrient leaching is a major constraint. Here, it pays to imitate natural cycles rather than struggle to impose simplistic ecosystems that are not inherently complex. For this reason, many researchers think that successional ecosystems can be particularly appropriate templates for the design of sustainable tropical agro-ecosystems.

The industrialized agricultural techniques are exacting a huge toll on surrounding environments, polluting waterways, creating dead zones in the oceans, destroying bio diverse habitats, releasing toxins into food chains, endangering public health via disease outbreaks and pesticide exposures, and contributing to climate warming (Horrigan et al., 2002, Tilman et al., 2002; Diaz & Rosenberg 2008; Marks et al., 2010; Foley et al., 2011). Moreover, industrial agricultural methods are inherently unsustainable in mining soils (Montgomery, 2007) and aquifers far more quickly than they can be replenished, and in their high use of fossil fuels (Lynch et al., 2011). These numerous environmental and social externalities create a huge economic cost that industrialized food producers seldom pay. For instance, pesticide use alone causes up to $10 billion in damage to humans and ecosystems in the United States every year (Pimentel, 2005). Finally, although the agricultural sector currently produces more than enough calories to feed humanity, one billion people remain hungry and an additional one billion have micronutrient deficiencies. This paradoxical situation occurs because many people still lack access to sufficiently diverse and healthy food, or the means to produce it, which is primarily a problem of distribution rather than production. As further evidence of this paradox, global obesity rates have more than doubled since 1980 (WHO, 2012), reflecting an overproduction of food in industrialized countries that creates strong incentives for agri-food companies to absorb excess food production into processed foods and to market and distribute them to customers in supersized portions (Nestle, 2003).

Components of the agro-biodiversity within diversified agro-ecological system interact with one another and/or the physical environment to supply critical ecosystem services to the farming process, such as soil building, nitrogen fixation, nutrient cycling, water infiltration, pest or disease suppression, and pollination, thereby achieving a more sustainable form of agriculture that relies primarily upon inputs generated and regenerated within the agro-ecosystem, rather than primarily on external, often nonrenewable, inputs (Shennan, 2008). Spatial considerations are important, since different components of the system must be in sufficient proximity, at each relevant scale, to create needed interactions and synergies. For example, the utility of intercropping for reducing belowground soil disease depends on spacing the different crops such that their root systems interact (Hiddink et al., 2010). Similarly, wild bee communities can only provide complete crop pollination services when a sufficient proportion of their natural habitat occurs within a given distance of crop fields. The diversified agro-ecological systemis not only spatially heterogeneous, but is variable across time, due both to human actions (e.g., harvest, crop rotations, fallows, and other management practices or land use changes), and natural successional processes.

AGRO-ECOSYSTEMS DIVERSITY AND DIVERSIFICATION TERMINOLOGY

Gliessman compares the properties of natural ecosystems, sustainable agro-ecosystems and conventional agro-ecosystems at the farm scale, based on which he derives a general principle that "the greater the structural and functional similarity of an agro-ecosystem to the natural ecosystems in its biogeographic region, the greater the likelihood that the agro-ecosystem will be sustainable" (Gliessman, 2006). The maintenance of agro-ecosystems diversity in the form of spatial and temporal arrangements of crops, trees, animals and associated biota becomes a basic attribute of agricultural sustainability. Such level of high plant and animal biodiversity is very typical for the traditional farming systems and for the so called in science "alternative low-input" agricultural systems, performing under permaculture and biodynamic principles. The use of the term "diversification" in agriculture, permaculture and biodynamic agriculture can be confusing. In the literature, Emrys and Ngau, (1991) identify two forms of diversification: farm diversification, which is linked to crop diversification, and farm income diversification, which is related to the diversification of on-farm activities. The difference between the two is explained by the nature of the activities. According to Ilbery (1991), whereas farm diversification is located within the farm and implies primarily activities in the agricultural sphere, diversification of activities refers to income diversification coming from activities undertaken inside and outside the farm. Shome (2009) separates diversification in three categories: i) employment diversification - a shift of labor from farm to non-farm activities; ii) crop diversification - a shift from a less profitable crop to a more profitable one; and iii) resource diversification – the use of resources in diverse but complementary activities. Crop diversification is in the focus of agro-ecology since its emergence as a scientific field in the beginning of 20thcentury. Singh et al., (2001) distinguish between i) horizontal crop diversification; and ii) vertical crop diversification. In the vertical crop diversification various downstream activities are undertaken. The main form and commonly understood concept of horizontal crop diversification is the addition of more crops to the existing cropping system. Multi-cropping, also referred to as intercropping or mixed cropping, is the agricultural practice of growing multiple crop species simultaneously in the same field for a significant part of their life cycle. Mixed cropping can be applied to field-crop species, pasture species, trees, or a combination of them. Tree-based intercropping systems represent alley-cropping or agroforestry (Ehrmann & Ritz, 2014). Intercropping is further described as a system where available space between rows is used by different crops to allow maximum use of the soil moisture (Iglesias et al., 2006). Other authors describe the terms and conditions of species combinations in five main types (Malézieux et al., 2009): row intercropping, alley crops or strip intercropping, mixed cropping, mosaic intercropping and relay/sequential crops. These types combine perennial and annual plants in various configurations and for cycles of varying duration and multiple uses in all continents.

DIVERSIFIED AGRO-ECOLOGICAL SYSTEMS

The diversified agro-ecological systems are complex social-ecological systems that enable ecological diversification through the social institutions, practices, and governance processes that collectively manage food production and biodiversity. As many political ecology scholars emphasize, ecosystems are densely interconnected with social relationships. Ecological variables such as soil, water, and habitat help configure an array of farming practices, exchanges of food and resources, and landscape management decisions that, in turn, influence the structure and function of the ecosystem. Further, as ecosystem services are generated and regenerated within a diversified agro-ecological system, the resulting social benefits (including a range of livelihood benefits, such as healthier diets and increased farmer autonomy) in turn support the maintenance of the diversified agro-ecological system, enhancing its ability to provision these services sustainably (Bacon et al., 2012). This interplay underlies numerous historically occurring and emerging diversified agro-ecological systems worldwide. Conversely, socio-political and economic processes such as the decrease of access and control over seeds (often associated with the expansion of crop biotechnology) or increased dependence on commodity markets can intervene to disrupt such feedback cycles, thus weakening diversified agro-ecological system. The industrialization of agriculture has led to growing homogeneity across food systems as farming techniques and markets become more standardized. As a consequence, the complex social relationships underlying agriculture and ecosystem service provision have become less visible. Focusing on diversified agro-ecological system can help farming communities, researchers, policy makers, and industry recognize and restore these relationships.

At their core, diversified agro-ecological system depend on agro-ecological principles that are developed in and through the social relationships among working farmers, their communities and environments, and researchers, including ecologists, anthropologists, agronomists, and ethnobiologists (Wezel et al., 2009). To understand how diversified agro-ecological system may develop, function, and evolve over time and space, the particular context of each diversified agro-ecological system needs to be studied, paying particular attention to the politics and power relations that reciprocally shape its ecological conditions. Many diversified agro-ecological system were developed through traditional and indigenous farming knowledge and agro-biodiversity that was accumulated over millennia (e.g., the *milpa* landscape in Mesoamerica. More recently, other diversified agro-ecological system has been created through targeted agro-ecological studies designed by scientists to solve particular problems (e.g., the push-pull system for maize agriculture in Kenya (Khan et al., 2011). Historically, much knowledge about biologically diverse farming practices has been created and shared through peer-to-peer learning within traditional farming communities and, more recently, also through their collaboration with researchers interested in further developing agro-ecology. These relationships continue to be critical to the growth of diversified agro-ecological system in new societal contexts and geographic locations. An illustration of how social and ecological systems interpenetrate within diversified agro-ecological system is in the Andean highlands, where indigenous farmers have managed their lands agro-ecologically for 3,000 years. The ongoing interplay between human management and physical ecology has created a landscape of agro-climatic belts at different altitudes, each characterized by specific field rotation practices, terraces, and irrigation systems, and the selection of specific animals, crops, and crop varieties. Within these belts, traditional knowledge has helped sustain tremendous genetic diversity, by perpetuating adapted landraces and wild relatives of crops. Social cooperation is essential to managing the verticality and heterogeneity of the Andean ecosystem. A barter economy based on reciprocity, for example, facilitated complementary exchanges of plants and animals between ecological zones along the steep elevation gradient.

In industrialized systems in both developed and developing countries, farmers must now negotiate with corporate food buyers, buy agrochemical and seed inputs from agents, seek loans from bank officials, and work with agricultural extension experts trained in pesticide use. Farmers rely on such relationships to compete effectively in supply chains and to manage changing ecological conditions, such as pest outbreaks. Nonetheless, these particular types of relationships often push individual farms to increased dependence on banks, damaging livelihoods, and undermining collaborative social learning groups as farmers specialize in a single crop and maximize short-term yields through the use of external inputs, to meet loan repayments. The economic pressures in these tightly linked systems generally corrode ecosystem services, which are the very foundation of support for potential diversified agro-ecological system. Farmers in industrialized systems may also engage in exploitative relations with immigrant or impoverished laborers, paying inadequate wages and enforcing long hours, helping perpetuate the apparent cheapness of food.

Industrial production creates a number of “distances” between producers and consumers (geographical, temporal, or cultural) such that information flow diminishes across the supply chain. Thus within the industrial agri-food system, consumers remain relatively ignorant about the conditions of production, and would be less able to choose between products based on sustainability criteria, if they value these, and to exercise their buying power in favor of diversified agro-ecological system. In turn, the risk perceptions of consumers and corporations may inhibit the growth of diversified agro-ecological system. For example, during the recent food safety scare in fresh leafy vegetables in California, corporate buyers insisted that growers remove native vegetation bordering fields that might attract wildlife. This action was taken largely to assuage consumer concerns, despite the lack of scientific support. In alternative agricultural systems such as organic or low-input farming, farmers can build particular forms of relationships that help sustain ecosystem services and social infrastructure more effectively. We discuss many of these relationships, including direct marketing, fair trade certification, and food justice movements. In developing and studying these alternative systems, however, researchers, policy makers, and NGOs often neglect race, socioeconomic, and gender issues, or sublimate them into a broad social justice category. Finding ways to be far more inclusive of diverse racial, gender, and socioeconomic groups can help strengthen the social-ecological basis of agriculture.

INDUSTRIALIZED AGRICULTURE

The expansion of large-scale industrialized monoculture systems of agriculture often occurs at the expense of more diversified farming systems. The widespread transformation of agriculture to large-scale monoculture systems began with the European colonial plantations of the 1500-1800s (McMichael 2009; Perfecto et al., 2009), and expanded with the mechanization of agriculture in the late 1800s and the introduction of synthetic fertilizers and pesticides by the mid 20th century. By the 1960s, a wave of agricultural science and technological innovations had created the "Green Revolution," an integrated system of pesticides, chemical fertilizers, and genetically uniform and high-yielding crop varieties that governments, companies, and foundations vigorously promoted around the world. In the subsequent fifty years, the expansion of industrialized agriculture increased global nitrogen use eightfold, phosphorus use tri-fold, and global pesticide production eleven-fold (Tilman et al., 2001). By 2000, Green Revolution crop varieties were broadly adopted throughout the developing world, e.g., circa 90% of Latin America for the area under wheat, and circa 80% in Asia for the area under rice (Evenson & Gollin, 2003), and the world's irrigated cropland doubled in area. Encouraged by a range of economic factors, including the incentives of U.S. federal commodity programs, the pressures of global market competition, neoliberal economic reforms, historically inexpensive synthetic inputs, and the advantages of economies of scale, field and farm sizes increased in some areas, while non-crop areas in and around farms decreased, leading to higher levels of homogeneity at both the field and landscape scale (Liverman & Vilas 2006; Snapp et al., 2010).

