SOIL REMEDIATION AND PLANTS



PROSPECTS AND CHALLENGES

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Soil Remediation and Plants

Preface

For a layman, soil is the homogenous material also called 'dirt', 'mud' and 'ground' or 'earth'. We have disposed of our wastes through the soil and neglected its uses for as long as we have been living on mother earth. The living soils are not just the foundation of our food chain, but of our civilization in general. Knowing that the soils are a source of our food, it becomes imperative that we keep it healthy. It has always been considered as a disposable commodity. Our future will be dark if we do not look after our soils. Currently, every second, fertile soil equivalent to fill nearly 30 soccer fields is being destroyed, and around 52 million ha are being affected by different soil contaminants. Approximately 10 million ha of farmland is lost every year and about 1.6 billion ha of the world's best, most productive lands are used to grow crops at present. Unsustainable farming practices are leading to water and wind erosion, loss of organic matter, compaction of the soils, salinization and pollution, and nutrient loss. A New Paradigm for Agriculture, released earlier this year by FAO has been 'Save and Grow'; this save the soils campaign will run until December 2017, the international year of soils. As world population and food production demands rise, keeping our soil healthy and productive is of paramount importance. By focusing more attention on soil health and by educating ourselves about the positive impact healthy soils can have on productivity and conservation, we can save this living and life-giving substance, without which we would perish.

This thin layer is suffering from pollution, a common observation in our present day lives, which originates from our activities and our wastes which are full of chemicals lacking in nature and end up with the pollution of our soils. Nature itself produces wastes such as dead plants, dead animals, spoiled fruits and vegetables, but they increase the fertility of the soil. Our ancestors used the wastes to fertilize it, the populations then were small and this was no problem. Today demographic outburst is putting a pressure on the soil ecosystem to produce more and more food.

All through the 20th century the additions of fertilizer, pesticides and herbicides have created problems for us and all species. Industrialization has been the greatest contributor contaminating by the release of xenobiotics, which enter our ecosystems and degrade the soils. The toxic chemicals decrease the fertility, making the land unsuitable for the growth of natural plant cover or agriculture. The air pollutants return back to us as acid rains dissolving some of the soil nutrients, posing major problems for our health in the long run, because all the plants consumed by us absorb much of the pollution from the soils polluted by us. This is the cause for the sudden increase in some terminal illnesses, but long-term exposures can prove detrimental to our genetic make-up, resulting in congenital illnesses and chronic health problems.

Pollutants added to the soil may adhere to the soil matrix, become immobile, but may still be available to plant roots. They may be taken up into the plant structure and enter the food chain, or can percolate from the soil surface into our groundwaters and cause problems like nitrate loading in drinking waters. Whatever agriproduct we will cultivate on polluted soils, that will lack the quality and may even contain poisonous compounds causing serious health problems. The soil contaminants can have significant deleterious consequences for ecosystems. There are radical soil chemistry changes which can arise from the presence of many hazardous chemicals even at low concentrations of the contaminant species. We thus have to use very expensive primary accredited methods with proven high precision like X-Ray Fluorescence (XRF), ASV (Anodic Stripping Voltammetry), Colorimetric test kits, Atomic absorption and ICP (Inductive Coupled Plasma) to look at the pollution status of our soils. However, prevention is better than cure; therefore, we can restore 720 million hectares of lightly degraded soils on our planet simply by using sustainable and agro-ecological farming techniques. We can use several principal strategies for remediation like excavating the soil and disposing of it away from the human or sensitive ecosystem contact, but it will not serve the purpose in the long run. Phytoextraction, phytodegradation, phytovolatilization, rhizofiltration, evapotranspiration, phytostabilization and hydraulic control techniques are also available which can be applied. These remediations are becoming a subject of public/scientific interest as cost-effective technologies for cleaning our soils. The efficiency, however, depends on the physical and chemical properties of the soil, bioavailability of the pollutant, and the ability of the plants for uptake, accumulation, translocatation, sequesteration and detoxification. They are a type of ecological engineering, intermediate between engineering and natural attenuation. Genetic approaches have also been started to solve these problems.

In this book, an attempt has been made to provide a common platform to the biologists, agricultural engineers, environmental scientists and chemists, working with a common aim of finding sustainable solutions to various environmental issues. The volume addresses the topics crucial for understanding the ecosystem approaches for a sustainable development. Contributions from different authors present an overview of soil contaminants as well as the significant role of plants. The book provides an overview of ecosystem approaches and phytotechnologies and their cumulative significance in relation to various environmental problems and solutions. It will be a useful asset to students, researchers, practitioners and policy makers alike.

We are thankful to the contributors for their collaboration that made the present volume possible. We also extend our appreciation to Elsevier for their exceptional kind support, which made our efforts successful.