Several recent signs of the continued expansion of industrial agriculture are seen in the rapid growth of land grabs, biofuel production, and plantations across the Global South. Land grabbing refers to the practice of agri-food companies, commodity traders, pension funds, and nationally-owned investment banks buying land in other countries for eventual large-scale food and resource production in response to food security concerns and food speculation (McMichael, 2010; Borras et al., 2011; de Schutter, 2011). For example, the provincial government of Rio Negro in Argentina recently agreed to lease up to 320,000 ha of land to Beidahuang, a Chinese government-owned agri-food company, to produce soybeans, wheat, and oilseed rape primarily for animal feed. Negotiations occurred in secret and the agreement was signed before it became public. Local farming communities are now organizing against the deal, contending that they will be displaced by the industrialized irrigation methods being planned.The expansion of large-scale commercial agriculture has also caused deforestation of some of the most biodiverse forests in the world, such as in the Amazon, for soybean production (Defries et al., 2008), and in Southeast Asian rain forests, for oil palm (Wilcove and Koh, 2010). Since the 1990s, particularly in Brazil and Indonesia where the greatest amount of deforestation occurred, the agents of deforestation shifted from primarily smallholder to enterprise-driven agriculture for global markets (Rudel et al., 2009; De Fries et al., 2010). Much recent forest loss, along with agricultural land conversion, can be attributed to the rapid growth in biofuel production, centering in Southeast Asia and Latin America but expanding to Africa. Biofuel production is driven by mandates for renewable transport fuels, weak land use regulation, production subsidies, and speculation by energy and commodity companies in both developing and industrial countries (Borras et al., 2011). Although global estimates of the scale of industrial biofuel production are difficult to make, the World Bank (Deininger, 2011) calculates that 36 million ha were dedicated to biofuel production (primarily maize, sugar cane, and oil crops) globally in 2008, doubling the 2004 level. Oil palm production in Indonesia and Malaysia indicates the emerging trajectory: aided by government policies and subsidies, oil palm plantations grew in Indonesia from 3.6 million ha in 1961 to 8.1 million ha by 2009 (McMichael, 2010). The consequences of the expansion of oil palm include ongoing displacement of smallholders, increasing monoculture, and abandonment of food cropping, though the extent to which these effects are occurring remains uncertain. Across the Global South, oil palm and sugarcane plantations may provide only a tenth of the jobs when compared to the livelihoods generated through smallholder farming (Holt-Giménez, 2007).

SMALLHOLDER AGRICULTURE

Despite expansion of large-scale commercial agriculture, smallholders (< 2 ha) still make up 85% of circa 525 million farms worldwide. Such farmers span a spectrum from traditional, indigenous growers using no external inputs to those with heavy dependency on modern seed varieties, fertilizers, and pesticides, but up to 50% of smallholders are thought to utilize resource conserving farming methods (Altieri and Toledo, 2011). While they represent the bulk of the agricultural population, estimated at circa 2.6 billion people (Dixon et al., 2001), due to land inequalities they often do not control the bulk of the arable land (Nagayets, 2005). These disparities are largest in South America, (e.g., in Ecuador, smallholders constitute 43% of the farmers but use only 2% of the land) and least pronounced in Africa (e.g., in Egypt, smallholders constitute 75% of the farmers and use <50% of the land). Another sign of intensifying inequalities is that mean farm size has decreased in many parts of Africa and Asia (e.g., from 2.3 to 1.6 ha from 1970 to 1990 in India), increasing the vulnerability of small farmers and exacerbating the poverty in these regions, while large landholdings are increasingly controlled by a small number of people. Despite poverty, the current contribution of small farms to global food production is significant. It is estimated that mixed crop and livestock systems supply 50% of the worlds' cereal, 60% of the world's meat and 75% of the world's dairy production. Much of this production is locally produced and consumed, and provides the main source of food for the world's 1 billion poor (defined as living on <$1/day). Altieri (2004) considers that traditional indigenous agriculture supplies 30 – 50% of the world's food. Nagayets (2005) suggests that the contribution of smallholders to food production is increasing in some countries because of changing national socioeconomic and political situations and government policies favoring domestic food self-sufficiency. As indicated previously, not all smallholder agriculture would be considered diversified agro-ecological system. Perhaps 50% of smallholder farmers use agro-industrial inputs or have not adopted agro-ecological methods (Altieri & Toledo, 2011). Qualitative research suggests that through implementation of sustainable intensification, a set of resource conserving practices also used in diversified agro-ecological system, such farms could become 60-100% more productive, potentially contributing far more to local and global food security, although rigorous, quantitative comparisons are both lacking and needed (Seufert et al., 2012).

Overall, small-scale diversified farmers face continuous, intensifying pressures from the encroachment of industrial supply chains. However, in parts of the developing world, diversified farming systems are actually expanding, in response to food sovereignty movements, smallholder desires for healthier and more economically independent lives, and some level of civil society and government support. Agro-ecological techniques are site-specific and tend to be transferred from location to location through horizontal communication and social networks, with much adaptation by local communities (Holt-Giménez, 2006, Altieri & Toledo, 2011). Evidence of the rising adoption of agro-ecological principles in many Latin and Central American countries exist through the many cases of *campesino*-to-*campesino* training reported, as well as the increasingly global spread of the La ViaCampesina movement. Cuba is a case where the transition to agro-ecological practices has been particularly rapid; in this case the expansion was a response to a severe food security crisis and lack of fossil fuel inputs following collapse of the former USSR and associated subsidies to industrialized agriculture (Rosset et al., 2011).

To some degree, diversified agro-ecological system is also expanding in industrial countries despite the vastly more inhospitable political and economic conditions that may prevail, particularly in the U.S. There, as in Australia and many European countries, there is growing demand for organic and locally produced fruits, vegetables, fish, and meat, which is spawning an increase in the number of small-scale, highly diverse farms, often supplying urban markets. In the U.S., certified organic agriculture has grown markedly, rising from less than 1 million acres in 1990 to 4.8 million acres in 2008 (of which 56% is croplands and the remainder rangelands) and comprises 0.7% of agricultural production with 20,000 producers (United States Department of Agriculture 2011). Worldwide, organic agriculture has tripled from 11 million ha in 1999 to 37.2 million ha in 160 countries as of 2009 and currently makes up 0.9% of agricultural production (Willer & Kilcher, 2011), with 1.8 million producers in 2009, predominantly from Asia and Africa. Nonetheless, while organic agriculture tends to support greater biodiversity than conventional farms not all organic farms are diversified agro-ecological system. Much organic agriculture has become increasingly large-scale and homogeneous as producers and food companies strive to maximize profits and meet growing market demand (Guthman, 2004).Pulighe et al., (2016) has explored explores recent progresses in mapping ecosystem services provided by urban green infrastructures (GI) and discuss how GI can contribute to promoting cohesion, resilience and livability toward sustainable and green cities. It also investigates the inter-linkages between ecosystem services paradigm, mapping approaches at urban level and benefits provided for human well-being.

CONCLUSION

The diversified agro-ecological system is associated management strategies contribute to an agro-ecosystem that is resilient to various aspects of climate change. Diversification provides many essential ecosystem services. The different components of biodiversity interact with one another and the physical environment to supply critical ecosystem services to the farming process, such as soil building, nitrogen fixation, nutrient cycling, water infiltration, pest or disease suppression, and pollination. In this way, diversified farming is a more sustainable form of agriculture that relies primarily on inputs generated and regenerated within the agro-ecosystem, rather than primarily on external, nonrenewable, inputs. An immense challenge facing the farm is the threat of invasive species. Climate is a significant driver of pest population dynamics; there is an agricultural trend of increased pest pressure with warmer climates. The promoting and mainstreaming agro-ecosystems diversification across farms and regions requires targeted and simultaneous actions at the local, national and International levels both in terms of institutional and policy support and development of world.

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Chapter 9
Red Mud (RM) and Soil Amelioration:
Improvement in Soil Quality

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ABSTRACT

Rapid growth in industrialization, which is necessary and inevitable for society progress, has also created negative encroachment. Red mud produced during alumina production has strong alkanity in a pH range of 10-13% because of the sodium hydroxide solution used in the refining process. The base is strong enough to kill plant and animal life, and due to finer particle and trace metal content, it creates soil contamination, ground water pollution, and suspension in ocean; hence, we need precautions while we use this waste to add with soil. Red mud occupies a large area or its deposition in it. Red mud has properties similar to sandy clay. Red mud has property similar to clay and sand, even if it does not contain quartz or clay mineral. Bauxite residue/red mud can be mixed with variant type of saline soils, acid soils organic rich material, and silicate soil suitable pH conditions were achieved to promote vegetation growth.

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BACKGROUND

In India millions of tons of red mud are produced from alumina industries. Its property is similar to sandy clay and it mainly comprises of oxides of aluminum, iron and silicon. Its storage has created enormous problems. To solve this problem alternate uses of red mud should be investigated. Red mud is a waste byproduct generated during the production of alumina from bauxite by the Bayer process. During the production of 1 ton of alumina 0.8 to 1.5 tons of red mud is produced. In country like India, where land resource is scarce storage and disposal of red mud have created a great disaster. Therefore, researches are going on to find alternate uses of red mud. Literatures are available on alternate uses of red mud, like production of geo-polymer, cement, bricks, etc. Red mud has also been used as a road construction material. Red mud has properties similar to clay and sand; even if it does not contains any quartz or clay minerals. Similarity in properties is may be due to presence of hydroxysodalite, goethite, and hematite in red mud. Frictional behavior of red mud is similar to sand and compression behavior similar to clay. Due to the similarity in properties with soil red mud can be used as substitute of soil, which can solve disposal and storage problem associated with it. The utilization of red mud, which is a residue from the extraction of aluminum from mined bauxite ore. There are some chemical aspects that may hinder the growth of, or even cause mortality in, plants such as very high pH, electrical conductivity (EC) and exchangeable Na and very low nutrient elements content.

RED MUD

The Red mud is the solid waste residue of the digestion of bauxite ores with caustic soda for alumina (Al_2O_3) production. It is a mixture of compounds originally present in the parent mineral bauxite and of compounds formed or introduced during the Bayer cycle. Red mud can be applied as soil ameliorant to acidic, sandy and micronutrient deficient soils. There are still knowledge gaps regarding the effects of red mud on the soil microbial community. According to average well color development, substrate average well color development and substrate richness 5–20% red mud increased the microbial activity of the acidic sandy soil over the short term, but the effect did not last for 10 months. Shannon diversity index showed that red mud at up to 20% did not change microbial diversity over the short term, but the diversity decreased by the 10th month. 30–50% red mud had deteriorating effect on the soil microflora. 5–20% red mud soil mixture in the low quality subsoil had a long lasting enhancing effect on the microbial community based on all parameters. However, 50% red mud soil mixture caused a decrease in diversity and substrate richness. The properties of red mud are listed in Table 1.

Red mud (bauxite residue) is a by-product of the alumina industry, deriving from the digestion of crushed bauxite with caustic soda. Due to the combined presence of ferric, aluminium and tectosilicate-like compounds in red mud (Gadepalle et al., 2007), it is proved to be an effective amendment in reducing metal mobility in contaminated soils and stimulating microbial abundance, diversity and activity (Garau et al., 2007; 2011, Lombi et al., 2002; Gray et al., 2006, Bertocchi et al., 2006; Castaldi et al., 2009; Feigl et al., 2012; Sprocati et al., 2014). Sandy soils, with little or no nutrient or water holding capacity could benefit from the uses of red mud as soil ameliorant (McPharlin et al., 1994; Barrow, 1982; Ujaczki et al., 2015; Ujaczki et al., 2016 a,b) due to the presence of sodalite in red mud, with an estimated cation exchange capacity (CEC) that exceeds the CEC of most natural clays. In addition, the alkaline nature of red mud can be used to raise the pH of organic or acidic soils (Summers et al., 1996, 2001; Snars et al., 2004), which tend to suffer from Al phytotoxicity (Alva et al., 2002). Additionally, due to red mud mineralogy (iron and aluminium oxides, hydroxides) it can increase the phosphorus retention of sandy soils adsorbing phosphate (Summers et al., 1993; Summers & Pech, 1997), thus reducing phosphate leaching and preventing eutrophication, and creating a phosphate

Table 1. Properties of red mud

S. No.	Properties	Value
1.	Specific gravity	2.8
2.	% Gravel size	3.60
3.	% Sand size	18.80
4.	% Silt and clay size	77.60
5.	Coefficient of Uniformity	14.97
6.	Coefficient of Curvature	1.81
7.	Liquid limit in percentage	43.2
8.	Plastic limit in percentage	31.55
9.	Plasticity Index in percentage	11.65
10.	Maximum dry density (in kN/m3)	16.48
11.	Optimum moisture content in percentage	24.75
12.	Void ratio at maximum dry density and OMC	0.66

pool that is available to plants and soil microorganisms. However, the alkalinity, the trace metal content and the naturally occurring radioactive material content of red mud may pose significant environmental risks (Akinci & Artir, 2008; Klauber et al., 2011), therefore its careful application is recommended in soil (Ruyters et al., 2011; Ujaczki et al., 2015, 2016a; Mayes et al., 2016).

The red mud can stimulate the recovery of the microbial abundance and activity in metal polluted soils (Lombi et al., 2002; Garau et al., 2007, 2011); in these studies the effect of red mud on the microbiological parameters was associated with the reduction of metal mobility. Therefore, further studies are needed to better understand the influence of red mud not only on polluted soils but also in improving soil quality, given the scarcity of published research on this topic. Recently Ujaczki et al., (2016a) have studied the effect of red mud (RM) as acidic sandy soil (S) ameliorant. Similarly Ujaczki et al., (2016b) have studied in a field trial the potential application of red mud-soil mixture (RMSM) as additive to the surface layer of a landfill cover system made from low quality subsoil (LQS). The immobilizing ability of RM (Gadepalle et al., 2007; Summers et al., 1993) may contribute to the nutrient scarcity over the long term. For example, Snars et al. (2002) reported that environmental stress, such as drying or the addition of microbial suppressants could mitigate the effect of the red mud in decreasing P availability. Red mud addition also may have caused a stress to microbes enhancing their metabolic activity, thus the resources exhausted faster than in stress free soils. Furthermore, the experimental conditions, such as a relatively small amount, incubation at room temperature and irrigation at regular intervals may also contribute to a decrease in microbial activity. Otherwise the AWCD values in the acidic sandy soil were small (0.13 after 120 h), which indicates an originally low microflora activity in the acidic sandy soil (S), typical for degraded sandy soils (Garau et al., 2011).

Most of the carbohydrates are intermediates of soil organic matter degradation which explains the high affinity of bacteria to them (Kenarova et al., 2014). However, the utilization of some substrate groups (carboxylic acids and polymers with the highest utilization percentage) was maintained at a higher level in the treated soils (at up to 20% RM and 10% RM, respectively) than in the untreated acidic sandy soil (S) over the long term, suggesting that RM addition created a more favorable environment for certain microbial groups in the soil to utilize specific substrates (Garau et al., 2011). At 30–50% RM dose all values clearly indicated deteriorating effect on the microbial activity of the acidic sandy soil. The higher the RM amount added to the soil the lower the bacterial diversity in soil. At 30–50% RM does substrate richness was 0 or 1, which means that only some species were able to remain metabolically active upon the great RM load in soil. As a consequence, we established the maximum RM dose that was still beneficial for the microbial community of the treated soil at 20% RM, although Ujaczki et al., (2016a) found that toxic metal content (As, Cr and Ni), Na content and toxicity input from red mud is tolerable by the acidic sandy soil ecosystem (based on ecotoxicity testing) only at up to 5% RM, therefore higher RM amounts are not recommended to be mixed into the soil.

MICROBIAL COMMUNITY AND SOIL QUALITY

Microbial communities have an important role in many soil processes (e.g. organic matter formation and decomposition, respiration, nutrient cycling) (Condron et al., 2010; DelgadoBaquerizo et al., 2016; Schimel & Schaeffer, 2012; Schulz et al., 2013) and the delivery of essential soil ecosystem services (Jeffery et al., 2010, Van Der Heijden et al., 2008). In contrast to the physical and chemical properties of soil which change very slowly, biological properties are sensitive even to small environmental fluctuations (Nannipieri et al., 2003; Jezierska-Tys, 2008; Carbonell, 2009; Gryta et al., 2014). Some scientists realised that standard microbiological methods can be combined with a community approach in order to detect any possible structural and/or functional change of soil microbial population (Kelly et al., 1999; Larkin, 2003; Viti et al., 2006; Garau et al., 2007). The BiologMicroPlates developed in the late 1980s were 96-well Gram-negative (GN) plates containing carbon sources and a tetrazolium violet redox dye that turned purple if inoculated microorganisms extracted from the soil utilised these sources (Garland & Mills, 1991; Garland, 1997). Later, a new plate specifically designed for community analysis and microbial ecological studies was created, referred to as the EcoPlate. The EcoPlate contains three replicate wells of 31 of the most useful carbon sources for soil community-level physiological profiling (CLPP) of heterotrophic bacterial assemblages capable of being metabolically active and growing in plate conditions (Insam, 1997; Stefanowicz, 2006). According to Gryta et al., (2014) the BiologEcoPlate method is more dedicated to compare functional diversity of microbial communities from contaminated and uncontaminated soils rather than to characterize microbial community, as applied by other authors (Preston-Mafham et al., 2002; Arias et al., 2005).

The major ill effect of global industrialization and urbanization processes leads the production of large quantities of industrial wastes and the problems related with their safe management and disposal. Among such type of hazardous industrial wastes Red Mud is the one. Red Mud is produced in the Bayer process of extraction of alumina from bauxite, the insoluble product generated after bauxite digestion with sodium hydroxide at elevated temperature and pressure is known as red mud. With increasing production of red mud, the environmental problems caused by it are increasing seriously; and thus the integrated treatment of red mud is imminent. Globally, aluminum industries are producing approximately 75 million tons of red mud every year. Less than half of this is used. Storage of this unutilized red mud apart from covering vast tracks of usable land also pollutes land and water in the vicinity. Thus, through this paper an attempt has been made in the study to utilize the Red Mud mixed with Fly Ash in soil stabilization. It is found that Red Mud when mixed with Fly Ash improves the strength of low bearing soil. Highly compressible soils are considered to be marginal because they lack the required engineering properties for use in pavement base courses, sub-base courses, subgrades, and as a foundation supporting layer under buildings and various structures and for landfilling. Engineers and practitioners are continually looking for methods to improve the properties of fine grained soils. Traditional stabilization techniques require large amounts of additives and specialized skills and equipment to ensure adequate performance (Tutumluer et al., 2004). For soil stabilization and improvement purposes, Fly Ash have been used extensively due to their low cost, light weight, and significant contribution to strength gain. The addition of Fly Ash increases the loadbearing capacity of soil.

INORGANIC AMENDMENTS

A number of inorganic amendments such as liming materials, phosphate compounds, and clay materials are used for immobilizing heavy metal(loid)s and improving soil conditions to facilitate re-vegetation of contaminated soils. For example, the addition of liming materials is a common practice to overcome plant growth constrains relating to soil acidification. Normally, as the pH decreases, the mobility of some metal(loid)s is elevated. The solubility of Zn and Ni in dredged sediment increased when the pH was less than 6, pH 4 for Cd, pH 6 for Co, and pH 2 for Cu and Pb. The addition of lime as ground limestone not only raises pH but also renders metal(loid)s insoluble, thus reducing their bioavailability to plants. Lime is effective in reducing the phytoavailability of Cd and Cr^{3+}. Sugar beet lime, a residual material from the sugar manufacturing process with 70–80% (dry basis) of $CaCO_3$ and biosolids compost, reduced $CaCl_2$-extractable Cd, Cu, and Zn concentrations. This behavior seems to be related to the pH increase as it is well known that increasing the pH of the soil leads to a decrease in metal(loid) mobility. Soluble Cd, Cu, and Zn concentrations in soils are often found to be negatively correlated with pH values.

The effectiveness of lime to reduce Pb availability, and the treatment reduced Pb concentration of pore water and NH_4NO_3-extractable Pb concentration of the amended soil has already been evaluatd by mya investigators. Three soil amendments (red mud, beringite, and lime) were applied to metal(loid)-contaminated soil. Treatment of lime and red mud reduced Pb concentrations in plants. Treatment applications shifted the distribution of Pb from the exchangeable fraction to the carbonate and oxide fraction and decreased acid extractability of Pb. Lead solubility is generally very low in nonacidic soils, and the amendments used can only slightly reduce its mobility. Inorganic amendments such as quarry waste, pulverized refuse, and pulverized fuel ash have also been used to improve substrate characteristics. For instance, expanded clay and N and P fertilizer increased the plant biomass of *Andropogongerardii* in mine tailings. Lead immobilization efficiency in artificially polluted soil with modified clay was 93% for Mn-montmorillonite, 86% for Mn-diatomite, 81% for Fe-montmorillonite, and 80% for Fe-diatomite. The results of sequential extraction of Pb from soil after immobilization with modified clays indicated that mobile fraction (i.e., exchangeable and carbonate fraction) decreased as contact time increased, while less mobile (i.e., reducible) fraction increased from 27% to 60% of the total amount extracted. Researcher has demonstrated that P compounds immobilized Cd through phosphate-induced metal(loid) adsorption and the formation of cadmium–phosphate complex. The potential value of both soluble and insoluble P compounds in the immobilization of Pb, thereby reducing its bioavailability and toxicity.

Some minerals are known to have a metal(loid) immobilizing capacity. The application of synthetic zeolite pellets to Cd-contaminated soils has been shown to significantly reduce the concentrations of Cd in the roots and shoots of a range of crop plants. The addition of beringite, a modified aluminosilicate, resulted in a complete disappearance of visual and metabolic symptoms of metal(loid) phytotoxicity by metal(loid) immobilization. The high metal(loid) immobilizing capacity of beringite is based on chemical precipitation, ion exchange, and crystal growth.

When combined with compost, inorganic metal(loid) immobilizing amendments resulted in better plant responses when compared to the addition of inorganic amendments alone. Compost, beringite, and steel shots treatment in metal(loid)-contaminated sandy soil reduced phytotoxicity and metal(loid) accumulation in grasses. This may be attributed to an increased efficiency of metal(loid) binding on Fe or Mn oxides due to the high pH and precipitation of Fe oxides on clay particles induced by the beringite. Hydrous manganese oxides reduced Cd or Pb transfer from soil to soil solution and their entry into the food chain via plant uptake. This material would be promising for restoration of Cd and Pb-contaminated soils.

Pb-contaminated soils with zeolite, compost, and $Ca(OH)_2$ increased the residual fraction of heavy metal(loid)s in the soils and decreased the Pb uptake by white lupin (*Lupinusalbus* L., cv. Multitalia). The concentration of Pb in the aerial part of plants grown in compost soil was 87% lower than in the control sample. All treatments with amendments had higher plant yield than control, especially, compost and $Ca(OH)_2$. The red mud, bauxite ore processing waste, and/or fly ash produced by coal-fired power stations to immobilize the heavy metal(loid)s has been used in severely contaminated soils to enhance the soil quality. Eluted Pb concentration from red mud and fly ash amended soil was reduced by 59–97% compared to the control.

SOIL REMEDIATION

The use of conventional, engineering-type techniques to clean up metal-contaminated soils is typically invasive and expensive. For example, in soil-washing, the soil has to be excavated first and usually treated off-site. The treated soil may be returned to the site or landfilled. The washing not only irreversibly destroys the integrity of the soil in a general sense, but also produces a secondary waste – the washing effluent, which is usually a chelate solution now laden with metals. The most logical, ecologically friendly and economically viable method is by *in situ* immobilization of metals using abundant, inexpensive soil amendments. This technique is particularly suitable for the treatment of big tracts of land where the soil is mostly contaminated. Soil amendments that have been successfully tested in North America, Europe, and Australia include liming materials, rock phosphate (hydroxyapatite), alkaline bio-solids and/or compost, Fe-rich by-products (steel shot, red mud, 'Fe-rich' from aluminum processing), and coal residues (alkaline coal fly ash, beringite).

CONCLUSION

Red mud is an insoluble waste material from the production of high-grade aluminum from bauxite. It is a highly alkaline mixture of fine metal oxides, and therefore the deposits of red mud pose number of environmental and health risks. The most common method for its disposal is storage in impounded dike deposits. The ecological rehabilitation of red mud residue deposits is complicated by many factors, including its hazardous nature, extremely high pH and salinity, poor water-holding capacity, and extremely low microbial activity. Establishment of vegetation cover has rehabilitated the red mud residue in rare successful cases; however, the nutrient concentrations in vegetation tend to be low, which can be improved to some extent by addition of ameliorants such as gypsum and sewage sludge. Gypsum is a calcium sulfate ($CaSO_4 \cdot 2H_2O$), and it reduces alkalinity via calcium carbonate ($CaCO_3$) formation and improves the structure of the substrate through the exchange of sodium for calcium, which help reduce pH as the calcium absorbs hydroxide ions. Red mud closely resembles alkali soil in its high pH and exchangeable sodium percentage and the associated physicochemical properties, and hence it is likely to react in a similar way to gypsum. Red mud is effective at increasing soil pH and reducing the bio-oil total acid number. Red mud is able to produce a better bio-oil, however, the catalyst loading must be considered. Soil health is the foundation of productive farming practices. Fertile soil provides essential nutrients to plants. Important physical characteristics of soil-like structures and aggregation allow water and air to infiltrate, roots to explore, and biota to thrive. Diverse and active biological communities help soil resist physical degradation and cycle nutrients at rates to meet plant needs. Soil health and soil quality are terms used interchangeably to describe soils that are not only fertile but also possess adequate physical and biological properties to sustain productivity, maintain environmental quality and promote plant and animal health.

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Chapter 10
Soil Quality Near Indian Oil Corporation Limited Pol Depot Ahmednagar, Maharashtra, State of India

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ABSTRACT

The area in question has diversified relief and amount of rainfall and soil types. It is dry region lies in east, irrigated region in north and tribal-dominant population dominant in the west. Ahmednagar district is situated partly in the upper Godavari basin and partly in the Bhīma basin occupying a somewhat central position in Maharashtra state. The climate of the district is characterized by a hot summer and general dryness throughout the year except during the southwest monsoon season (i.e., June to September). Physiographically the district forms part of Deccan Plateau. Part of Sahayadri hill ranges fall in the district. Here in this chapter, the author has elaborated about soil quality and ground water quality near IOCL Terminal Ahmednagar, Maharashtra, India.

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BACKGROUND

Ahmednagar is the town of the Ahmad. Ahmednagar district popularly called Nagar came into existence in 1818. After the moghal rule the district passed on to Maratha rule and finally British Rule since 1st May 1960 the district is a part of Maharashtra State. The district has an area of 17412 sq. km. While the area of the district accounts for 5.5 percent of the total area of the state. The district is first in the since of area. The district is named after the town Ahmednagar, Ahmad Nizam Shah, the founder of the Nizam Dynasty. After defeating the Bahamani troops, laid the foundation of the town in 1494 and called it after him. India has been divided into four macro level physical division *i.e.* The Nether Mountains, The Great Plains, the Deccan plateau and the coastal plain and Islands. Maharashtra falls under two of this macro level division: The Deccan plateau and coastal plains and Island respectively. The north south running of Sahyadri range separates these two divisions. The Deccan plateau lies to the east while the coastal plain and Islands lie to the west up to the Arabian Sea. The Deccan plateau is much larger of the two divisions and includes twenty-nine districts of the state while only six districts lie in the coastal plains and Island. The whole Deccan plateau is subdivided into 12 meso regions of these only two meso regions i.e. Northern Maharashtra and the Maharashtra plateau lie within the state. Northern Maharashtra is further divided in to two micro regions: the Tapi, Purna valley and the Wardha, Painganga Wainganga plain. The Maharashtra plateau is also further subdivided into two micro regions i.e. The Eastern plateau and the Western plateau with protruded hills. The coastal plain and Island is divided into four meso regions i.e. Gujarat region, Western coastal region, eastern coastal region and Island of these. The western coastal region covers Maharashtra. This region is divided into four micro level regions *i.e.* Maharashtra littoral Goa coast, Karnataka coast, and North Kerala coast. Only Maharashtra littoral falls within the state of Maharashtra. The whole district forms part of the great trap region of the Deccan. Throughout Ahmednagar the trap rocks are distinctly stratified and as in the rest of the Deccan, the alternative belts of basalt and amygdaloidal preserve a striking Parallelism to each other. The basalts are believed to have been extruded from fissures towards the end of the Cretaceous period on to an already mature land surface.

INTRODUCTION

Soil is the most vital and precious natural resource that sustains life on the earth. It takes almost 1000 years to produce an inch of top soil (Chandra & Singh, 2009). One of the major concerns in today's world is the pollution and contaminations of soil.

The degradation of soil has stared occurring both due to natural and human induced factors which in turn affecting the productivity. As human population continue to increase, human disturbance of the earth's ecosystem to produce food and fiber will place greater demand on soils to supply essential nutrients. The soils native ability to supply sufficient nutrients has decreased with higher plant productivity levels associated with increased human demand for food (Havlin et al., 2010). Therefore one of the greatest challenges today is to develop and implement soil, crop and nutrients management technologies that enhance the plant productivity and the quality of soil, water and air. If we do not improve the productive capacity of our fragile soils, we cannot continue to support the food and fiber demands of our growing population. With the introduction of green revolution technologies the modern agriculture is getting more and more dependent upon steady supply of synthetic inputs (mainly fertilizers) which are product of fossil fuel. Excessive and imbalanced use of chemical fertilizers has adversely affected the soil, causing decrease in organic carbon, reduction in microbial flora of soil, increasing acidity and alkalinity and hardening of soil (Jain, 2009). This situation contributes to the considerable loss of soil fertility.

The soil types of the district are broadly divided into four categories namely coarse shallow soil; medium black soil; deep black soil and reddish soil occupying about 38, 41, 13 and 8 percent of the cultivated area respectively. In the first two categories, soil moisture is the predominant limiting factor affecting productivity of crops particularly under rainfed condition.

METHODOLOGY

Total four number of soil samples was collected from surrounding areas including the IOCL Depot covering 10 km radius to assess the baseline status of soil quality (Table 1). The soil samples were analysed for physical and chemical parameters. Soil samples were collected by using core cutter (0-15 cm depth) and brought to the laboratory in polythene bags. Standard procedures were followed for soil sampling and analysis (Doran & Jones, 1986; Ben-Dor & Banin, 1995; Coleman & Crossley 1996; Lal 1998; Karlen et al., 2001; Chen et al., 2006; Malik & Bharti, 2007; Malik et al., 2008; Bharti, 2013a, b,c; Bharti & Chauhan, 2013; Chauhan & Bharti, 2015; Bharti & Chauhan, 2017; Chauhan & Bhart, 2015; Ashwini et al., 2016).

Table 1. Soil sampling locations

Code No.	Locations	Distance/Direction	Latitude/Longitude	Selection Criteria
S1	IOCL Depot Ahmednagar	-	18°59’30.60”N/74°40’9.27”E	Non-Agriculture
S2	Akolner	1.2 Km/SW	18°59’17.55”N/74°39’30.41”E	Agricultural field
S3	Sonewadi	2.7 Km/N	19° 0’57.65”N/74°40’27.24”E	Agricultural field
S4	Jadhavwadi	1.5 Km/SE	18°58’47.95”N/74°40’32.29”E	Agricultural field

RESULTS

The results of soil samples are listed in Table 2 and 3.

DISCUSSION

Based on soil analysis data it is concluded that soils are normal from salinity view point, but sodic as ESP is > 15 at the project site. The soils are low in nitrogen, phosphorus and potassium. The levels of total Fe, Cu, Cr, B and Zn are within the limits. However, for successful greenbelt development liberal quantity of organic manure (50 tons/ha) and double the quantity of recommended doses of N, P and K fertilizers should be applied. The soil at the project site requires amelioration. Apply acid forming amendments like Sulphur/Iron pyrite for removal of excess sodium from the exchange complex with provision of adequate drainage. The soil should be periodically monitored for EC, pH and ESP.

Topography

Topographically, the study area is undulating in nature. Highlands in the form of ridges, mostly flat topped table land topography or plateau, are occupied on western and northern sides of the study area. The general slope of the study area is toward East to NE and SE.

Table 2. Analysis of soil samples

S. No.	Parameters	Unit	S1	S2	S3	S4
1.	pH at 25^{0}C (20% leachate)	-	8.25	7.61	7.39	7.50
2.	Electrical Conductivity	dS/m	0.6	0.4	0.3	0.3
3.	Organic	%	0.7	0.40	0.36	0.44
4.	Calcium	meq/100gm	37.0	22.6	24.8	23.2
5.	Magnesium	meq/100gm	9.1	13.8	12.8	14.3
6.	Sodium	meq/100gm	14.0	5.8	6.2	6.5
7.	Potassium	meq/100gm	1.4	4.0	3.5	3.8
8.	CEC	%	61.5	46.2	47.3	47.8
9.	SAR	-	4.1	1.9	2.0	2.1
10.	ESP	%	22.8	12.6	13.1	13.6
11.	Total Phosphorus	mg/100gm	23.5	14.4	13.2	13.8
12.	Total Nitrogen	mg/100gm	12.7	13.0	12.5	12.9
13.	Nitrate	mg/100gm	6.2	4.0	4.8	4.4
14.	Zinc	mg/100gm	4.4	3.4	3.8	3.2
15.	Copper	mg/100gm	1.2	1.6	1.5	1.5
16.	Iron	mg/100gm	153.0	107.5	114.2	111.6
17.	Chromium	mg/100gm	1.0	2.0	2.5	2.2
18.	Boron	mg/100gm	1.26	1.22	1.24	1.28
19.	Water Holding Capacity	%	23.8	35.6	34.2	36.5

Table 3. Grain size analysis and texture of soil samples

S. No.	Parameters	Unit	S1	S2	S3	S4
1.	Sand	%	12.6	34.2	32.6	35.2
2.	Silt	%	44.9	28.8	28.1	28.8
3.	Clay	%	42.5	37.0	39.3	36.0
4.	Texture	-	Silty Clay	Clay Loam	Clay Loam	Clay Loam

Drainage Pattern

Major drainages in the form of primary and secondary streams are originates from highlands of western & northern sides and flows toward east. It is observed that drainages originates from north-western highland flows toward NE while drainages originates from western and southwestern side flows toward SE direction. One small stream is passing on southern part of site, flows SE and merges with seasonal river Walthumba Nadi.

Geological Setup

Basalt rocks and their verities in the form of numerous horizontal flows cover entire study area. These flows occurred in layered sequence ranging in thickness. Dykes further intrude these flows and forms dissected ridges. Low laying areas are covered by black cotton soil ranging in thickness. The only aquifer of the study area is Basalt. Groundwater occurs mostly in joints/fractures, voids and weak plans of Basalt. Groundwater occurs in water table i.e. Phreatic, semi-confined and confined condition and showing considerable fluctuations during pre and post monsoon seasons. As per Groundwater brochure for Ahmednagar district published by CGWA in 2014, Ahmednagar taluka is falls under semi-critical zone. As per the brochure, at some places, groundwater quality is affected due to presence of high level of Nitrates and Total Hardness.

Ground Water Resources

To assess the quality of ground water, samples were collected from 14 numbers of locations for the analysis of physico-chemical and microbiological parameters. Sampling was done one time during the study period (Table 4). All the results are below permissible limits as per IS:10500 standards for drinking water. However, at GW 7 (Aragon), TDS, Total Hardness, Total Alkalinity and chloride have been observed well above desirable limits (Table 5).

CONCLUSION

The available nitrogen and phosphorus in the soils are in low category. However, higher content of K was observed in the soils. The high values of K in the soils are attributed to release of K from clays under high pH conditions besides the use of potassic fertilizers. The boron in the soil ranges from 1.22to 1.28 mg/100gm in a narrow range. This is possibly the result of high soil pH, limited leaching and clay texture of the soil in the area. Fertilizer recommendations on the basis of soil test data can be done for maximum crop yield. Improper agriculture practices, intensive farming, monoculture type of cropping pattern and over irrigation are responsible for the deterioration of soil quality in the area. To overcome the adverse effect of these chemical cultivation efforts should be made to exploit all the available resources of nutrients under the theme of integrated nutrient management (INM).

Table 4. Location for ground water

Code No.	Locations	Distance/ Direction	Latitude/Longitude	Source
GW1	IOCL Depot Ahmednagar Bore well	-	18°59’31.24”N/74°40’8.43”E	Bore well
GW2	IOCL Depot Ahmednagar Open well	-	18°59’21.40”N/74°40’10.97”E	Open well
GW3	Sonewadi	2.7 Km/N	19° 0’57.26”N/74°40’25.84”E	Open well
GW4	Akolner	1.3 Km/SW	18°59’17.66”N/74°39’28.56”E	Bore well
GW5	Khandala	3.7 Km/E	18°59’49.31”N/74°42’15.26”E	Hand pump
GW6	Chass	5.2 Km/NW	19° 2’3.64”N/74°39’1.03”E	Bore well
GW7	Arangon	6.1 Km/NE	19° 1’24.60”N/74°42’59.17”E	Bore well
GW8	Sarola	4.6 Km/S	18°57’2.98”N/74°39’25.68”E	Bore well
GW9	Akolner-2	0.6 Km/SSE	18°59’11.80”N/74°40’15.65”E	Bore well
GW10	Akolner-3	1.0 Km/NE	18°59’48.64”N/74°40’39.67”E	Bore well
GW11	Jadhavwadi-1	1.4 Km/SE	18°58’52.14”N/74°40’34.82”E	Bore well
GW12	Jadhavwadi-2	1.7 Km/ESE	18°59’5.98”N/74°41’0.74”E	Bore well
GW13	Khadki	5.0 Km/SE	18°57’30.03”N/74°42’5.77”E	Bore well
GW14	Walki	8.8 Km/ESE	18°58’14.35”N/74°44’59.98”E	Bore well

Under this approach the best available option lies in the complimentary use of bio-fertilizers, organic manures in suitable combination of chemical fertilizers. ‘Organic agriculture’ system should be inculcated which begins to consider potential environmental and social impacts by eliminating the use of synthetic inputs such as synthetic fertilizers, pesticides etc. The camps, rallies and training programs for the farmers should be arranged for increasing awareness regarding the benefits of organic agriculture, bio-fertilizers etc. in crop production and thereby improving soil fertility and nutrient status.

Table 5. Analysis results of groundwater

S. No.	Parameters	Unit	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	Drinking Water Specification IS 10500: 1992 (Reaffirmed 2012)	
											Desirable Limit	Permissible Limit
1.	Temperature	^{0}C	26.5	26	27	27.5	26.5	25.5	26	27	**--**	**--**
2.	pH	pH Unit	7.97	8.79	8.35	8.24	8.27	8.41	7.39	8.31	**6.5 – 8.5**	**No Relaxation**
3.	Colour	Pt.Co.scale	<5	<5	<5	<5	<5	<5	5	<5	**5**	**15**
4.	Odour	--	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	**Agreeable**	**--**
5.	TDS	mg/L	612	388	409	318	378	393	**1658**	675	**500**	**2000**
6.	Conductivity	µmho/cm	940	600	630	490	580	600	2550	1040	**--**	**--**
7.	Turbidity	NTU	0.4	0.4	0.5	0.6	0.4	0.7	1	0.7	**5**	**10**
8.	Total Hardness	mg/L	252	336	188	144	212	264	344	396	**200**	**600**
9.	Calcium	mg/L	47	51	48	45	45	66	80	87	**75**	**200**
10.	Total Alkalinity	mg/L	264	270	200	150	204	226	384	405	**200**	**600**
11.	Chloride	mg/L	190	70	104	88	89	83	**675**	148	**250**	**1000**
12.	Magnesium	mg/L	33	50	17	8	24	24	35	44	**30**	**100**
13.	Sulphate	mg/L	24	14	18	10	20	22	74	25	**200**	**400**
14.	Total Phosphorus (PO_4-P)	mg/L	1.5	1	1.1	0.9	1.3	1.2	2	1.2	**--**	**--**
15.	Sodium	mg/L	134	38	82	65	66	54	450	105	**--**	**--**
16.	Potassium	mg/L	18	8	16	8	7	5	105	18	**--**	**--**

continued on following page

Table 5. Continued

S. No.	Parameters	Unit	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	Drinking Water Specification IS 10500: 1992 (Reaffirmed 2012)	
											Desirable Limit	**Permissible Limit**
17.	Fluoride	mg/L	0.5	0.3	0.5	0.5	0.6	0.5	0.9	0.8	**1.0**	**1.5**
18.	Phenolic Compound	mg/L	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	**0.001**	**0.002**
19.	Oil and Grease	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	**--**	**--**
20.	Dissolved Oxygen (DO)	mg/L	5.5	5.8	5.3	6	5.9	5.5	4.9	5.5	**--**	**--**
21.	Nitrate	mg/L	1.2	1	1.3	1	1.5	1.1	2.1	1.3	**45**	**No Relaxation**
22.	Total Nitrogen	mg/L	1.6	1.4	1.8	1.5	1.9	1.6	2.8	1.8	**0.5**	**0.5**
23.	Iron	mg/L	0.14	0.14	0.16	0.18	0.24	0.24	0.36	0.28	**0.3**	**No Relaxation**
24.	Copper	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07	0.07	**0.05**	**1.5**
25.	Boron	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.5**	**1.0**
26.	Chromium	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	**0.05**	**No Relaxation**
27.	Zinc	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	0.02	**5**	**15**
28.	Total Coliform	Present/ Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	**Shall not be detectable in any 100mL of sample**	**-**

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Chapter 11
Soil Quality Assessment at Nganglam, Bhutan

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ABSTRACT

The study area considered for environment impact assessment (EIA) studies is an area covering 5 kms radial distance from proposed plant site in the foothills of Himalaya at Nganglam, Pemagatshel, Bhutan. Analyzing the soil samples collected from six locations in the study area has assessed the soil characteristics in the study area, especially the extent of pollution undergone by the soils due to various sources and reasons. Sampling locations were chosen to represent the soil quality of the study area. A preliminary reconnaissance survey was made to get a general picture of the area's land use. The activities around the sampling sites were also taken into consideration to learn the sources of pollution if any or factors governing the physico-chemical properties of the soil. To analyze the soil quality of the area and to assess the impact of industrial or urban activities on land environment with respect to any specific contamination, soil quality studies were carried out under EIA study.

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BACKGROUND

Bhutan has 72 per cent forest coverage, and that 20 per cent of its land is designated as protected areas, while the cultivated area accounts for only 8%. Pastures account for nearly 4% of the total land. Usable land is severely limited due to rugged and mountainous terrain and vast areas of snow and rocks (SIIR, 2009). As in other parts of the world, Bhutan is also experiencing land use changes due to a number of activities - both man-made as well as natural. Land degradation in the country is mostly manifested in the displacement of soil material through water erosion and internal biophysical and chemical deterioration. The rising population has aggravated the situation and will further worsen it if timely counter measures are not taken. Soil quality is simply defined as "the capacity of a specific kind of soil to function", i.e. mainly to provide nutrition to plants and absorb the drain water (Bharti, 2007). The different properties of soil are - texture, moisture, fertility (level of nitrogen, phosphorus, potassium) and pH level. The pH is the measure of a soil's acidity or alkalinity. Each of these properties depends on different factors. For example, soil moisture depends on climate, topography and other soil characteristics. The temperatures of soils vary depending on their water holding capacity. Soils with low water holding capacity are warm (Bharti & Chauhan, 2013; Bharti & Singh, 2013; Chauhan & Bharti, 2015; Ezeaku & Bharti, 2015). The most significant environmental problems in Bhutan were soil erosion and water pollution. The erosion of the soil occurs because 50% of the land in Bhutan is situated on mountainous slopes, which are subject to landslides during the monsoon season. Soil represents the loose and unconsolidated materials derived through the breaking down of rocks. The soil is a natural body of animal, mineral and organic constituents differentiated into horizons of variable depth, which differ from the material below in morphology, physical make up, chemical properties and composition and biological characteristics (Bharti & Chauhan, 2017; Bharti, 2013a; Bharti, 2013b; Bharti, 2013c). The comprehensive study of soil system in terms of its contamination with a toxic chemical is of vital significance because it is an integral part of the bio-geographic system. Land environment study is an important study for prediction of various impacts due to industrialisation and urbanisation. The impact of pollutants on soil quality may be a rather slow process but it can sometimes cause concern in the long run (Bharti et al., 2013a; Bharti et al., 2013b). The fall out of heavy metals and other pollutants present in the smoke and dust emitted from industries, traffic and other sources may get accumulated in the soil and ultimately affect the trace metal concentration. Such accumulation could also prove to be beneficial to plant growth but beyond a certain limit, the pollutant concentration may be deleterious to the vegetation. Studies were carried out in the study area, for estimation of physico – chemical characteristics of the existing soil.

POLLUTANT MIGRATION POTENTIAL

The migration of pollutants released in an environment in the land occurs through the ground & when it interacts with the water table, it can pollute the ground making it unsuitable for domestic and agricultural use. Part of pollutants may be transported during monsoon floods when water flows as sheet run off. As no major polluting industries are present in the study area, only the domestic effluents which seep through the local streams runs and get dried in a open land which is not used for cultivation.

STUDY AREA DESCRIPTION

Pemagatshel is located in the south east of Bhutan with an area of 517.8 km2 and has a total of 2,547 households. The dzongkhag is characterized by highly dissected mountain ranges, steep slopes and narrow valleys with little flat land. The elevation in the dzongkhag ranges from 1,000 meters to 3,500 meters above the sea level. The dzongkhag experiences an average annual rainfall of 1500 mm to 3000 mm. Nganglam or Namglam is a town in south-eastern Bhutan. It is located in Pema Gatshel District. The population of Nganglam is 1,018 as per 2005 census. The project site of DCCL is located very close to Nganglam.

The study area considered for REIA studies is an area covering 5 kms radial distance from proposed plant site. The area has an undulating topography is a pediplain with number of residual hills which have steep slopes. The existing quality of the soil environment serves as an index for assessing the pollution load and the assimilative capacity of any region and forms an important tool for planning project activity in the area.

Comprehensive baseline soil quality assessment was carried out through Dungsam Cement Project Authority (DCPA) now Dungsam Cement Corporation Limited (DCCL) in 2009 at seven locations in Nganglam and adjacent areas. The sampling sites included both urban and rural landscapes. Nganglam cement plant site and Nganglam High School areas representing urban landscape. Upper Chenkari, Menchu, Gacheri and Dechilling places representing the rural landscapes of the vicinity of project area. There are no factories or industrial establishments in these areas. The site generally falls under sub-tropical forest with altitude ranging from 200–1000 m above sea level. The initial section of the alignment from Nganglam town to Dezama and Shuguri villages passes through an agricultural area which consists of mainly Kamzhing, and orange orchard. Bamboo and banana forests are common in the area. About 120 tree species, 64 shrub species, 40 herbs, 34 climbers, 15 epiphytes, 15 underground rhizome, sucker and rhizomatous herbs, 7 endemic plants, 17 plants with medicinal value, 5 recognized threatened plants and 3 plants recorded under CITES Appendix II.

SOIL DESCRIPTION

Two different types of soil have been observed and are classified according to texture as sandy silt and silty sand. Results of analysis indicated that the soil is neutral to alkaline in nature. All the parameters, especially heavy metals were found to be present in very less concentration.

SELECTION OF SAMPLING LOCATION

Analysing the soil samples collected from 6 locations in the study area has assessed the soil characteristics in the study area, especially the extent of pollution undergone by the soils due to various sources and reasons. Sampling locations were chosen to represent the soil quality of the study area. Details of the soil sampling locations are given in Table 1.

Table 1. Sampling locations

S. No.	Station	Station Code	Location	Direction w.r.t. the project site	Distance from the Central site (Km)	No. of Samples Taken/Season
1	Project Site	SQ – 1	Near DCPA Site Office	---	--	1
2	Menchu	SQ – 2	Drujay's Garden	SSE	2.4	1
3	Nganglam	SQ – 3	Thring Chojaoy's Land, Near Lower Sec. School	S	3.5	1
4	Gacheri	SQ – 4	Tashis's Orchards	WSW	1.5	1
5	Kangrizhe Mines	SQ – 5	Mines Area	NNW	1.7	1
6	Marung Ri Mines	SQ – 6	Mines Area	NNE	3.1	1

SAMPLING AND ANALYSIS METHODOLOGY

A preliminary reconnaissance survey was made to get a general picture of the area's land use. The activities around the sampling sites were also taken into consideration to learn the sources of pollution if any or factors governing the Physico-chemical properties of the soil. To analyse the soil quality of the area and to assess the impact of industrial / urban activities on land environment with respect to any specific contamination, soil quality studies werecarried out under EIA study.

Sampling

Our team visited the site and identified the exact locations for soil sampling. At each location the sample was collected by hand-driven sampling augers from sub-surface region. Topsoil samples from all six locations at depth of 15 cm. (sub surface) region of the soil profile were collected for physico-chemical analysis.

Analysis

Attention was paid to collect adequate amount of composite samples for analysis with the standard methods. Samples were homogenised before testing. The samples were packed in dependable, waterproof containers. They were marked accurately and distinctly, brought to the SRI laboratory for testing and analysed there as per ASTM, USEPA, IS: 2720, M.L.Jeckson (Soil Chemical Analysis). A brief methodology of each parameter is as under:

Parameters and methods for analysis of soil samples are given in Table 2.

SOIL QUALITY

Soil analysis study was taken because the fall out of heavy metals and other pollutants present in the smoke and dust emitted from vehicles and other sources may get accumulated in the soil and ultimately affects the trace metal concentration (SIIR, 2009). The migration of pollutants released in an environment in the land seeps through the ground & when interacts with the water table can pollute the ground water making it unsuitable for domestic and agricultural use (Malik et al., 2008a; Malik et al., 2008b). Studies were carried out in the study area for estimation of

Table 2. Parameters and methods for analysis

S.No	Parameters	Method	Protocol
1.	pH (30 gms/ 75 ml)	pH meter	IS:2720(Pt.-26)
2.	E. conductivity, μmho/cm (1:5 with water)	Conductivity meter	Handbookof Soil Chemical analysis by ML Jackson
3.	Moisture, % by mass	Oven dry	Oven dry
4.	Texture	Grain size analysis	IS:2720(Pt.-4)
5.	Particle Size Distribution	Sieve analysis	IS:2720(Pt.-4)
6.	Water Holding Capacity	Mechanical	Mechanical
7.	Alkalinity as $CaCO_3$	Titrimetric	APHA, 21^{th} Ed.
8.	Organic Carbon	Titrimetric	IS:2720 (Pt.-22)
9.	Chlorides as Cl, % by mass	Volhard's method	Volhard's method
10.	Sulphates as SO_4, % by mass	Gravimetric method	IS:2720 (Pt.-27)
11.	Avialable Nitrogen as N, mg/kg	Kjeldhal's method	Titrimetric
12.	Avialable Potassium as K, mg/ kg ass	AAS	AAS
13.	Avialable Phosphorus as P, mg/kg	Gravimetric	Handbookof Soil Chemical analysis by ML Jackson
14.	Sodium as Na_2O, % by mass	AAS	AAS
15.	Copper as Cu	AAS	APHA, 21^{th} Ed.
16.	Zinc as Zn	AAS	APHA, 21^{th} Ed.
17.	Lead as Pb	AAS	APHA, 21^{th} Ed.
18.	Iron as Fe_2O_3	AAS	APHA, 21^{th} Ed.
19.	Cadmium as Cd	AAS	APHA, 21^{th} Ed.
20.	Chromium as Cr	AAS	APHA, 21^{th} Ed.
21.	Sodium absorption ratio	By calculation	By calculation

physico-chemical characteristics of the soil. Soil samples were collected from 6 locations in the study area. Sampling locations were chosen to represent the soil quality of the study area. Details of the soil sampling locations are given in Table –6.5 (1). In the study area of 5-km radius, two different types of soils have observed, and classified according to texture as sandy silt and silty sand. The texture of soil samples collected from project site was observed sandy silt with 58% sand and 43% silt, 8.8% average moisture content and 48% water holding capacity. The pH of all the soil samples lies in the range of 4.5-7.1. Results of analysis indicate that the soil is slightly acidic and alkalinity was found nil. Electrical conductivity was

Table 3. Soil quality analysis at project site

S. No.	Parameters	Unit	Winter	Summer	Monsoon	Post-Monsoon	Avg. Results
Physical Parameters							
1.	pH (30 gm in 75 ml water)	---	5.6	7.1	4.5	5.3	5.6
2.	E. Conductivity (1: 5 ratio)	µ mho/ cm	99	918	170	78	316.3
3.	Moisture Content	% by mass	7	11.9	9.3	7.0	8.8
4.	Texture	---	Sandy Silt	Sandy Silt	Sandy Silt	Sandy Silt	Sandy Silt
5.	Particle Sizes Sand Silt Clay	% by mass	66 33 01	62 47 01	59 40 01	46 51 03	58.3 42.7 1.5
6.	Water Holding Capacity	% by mass	49.1	48.2	47.6	47	48
Chemical Characteristics							
1.	Alkalinity as $CaCO_3$	% by mass	Nil	Nil	Nil	Nil	Nil
2.	Organic Carbon	% by mass	0.10	0.15	0.15	0.66	0.27
3.	Chlorides as Cl	% by mass	0.12	0.14	0.08	0.03	0.09
4.	Sulphates as SO_4	% by mass	<0.01	<0.01	<0.01	<0.01	<0.01
5.	Available Nitrogen as N	mg/kg	98.1	219	220	201	184.5
6.	Available Potassium as K	mg/kg	31.3	102	105	103	85.3
7.	Available Phosphorus as P	mg/kg	31.1	7.6	7.9	9.3	14
8.	Sodium as Na_2O	% by mass	0.8	0.8	1.9	1.0	1.1
9.	Copper as Cu	mg/kg	11.6	30	17	40	24.7
10.	Zinc as Zn	mg/kg	44.4	39.7	77	136	74.3
11.	Lead as Pb	mg/kg	4.9	81	51	410	136.7
12.	Iron as Fe_2O_3	% by mass	3.6	3.1	2.8	6.7	4.1
13.	Cadmium as Cd	mg/kg	1.1	2.0	1.4	0.7	1.3
14.	Chromium as Cr	mg/kg	21.8	26	28	103	44.7
15.	Sodium absorption ratio (SAR)	-	3.1	3.5	12.7	5.2	6.1

Table 4. Soil quality analysis at Menchu

S. No.	Parameters	Unit	Winter	Summer	Monsoon	Post-Monsoon	Avg. Results
	Physical Parameters						
1.	pH (30 gm in 75 ml water)	---	5.0	6.3	4.9	5.4	5.4
2.	E. Conductivity (1: 5 ratio)	µ mho/ cm	225	353	209	62	212.3
3.	Moisture Content	% by mass	5	8.2	9.1	6.3	7.2
4.	Texture	---	Silty sand	Silty sand	Silty Sand	Sandy Silt	Silty Sand
5.	Particle Sizes Sand Silt Clay	% by mass	 47 52 02	 51 47 02	 46 50 04	 39 66 06	 45.7 53.8 3.5
6.	Water Holding Capacity	% by mass	48.7	49.2	50.1	51	49.8
	Chemical Characteristics						
1.	Alkalinity as $CaCO_3$	% by mass	Nil	Nil	Nil	Nil	Nil
2.	Organic Carbon	% by mass	0.26	0.21	0.21	0.64	0.33
3.	Chlorides as Cl	% by mass	0.10	0.11	0.04	0.01	0.07
4.	Sulphates as SO_4	% by mass	<0.01	<0.01	<0.01	<0.01	<0.01
5.	Available Nitrogen as N	mg/kg	147.1	237	234	216	208.5
6.	Available Potassium as K	mg/kg	320.5	96	85	70	142.9
7.	Available Phosphorus as P	mg/kg	262.2	8.1	8.5	8.9	71.9
8.	Sodium as Na_2O	% by mass	0.6	0.9	0.7	0.7	0.7
9.	Copper as Cu	mg/kg	8.7	25	25	26	21.2
10.	Zinc as Zn	mg/kg	107.6	90	84	53	83.7
11.	Lead as Pb	mg/kg	31.1	32	114	331	127
12.	Iron as Fe_2O_3	% by mass	7.92	2.7	4.5	5.9	5.3
13.	Cadmium as Cd	mg/kg	1.22	0.4	0.3	1.1	0.75
14.	Chromium as Cr	mg/kg	75.02	61	57	72	66.3
15.	Sodium absorption ratio (SAR)		2.8	4.8	3.9	3.8	3.8

Table 5. Soil quality analysis at Nganglam

S. No.	Parameters	Unit	Winter	Summer	Monsoon	Post-Monsoon	Avg. Results
Physical Parameters							
1.	pH (30 gm in 75 ml water)	---	3.8	5.7	7.1	5.2	5.5
2.	E. Conductivity (1: 5 ratio)	μ mho/ cm	100	280	140	60	145
3.	Moisture Content	% by mass	6	7.5	7.1	6.7	6.8
4.	Texture	---	Sandy Silt	Sandy Silt	Silty Sand	Sandy Silt	Sandy Silt
5.	Particle Sizes Sand Silt Clay	% by mass	51 47 02	53 46 01	47 50 03	41 64 05	48 51.8 2.8
6.	Water Holding Capacity	% by mass	48.4	48.2	53.5	54	51
Chemical Characteristics							
1.	Alkalinity as $CaCO_3$	% by mass	Nil	Nil	Nil	Nil	Nil
2.	Organic Carbon	% by mass	0.24	0.14	0.24	0.60	0.31
3.	Chlorides as Cl	% by mass	0.13	0.10	0.05	0.03	0.08
4.	Sulphates as SO_4	% by mass	<0.01	<0.01	<0.01	<0.01	<0.01
5.	Available Nitrogen as N	mg/kg	109	199	285	234	206.8
6.	Available Potassium as K	mg/kg	76.4	58	32	41	51.9
7.	Available Phosphorus as P	mg/kg	88.2	7.5	7.8	8.2	27.9
8.	Sodium as Na_2O	% by mass	1.1	0.8	0.8	0.2	0.7
9.	Copper as Cu	mg/kg	15.2	31	25	28	24.8
10.	Zinc as Zn	mg/kg	56	74	302	53	121.3
11.	Lead as Pb	mg/kg	24.2	32	95	292	110.8
12.	Iron as Fe_2O_3	% by mass	3.1	4.4	3.5	3.7	3.7
13.	Cadmium as Cd	mg/kg	1.5	1.0	0.1	0.5	0.8
14.	Chromium as Cr	mg/kg	22.1	24	102	61	52.3
15.	Sodium absorption ratio (SAR)		6.8	4.1	2.3	1.5	3.7

Table 6. Soil quality analysis at Gacheri

S. No.	Parameters	Unit	Winter	Summer	Monsoon	Post-Monsoon	Avg. Results
Physical Parameters							
1.	pH (30 gm in 75 ml water)	---	5.0	5.2	5.6	5.7	5.4
2.	E. Conductivity (1: 5 ratio)	µ mho/ cm	131	241	296	53	180.3
3.	Moisture Content	% by mass	5	10.5	10.4	4.9	7.7
4.	Texture	---	Silty sand	Sandy Silt	Sandy Silt	Sandy Silt	Sandy Silt
5.	Particle Sizes Sand Silt Clay	% by mass	46 52 02	45 52 03	53 44 03	44 64 02	47 53 2.5
6.	Water Holding Capacity	% by mass	49.4	50.4	50.1	52	50.5
Chemical Characteristics							
1.	Alkalinity as $CaCO_3$	% by mass	Nil	Nil	Nil	Nil	Nil
2.	Organic Carbon	% by mass	0.28	0.17	0.17	0.63	0.31
3.	Chlorides as Cl	% by mass	0.14	0.16	0.03	0.02	0.09
4.	Sulphates as SO_4	% by mass	<0.01	<0.01	<0.01	<0.01	<0.01
5.	Available Nitrogen as N	mg/kg	132.4	214	218	187	187.9
6.	Available Potassium as K	mg/kg	348.3	31	98	62	134.8
7.	Available Phosphorus as P	mg/kg	116.3	7.4	8.5	7.6	34.9
8.	Sodium as Na_2O	% by mass	0.5	1.2	0.4	0.5	0.65
9.	Copper as Cu	mg/kg	17.0	19	16	12	16
10.	Zinc as Zn	mg/kg	86.3	62	66	41	63.8
11.	Lead as Pb	mg/kg	7.7	28	69	262	91.7
12.	Iron as Fe_2O_3	% by mass	6.6	2.0	3.1	2.6	3.6
13.	Cadmium as Cd	mg/kg	0.9	2.3	<0.1	0.6	1.0
14.	Chromium as Cr	mg/kg	108.4	109	64	32	78.4
15.	Sodium absorption ratio (SAR)		2.7	7.8	2.7	3.4	4.2

Table 7. Soil quality analysis at Kangrizhe mines

S. No.	Parameters	Unit	Winter	Summer	Monsoon	Post-Monsoon	Avg. Results
Physical Parameters							
1.	pH (30 gm in 75 ml water)	---	6.6	4.5	5.9	5.3	5.6
2.	E. Conductivity (1: 5 ratio)	µ mho/ cm	119	184	356	58	179.3
3.	Moisture Content	% by mass	7	8.4	7.5	4.7	6.9
4.	Texture	---	Silty sand	Silty sand	Silty Sand	Silty Sand	Silty Sand
5.	Particle Sizes Sand Silt Clay	% by mass	 45 52 3	 47 51 02	 45 53 02	 52 47 01	 47.3 50.8 2.0
6.	Water Holding Capacity	% by mass	52.4	51.2	52.0	52	51.9
Chemical Characteristics							
1.	Alkalinity as $CaCO_3$	% by mass	Nil	Nil	Nil	Nil	Nil
2.	Organic Carbon	% by mass	0.22	0.24	0.24	0.69	0.35
3.	Chlorides as Cl	% by mass	0.05	0.10	0.04	0.01	0.05
4.	Sulphates as SO_4	% by mass	<0.01	<0.01	<0.01	<0.01	<0.01
5.	Available Nitrogen as N	mg/kg	93.4	232	236	244	201.4
6.	Available Potassium as K	mg/kg	51.9	65	63	89	67.2
7.	Available Phosphorus as P	mg/kg	68.7	9.2	9.5	8.6	24
8.	Sodium as Na_2O	% by mass	0.6	0.2	0.4	0.7	0.48
9.	Copper as Cu	mg/kg	8.65	14	32	21	18.9
10.	Zinc as Zn	mg/kg	49.5	29	89	89	64.1
11.	Lead as Pb	mg/kg	14.32	33	85	238	92.6
12.	Iron as Fe_2O_3	% by mass	4.1	0.5	3.5	3.3	2.9
13.	Cadmium as Cd	mg/kg	1.6	1.6	<0.1	0.2	0.9
14.	Chromium as Cr	mg/kg	26.8	31	33	47	34.5
15.	Sodium absorption ratio (SAR)		2.5	1.6	2.1	3.9	2.5

Table 8. Soil quality analysis at Marung Ri mines

S. No.	Parameters	Unit	Winter	Summer	Monsoon	Post-Monsoon	Avg. Results
Physical Parameters							
1.	pH (30 gm in 75 ml water)	---	7.7	7.0	6.8	6.3	7.0
2.	E. Conductivity (1: 5 ratio)	µ mho/ cm	74	400	518	109	275.3
3.	Moisture Content	% by mass	7	7.6	8.6	7.4	7.7
4.	Texture	---	Silty sand	Silty sand	Sandy Silt	Silty Sand	Silty Sand
5.	Particle Sizes Sand Silt Clay	% by mass	45 49 6	43 52 05	51 48 01	58 41 01	49.3 47.5 3.2
6.	Water Holding Capacity	% by mass	58.8	54.6	49.6	46	52.3
Chemical Characteristics							
1.	Alkalinity as $CaCO_3$	% by mass	Nil	Nil	Nil	Nil	Nil
2.	Organic Carbon	% by mass	0.17	0.24	0.14	0.63	0.3
3.	Chlorides as Cl	% by mass	0.17	0.13	0.08	0.03	0.16
4.	Sulphates as SO_4	% by mass	<0.01	<0.01	<0.01	<0.01	<0.01
5.	Available Nitrogen as N	mg/kg	87.4	279	202	200	192.1
6.	Available Potassium as K	mg/kg	47.8	84	59	61	63
7.	Available Phosphorus as P	mg/kg	24.3	8.6	7.6	9.0	12.4
8.	Sodium as Na_2O	% by mass	0.4	0.9	0.8	0.9	0.8
9.	Copper as Cu	mg/kg	2.8	52	14	14	20.7
10.	Zinc as Zn	mg/kg	57.5	149	87	110	100.9
11.	Lead as Pb	mg/kg	10	45	42	176	68.3
12.	Iron as Fe_2O_3	% by mass	6.2	2.5	2.6	3.1	3.6
13.	Cadmium as Cd	mg/kg	0.66	1.8	0.5	0.05	0.8
14.	Chromium as Cr	mg/kg	64.1	54	26	51	48.8
15.	Sodium absorption ratio (SAR)		1.3	4.5	4.7	5.1	3.9

in the range of 78-918 μmho/cm. Organic carbon content was around 0.1-0.66% by mass. All the parameters were found to be in low concentration. Heavy metals (like Pb, Cd, Cu, Cr, Zn) were found to be present in different quantity i.e. Cu 24.7 mg/kg, Zn 74.3 mg/kg, Pb 136.7 mg/kg, Cd 1.3 mg/kg and Cr 44.7 mg/kg. Sulphate concentration in all the samples is Below Detection Limit. Average available N, P and K were found 184.5, 14.0 and 85.3 mg/kg. Average Sodium absorption Ratio (SAR) was found 6.1 during the study period at this site.

The texture of soil samples collected from Menchu was observed sandy silt with 7.2% average moisture content and 49.8% water holding capacity. pH of all the soil samples lies in the range of 4.9-6.3. Results of analysis indicate that the soil is slightly acidic and alkalinity was found nil. Electrical conductivity was in the range of 62-353 μmho/cm. Organic carbon content was around 0.21-0.64% by mass. All the parameters were found to be in low concentration. Heavy metals (like Pb, Cd, Cu, Cr, Zn) were found to be present in different quantity i.e. Cu 21.2 mg/kg, Zn 83.7 mg/kg, Pb 127.0 mg/kg, Cd 0.8 mg/kg and Cr 66.3 mg/kg. Sulphate concentration in all the samples is Below Detection Limit. Average available N, P and K were found 208.5, 71.9 and 142.9 mg/kg. Average Sodium absorption Ratio (SAR) was found 3.8 during the study period at this site.

The texture of soil samples collected from Nganglam was observed sandy silt with 6.8% average moisture content and 51.0% water holding capacity. pH of all the soil samples lies in the range of 3.8-7.1. Results of analysis indicate that the soil is slightly acidic and alkalinity was found nil. Electrical conductivity was in the range of 60-280 μmho/cm. Organic carbon content was around 0.14-0.60% by mass. All the parameters were found to be in low concentration. Heavy metals (like Pb, Cd, Cu, Cr, Zn) were found to be present in different quantity *i.e.* Cu 24.8 mg/kg, Zn 121.3 mg/kg, Pb 110.8 mg/kg, Cd 0.8 mg/kg and Cr 52.3 mg/kg. Sulphate concentration in all the samples are Below Detection Limit. Average available N, P and K were found 206.8, 27.9 and 51.9 mg/kg. Average Sodium absorption Ratio (SAR) was found 3.7 during the study period at this site. The texture of soil samples collected from Gacheri was observed sandy silt with 7.7% average moisture content and 50.5% water holding capacity. The pH of all the soil samples lies in the range of 5.0-5.7. Results of analysis indicate that the soil is slightly acidic and alkalinity was found nil. Electrical conductivity was in the range of 53-296 μmho/cm. Organic carbon content was around 0.17-0.63% by mass. All the parameters were found to be in low concentration. Heavy metals (like Pb, Cd, Cu, Cr, Zn) were found to be present in different quantity *i.e.* Cu 16.0 mg/kg, Zn 63.8 mg/kg, Pb 91.7 mg/kg, Cd 1.0 mg/kg and Cr 78.4 mg/kg. Sulphate concentration in all the samples is Below Detection Limit. Average available N, P and K were found 187.9, 35.0 and 134.8 mg/kg. Average Sodium absorption Ratio (SAR) was found 4.2 during the study period at this site.

The texture of soil samples collected from Kangrizhe Mines were observed silty sand with 6.9% average moisture content and 51.9% water holding capacity. The pH of all the soil samples lies in the range of 4.5-6.6. Results of analysis indicate that the soil is slightly acidic and alkalinity was found nil. Electrical conductivity was in the range of 58-356 µmho/cm. Organic carbon content was around 0.22-0.69% by mass. All the parameters were found to be in low concentration. Heavy metals (like Pb, Cd, Cu, Cr, Zn) were found to be present in different quantity *i.e.* Cu 18.9 mg/kg, Zn 64.2 mg/kg, Pb 92.6 mg/kg, Cd 0.9 mg/kg and Cr 34.5 mg/kg. Sulphate concentration in all the samples is Below Detection Limit. Average available N, P and K were found 201.4, 24.0 and 67.2 mg/kg. Average Sodium absorption Ratio (SAR) was found 2.5 during the study period at this site.

The texture of soil samples collected from Marung Ri Mines were observed silty sand with 7.7% average moisture content and 52.3% water holding capacity. The pH of all the soil samples lies in the range of 6.3-7.7. Results of analysis indicate that the soil is very slightly acidic or neutral and alkalinity was found nil. Electrical conductivity was in the range of 74-518 µmho/cm. Organic carbon content was around 0.14-0.63% by mass. All the parameters were found to be in low concentration. Heavy metals (like Pb, Cd, Cu, Cr, Zn) were found to be present in different quantity *i.e.* Cu 20.7 mg/kg, Zn 100.9 mg/kg, Pb 68.3 mg/kg, Cd 0.8 mg/kg and Cr 48.8 mg/kg. Sulphate concentrations in all the samples are Below Detection Limit. Average available N, P and K were found 192.1, 12.4 and 63.0 mg/kg. Average Sodium absorption Ratio (SAR) was found 3.9 during the study period at this site.

The basic physico-chemical characteristics of soil of the vicinity may be influenced by many anthropogenic activities like querrying, erosion, top soil removal, wastewater discharging, oil spilling, grease spillage, gardening, solid waste dumping, etc (Malik & Bharti, 2007; Bharti & Chauhan, 2013). Many activities can create harmful effects on soil quality and a few activities especially conservation practices may pose positive effects on soil health (Ezeaku & Bharti, 2015; Bharti, 2007). During the EIA study, the soil quality monitoring is helpful to know the basic health profile of soil in current time as well as the prediction for the harmful effects can be done using appropriate modeling.

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Chapter 12
Soil Quality of Tripura State of India:
Sustainable Environment

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ABSTRACT

Soil quality can be defined as the fitness of a specific kind of soil to function within its capacity and within natural or managed ecosystem boundaries to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. Soil is one of the common factors that bring all agriculture together. It can also be used to describe more complex soil characteristics such as soil organic matter, nutrient amounts, soil structure, etc. The soil quality of Tripura state where ONGC has established numerous exploratory and development wells for exploration of natural gas has been studied and presented in this chapter.

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BACKGROUND

Agriculture is the key development in the rise of sedentary human civilization, whereby farming of domesticated species created food surplus that nurtured the development of civilization. Modern agronomy, plant breeding, agrochemicals such as pesticides and fertilizers, and technological developments have in many cases sharply increased yields from cultivation, but at the same time have caused widespread ecological damage and negative human health effects.

Being a North Eastern state of India, The climate of Tripura is influenced by its location which displays characteristics that are typical of the hilly and mountainous region. The change in the topographical features of the region also causes a change in the climatic conditions in Tripura. Tripura records a low average temperature of 10 degree Celsius in the winter season which rises to a maximum average of 35 degree Celsius in the summer. The altitude of the state also influences the climatic conditions of Tripura state. The state of Tripura influences a monsoonal climate with the well demarcated sub-tropical and temperate zones. The climate along with the other factors of the terrain and the soil are suitable conditions for horticulture in the state of Tripura. The horticultural sector is dependent on the seasonal rainfall that dominates the seasons of Tripura.The state is also enjoying four distinguishable seasons. The winter prevails from the month of December to February. The months of March and April witness the pre-monsoon season. The longest season of the state is the monsoon season that continues between the months of May to September. Tripura receives maximum rainfall in the month of June. The state records an average annual rainfall of 2100 mm. Kamalpur in Tripura receives the maximum amount of rainfall of 2855 mm while Sonamura receives the lowest average of 1811 mm.

INTRODUCTION

The major geomorphic element observed in Tripura is north-south running parallel hill regions and intervening valleys. The hills are tightly folded anticlines with broad synclinal valleys. Geologically, the area is occupied by the folded sedimentary formations ranging in age from lower Tertiary to Recent. In Tripura, the loamy soil type facilitates the percolation and infiltration of water from the surface into the ground water regime. Moreover, presence of sand stone facilitates the movement of water under the ground as well and acts as storage of water. It indicates that soil profile and nature of the bedrock helps runoff water to move into the ground water regime from recharge zone. In the state of Tripura, the ground water occurs in shallow aquifers under unconfined and semi – confined to confined conditions.

Fine to medium grained sand stones form the principal aquifer. In major part of the state, ground water occurs under unconfined condition in shallow depth. Ground water occurs under confined condition within shallow depths in small isolated zones. Aquifer system of the area is divided into two types, viz, shallow aquifer within 50 m bgl and deep aquifer between 50 to 300 m bgl. As per CGWB Report, 2008, the wells are constructed within a depth range of 6 to 171 m bgl. Discharge of the wells varies from 0.01 to 2.00 lit/sec during pre-monsoon period and from 0.02 to 2.5 l/sec during post-monsoon period.

TYPE OF SOIL IN TRIPURA STATE

Two categories of soil degradation are recognized in Tripura. The first category deals with degradation by displacement of soil material, principally by water. The second one deals with the internal soil deterioration resulting from loss of nutrients (chemical deterioration) or through physical processes, including waterlogging and flooding (physical deterioration). The 43.07% of the total land area of the state is occupied by the red loamy soil and the sandy soil. The soil covers a total area of 4,514 sq. km. The reddish yellow brown sandy soil of the region covers a total area of 3,468 sq. km. in the state of Tripura. The soil type is the second most dominant type in the region covering 33.06% of the land area. The three other types of soil that prevail in the region are the lateritic soil, younger alluvial soil and the older alluvial soil. The soil of Tripura is faced with the problem of rapid soil erosion. This occurs due to chemical weathering with the high annual rainfall. Another factor that is responsible for the rapid erosion of soil in Tripura is the withdrawal of vegetation in the state which has caused the high velocity of the wind to remove the soil cover.

In order to provide food for a large population— regular production, proper management and distribution of food is necessary. When plants of the same kind are grown and cultivated at one place on a large scale, it is called a crop. For example, crop of wheat means that all the plants grown in a field are that of wheat. Crops are of different types like cereals, vegetables and fruits. These can be classified on the basis of the season in which they grow. India is a vast country. The climatic conditions like temperature, humidity and rainfall vary from one region to another. Hence a diversity of crop production is also found in Tripura which includes different type of crops like Sugarcane, Cotton, Jute and Mesta, Pulses, Oil Seeds, Rice, Wheat and others type.

Hydrological Status

Three types of hydro-geological formations identified in the state of Tripura and they are as follows: Alluvial formation with thickness varies between 10-15 m and occurs along the bank of rivers and water can be extracted through dug well and ordinary hand pumps; Dupitila formation with thickness from 10-15m and nearly horizontal in disposition and it has low permeability and low storage capacity due to high clay content. It indicates that the water yielding capacity from this type of formation is very low; Sand stone of Tipam formation constituted the principle aquifer of this area and it consists of sub rounded fine to medium grained, friable sandstone with intercalated clay. Tipam formation is found in valleys of Tripura. The permeability of this formation is much higher than Dupitila and Surma sandstone. These formations divide the state into three main hydrogeological zones. The first one is confined to central part of Agartala-Udaipur, Khowai-Amarpur, Ambasa, Kailasker, Kumarghat and Dharam Nagar syncline valley; where the yield prospects are good. Fine to medium grained sand stones form the principal aquifer. The second one is confined to unconfined aquifers of moderate regional extent with yield prospect of 50-100 m^3/hr. This zone extends bordering the hill ranges i.e. the marginal part of Agartala-Udaipur, KhowaiAmarpur, Kamapur-Ambasa, Kailaskar-Kumarbagh and Dharam Nagar valleys. The third zone, comprising moderately thick discontinuous aquifers with yield prospects less than 50m^3/hr, is located in the intermountain and smaller valleys. These areas are mostly occupied by argillaceous formations belonging to Surma series. Besides this, 16springs or seepage zones are also present in the state. Tribal people living in the hilly areas are using spring water for drinking and domestic purposes. In the foothill areas, people arrest the spring water by constructing seasonal / permanent bund and use that water for irrigation purpose and sometimes for drinking and domestic purposes also. Moreover, it has been also observed during field survey that villagers made ‘kaccha’ wells having depth of 15-30 ft at the foot-hills of small hillocks. This water is being used in both domestic and agricultural purposes. It indicates that the recharge area of such ground water sources are located on the top of the adjacent anticline hillocks. Loamy soil with medium permeability facilitates the accumulation of water and moisture in the narrow valleys. Artesian zones also occur in the state of Tripura and local people are mainly using these wells for drinking and domestic purpose. Artesian belt has been delineated in West of Tripura and the yield of such wells are found to be in the order of 1 to 3 cubic meter /hr. High auto flow discharge of 54 cubic meter/hr is observed in Khowai valley.

Agricultural Sowing Area for Crops Production

Sowing is the most important part of crop production. Before sowing, good quality seeds are selected. Good quality seeds are clean and healthy seeds of a good variety. Always it should be practiced with good quality seeds which give a high yield. It is also should keep in mind that with good and healthy seeds nourishment of soil is important which is also related to selection of sowing areas and soil properties. In our state there are five major groups of soil are available. They are Reddish yellow brown sandy soil, Red loam and sandy loam soil, older alluvial soil, Younger alluvial soil and Lateritic soil. The agricultural sowing land of Tripura is enriched with these five groups of soil which help to grow different types of crop like Sugarcane, Cotton, Jute & Mesta, Pulses, Oil Seeds, Rice, Wheat and other. The rainy season in India is generally from June to September. Paddy, maize, soyabean, groundnut, cotton, etc., are Kharif crops. Rabi Crops are those crops which are grown in the winter season. Their time period is generally from October to March. Examples of Rabi crops are wheat, gram, pea, mustard and linseed. In Tripura state both Kharif and Rabi crops are sown in their desired time period.

Climate, soil and vegetation are considered as major factors of the exogenous processes relating to the prevalent morphological system as well as land use pattern in the area under study. The study area exhibits the effects of differential weathering mainly relating to the variations in distribution, terrain characteristics etc. The fluvial environment is also associated with the local climate, soil, vegetation characteristics vis-a-vis the prevailing geomorphic processes. Here, the climate, soil and vegetation have been considered in the context of the characteristic functions of geomorphic processes (exogenetic) towards the development of fluvial landform and varied land use patterns in North Tripura District.

Soil Conservation

Soil conservation helps achieve three types of benefit:

1. Long-term reduction in checking the decline of agricultural production;
2. Gradual increase in agricultural production,
3. Other non-agricultural benefits such as improved flow to the river during summer, reduction in periodicity and severity of flooding, reduction in siltation of reservoirs, reduction in damage of various costly infrastructure and low harmful impacts on farm lands.

Table 1. Details of soil sampling location

S.No.	Code	Latitude and Longitude
1	S1	23°38’15.38”N 91°11’33.31”E
2	S2	23°41’54.35”N 91°10’02.61”E
3	S3	23°30’15.01”N 91°16’14.52”E
4	S4	23°15’37.30”N 91°30’41.42”E
5	S5	23°29’01.42”N 91°24’33.93”E
6	S6	23°31’32.49”N 91°22’23.72”E
7	S7	23°54’20.21”N 91°24’49.17”E
8	S8	23°56’29.04”N 91°19’02.87”E

In Tripura many areas in the higher and middle elevations are under forest (58%). The tilla lands and the lower foothills are used for plantation of rubber and/or for agricultural and horticultural crops. These lands are highly susceptible to soil erosion, and therefore require soil conservation measures such as bench terracing.

Soil Quality Analysis

A preliminary reconnaissance survey was made to get a general picture of the area’s land use. Total 8 numbers of samples were collected from different locations near to gas exploratory/development wells to assess the base line status of soil. Analysis was also carried out for physico-chemical parameters as well as the parameters to define the texture class. Soil samples were collected by using core cutter and brought to the laboratory in polythene bags. Standard procedures have been followed for soil sampling and analysis (Doran & Jones.1986; Ben-Dor & Banin, 1995; Coleman & Crossley 1996; Lal1998; Karlen et al., 2001; Chen et al., 2006; Malik & Bharti, 2007; Malik et al., 2008; Bharti, 2013a,b,c; Bharti & Chauhan, 2013; Chauhan & Bharti, 2015; Bharti & Chauhan, 2017; Chauhan & Bhart, 2015; Ashwini et al., 2016).

Highlights of Soil Quality

1. The soils are categorized as sandy loam to sandy clay loam/clay based on different soil separates (sand, silt and clay).
2. They have moderate to high water holding capacity (29.1 to 74.1%), but soils are having moderate to good porosity as texture is sandy loam to clay as clay content is ranging from 15.4 to 60.4%.
3. The pH of the soil samples narrowly ranged from 7.12 to 7.74 during the study period.

Table 2. Soil sample analysis

S. No	Parameters	Unit	S1	S2	S3	S4	S5	S6	S7	S8
1	Water Holding Capacity	%	36.8	29.1	31.2	40.2	73.2	32.4	41.5	74.1
2	Porosity	%	50.4	48.5	46.2	51.4	52.2	45.6	48.1	53.2
3	Particle Size Distribution									
a.	Sand	%	52.4	56.2	58.4	50.2	23.2	56.3	51.3	25.4
b.	Silt	%	19.5	26.8	26.2	20.4	16.4	24.4	21.2	15.5
c.	Clay	%	28.1	17.0	15.4	29.4	60.4	19.2	27.5	59.1
4	Texture	-	Sandy Clay Loam	Sandy Loam	Sandy Loam	Sandy Clay Loam	Clay	Sandy Loam	Sandy Clay Loam	Clay
5	Cation Exchange Capacity	meq/100 g	35.6	19.5	18.4	36.9	41.9	21.2	42.5	45.9
6	pH	-	7.56	7.12	7.26	7.48	7.62	7.34	7.51	7.74
7	Electrical Conductivity	dS/m	1.8	1.2	1.1	1.9	1.9	1.3	2.0	2.2
8	Exchangeable Sodium	%	13.5	12.3	12.0	14.1	13.1	13.2	13.6	13.3
10	Exchangeable Calcium	meq/100g	20.4	11.2	10.6	21.8	24.2	12.1	23.6	25.1
11	Exchangeable Magnesium	meq/100g	9.2	5.3	5.1	8.6	10.4	5.6	11.5	12.8
12	Exchangeable Sodium	meq/100g	4.8	2.4	2.2	5.2	5.5	2.8	5.8	6.1
13	Exchangeable Potassium	meq/100g	1.2	0.6	0.5	1.3	1.8	0.7	1.6	1.9
14	Organic Carbon(OC)	%	0.56	0.62	0.68	0.66	0.80	0.78	0.72	0.84
15	Total Nitrogen	%	0.048	0.053	0.058	0.057	0.069	0.067	0.062	0.072
16	Nitrate N	kg/ha	121.0	138.9	112.0	129.9	143.4	134.4	147.8	138.9
17	Total Phosphorus	kg/ha	275.5	345.0	295.7	322.6	371.8	349.4	385.3	378.6
18	Total Iron	mg/100gm	76	66	72	80	84	64	78	92
19	Total Zinc	mg/100gm	0.82	1.02	0.94	0.78	0.92	0.86	0.88	0.96
20	Total Copper	mg/100gm	0.72	0.81	0.78	0.85	0.77	0.83	0.80	0.76
21	Total Boron	mg/100gm	1.12	1.18	1.10	1.16	1.22	1.15	1.12	1.18
22	Total Chromium	mg/100gm	0.62	0.58	0.52	0.64	0.59	0.63	0.61	0.55

4. The soil EC also varied from 1.1 to 2.2 dS/m and ESP ranged from 12 to 14.1. These parameters indicate that soils are neutral in reaction, saline (EC > 1.0 dS/m) in the surrounding areas and non-sodic as ESP is <15.0.
5. Among exchangeable basic cations predominance of calcium (10.6 to 25.1 meq/100 g soil) was seen followed by Mg (5.1 – 12.8 meq/100 g soil), Na (2.2 to 6.1 meq/100 g soil) and K (0.5 to 1.9 meq/100 g soil).
6. The loss on ignition (0.56 to 0.84% OC) indicate that soils are medium (<0.75% OC) to high (>0.75% OC) in organic carbon status. This shows that soils are medium to high in nitrogen status.
7. Considering only 2% available phosphorus based on total P, soils are classified as poor (>28 kg P_2O_5/ha) in available P.
8. On the basis of exchangeable potassium values soils are categorized as high (>280 kg K_2O/ha) in potassium status.
9. The results relating to total Fe, Cu, Cr, B and Zn do not show alarming concentrations in different soil samples as they are much lower than the interventional values for soils.

CONCLUSION

Based on soil analysis data it is concluded that soils are normal from soil reaction view point, but saline as EC exceeds 1.0 dS/m in all the soil samples. The soils are medium to high in nitrogen, low in phosphorus and high in available potassium status. The levels of total Fe, Cu, Cr, B and Zn are within the limits. However, for successful greenbelt development liberal quantity of organic manure (25 tons/ha) and recommended dose of N and double the quantity of recommended doses of P fertilizers should be applied. The potassium is adequate; hence 20% less than the recommended dose for green belt should be applied. The soil quality should be periodically monitored for EC, pH and ESP as well as OC (organic carbon), available P and K. Loss of crop yield due to loss of topsoil can be compensated by the use of manure and fertilizer. At the same time, loss of topsoil by soil erosion may also compensated by the formation of fresh soil layers through the process of pedogenesis. To calculate the loss of topsoil, it is necessary to take into account the amount of soil regenerated, keeping in view the difference in the rate of soil formation under different types of climatic conditions.

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Glossary

Agroecology: The science of ecology, or the branch of biology dealing with the relations and interactions between organisms and their environment, applied to the design, development, and management of agriculture.

Agro-Ecosystem: An ecosystem on agricultural land.

Allelopathic: Refers to the suppression of growth of one plant species by another due to the release of toxic substances.

Amelioration: The act of making something better; improvement.

Amendments: Something which is added to soil in order to improve its texture or fertility.

Biochar: Charcoal produced from plant matter and stored in the soil as a means of removing carbon dioxide from the atmosphere.

Biomass: As simple as above and below-ground vegetative material; or more complex to include microbial contributions or specific uses, such as for fuel.

Bulk Density: Bulk density is the weight of soil in a given volume. Soils with a bulk density higher than 1.6 g/cm^3 tend to restrict root growth.

Capability Classification System: A system developed by the USDA Natural Resources Conservation Service of grouping soils based on their inherent suitability for intensive uses.

Compost: Decayed organic material used as a fertilizer for growing plants.

Contamination: The action or state of making or being made impure by pollutants.

Denitrification: A process occurring naturally in soil, where bacteria break down nitrates to give nitrogen gas, which returns to the atmosphere.

Disturbance: An ecosystem disturbance can be natural or human induced stress. An example of a natural disturbance is a hurricane or a tornado. An example of a human-induced disturbance is tillage or pesticide application.

Dynamic Properties: Soil characteristics that can change in response to land use changes.

Ecosystem Function: Refers to the services performed by the organisms in the system such as energy flow, nutrient cycling, filtering and buffering of contaminants, and regulation of populations.

Ecosystem: A functioning system of interacting parts of the physical environment and biological Community in a geographic region.

Efficiency: The state or quality of being efficient.

Eutrophication: A process where water bodies receive excess nutrients, primarily nitrogen and phosphorus that stimulate excessive plant growth.

Fly Ash: Ash produced in small dark flecks by the burning of powdered coal or other materials and carried into the air.

Green Manure: Young and succulent plant material turned into the soil to improve its organic matter and nutrient content.

Heavy Metals: The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb).

Inherent Properties: Soil properties that do not change with land use.

Minimum Data Set (MDS): A limited number of biological, chemical and physical indicators that together give an overall measure of soil quality.

Phosphate: A salt or ester of phosphoric acid, containing PO_4^{3-} or a related anion or a group such as —$OPO(OH)_2$.

Pollutants: A substance that pollutes something, especially water or the atmosphere.

Population: A group of individuals of the same species that live in the same geographic region.

Resilience: A component of ecosystem stability is the ability of an ecosystem to recover after disturbance.

Resistance: A component of ecosystem stability is the ability of an ecosystem to remain stable in the face of disturbance.

Soil Properties: Chemical, physical, or biological characteristics of soil which can indicate its level of function of ecosystem services. Properties can be dynamic or inherent characteristics. Also see soil quality indicator.

Soil Quality Indicator: A chemical, physical or biological property of soil that is sensitive to disturbance and represents performance of ecosystem function in that soil of interest. These are dynamic soil properties.

Soil Quality, Soil Health, Soil Condition: These phrases are used in various ways and sometimes interchangeably. Soil quality sometimes refers to the inherent potential of soil, in contrast to soil health or soil condition.

Soil Stabilizer: Soil stabilizers convert ground of insufficient bearing capacity into soil that is highly suitable for placing and compacting.

Sustainability: Avoidance of the depletion of natural resources in order to maintain an ecological balance.

Synergism: The interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects.

Synergistic: It is when separate elements produce a greater effect when acting together than would be produced if they acted separately.

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