The Editors

Foreword

Land is a precious natural resource and base for agricultural sustainability and human civilization. Population growth, particularly the development of high-density urban populations leads to global industrialization and places major burdens on our environment, thereby considerably threatening environment sustainability. Contamination of soil mainly occurs due to release of industrial, urban and agricultural wastes generated by human activities. Controlled and uncontrolled solid discharge from industries, vehicle exhaustion, soluble salts, insecticides, pesticides, excessive use of fertilizers and heavy metals from organic and inorganic sources are environmental contaminants. These have resulted in build-up of chemical and biological containments throughout the biosphere, but most notably in soil and sediments. In addition to human-induced contamination of the environment, natural mineral deposits containing heavy metals are the major contaminants present in many regions of the globe.

Biological wastes and contaminants include raw and digested sewage, animal manures and vegetable wastes. However, microorganisms degrade or recycle these biological wastes into soil for agricultural benefits but increasing urbanization and continued expansion of cities require disposal of these materials far from cities. Traditional land disposal practices of biological wastes are often rendered uneconomic because of high transport costs. An additional problem regarding biological wastes is the risk of spread of infectious diseases when infected materials are applied to soil. Infected soil can facilitate disease transmission to plants, animals or humans who are directly or indirectly in contact with the soil.

Recent spreading out of the petroleum and chemical industries has resulted in the production of a wide range of organic and inorganic chemicals, which are considered major environmental pollutants. Among the chemical contaminants, inorganic contaminants being enriched with heavy metals are the most problematic for plants and humans. Industrial activities have also led to considerable contamination of soil and other media by enriching them with heavy metals, which have proven toxicity to both humans and animals. Contamination of soil and solid wastes with highly active radionuclides is another environmental risk with the potential for these metals to be radiotoxic to all life forms. Mention should also be made here of unwarranted concentrations of undesired chemicals mixed with commonly available inorganic fertilizers, such as nitrates, ammonia, phosphates, etc., which accumulate or contaminate water courses through run-off or air through volatilization. Although, several metals at their low levels are essential for normal functioning of metabolism, all metals are toxic to plants and other organisms when at higher concentrations. These heavy metals can easily replace essential metals associated with different pigments or enzymes, causing impairment of their functions.

Several legislative protocols have been framed aiming at reducing soil contaminants, but they are not so effective in controlling the contaminants. Many uncontrolled historical events like disposal of polychlorinated biphenyls by Hooker Company to the Love Canal area in Niagara Falls, and the dioxin crisis in Belgium, Italy and Bhopal caused miscarriages and birth abnormalities among the residents of affected areas. In addition, many chemicals have a great tendency to transfer from solid media to aqueous media and to be absorbed by plants or aquatic species.

The common remediation approaches being employed throughout the world to render soil enriched with toxic metals fit for use are based on the use of organic and inorganic chemicals. Some of the most common approaches are retention of toxicants within affected areas, degradation of organic contaminants by physico-chemical or biological means, and removal of contaminants from the soil. These approaches are being applied by an organization engaged in remediation to transform the contaminated soil into cultivable soil. Unfortunately, application of the above-stated strategies requires extensive earth moving and expensive machinery and infrastructure. For example, excavation of contaminated soil with heavy metals and offsite burial in landfill is not a suitable alternative, because it is just a shifting of the contamination problem somewhere else. Furthermore, non-biological processes have to bear heavy costs to remediate the entire known hazardous waste site worldwide. However, cost could be reduced substantially by using plants which are effective in phytoremediation.

Phytoremediation is the use of green plants to remove contaminants from contaminated sources such as soil, water, air and sediments. Generally, phytoremediation entails five processes of decontamination, for example rhizofiltration, phytostabilization, phytoextraction, phytovolatilization and phytodegradation. However, all these processes are meant for elimination of contaminants from soil and water, though to variable extents. Furthermore, these are the cost-effective and friendly techniques for cleaning the environment. Although thousands of species have been identified as heavy metal accumulators, there is a need to identify plants which can effectively phytoremediate the contaminated environment under the current scenario of climate change. The skill of selecting plant species, which can accumulate great amounts of heavy metals and are resistant to heavy metals, would facilitate reclamation of contaminated soils.

Phytoremediation is a hot topic being vigorously researched these days. Researchers, teachers and scholars engaged in the field of soil science, agronomy, ecology, botany, plant physiology, forestry, environmental chemistry, irrigation agriculture and biochemistry can greatly benefit from the detailed knowledge described in this book. Graduate and undergraduate students interested in phytoremediation may find this book to be a mandatory reference for their practical and theoretical study. Course instructors engaged with phytoremediation will find this book an adequate means to provide a fundamental background on the subject. I reviewed the book and a brief description is given below.

There are 24 chapters in the book written by the authors from 11 different countries. These cover topics like soil contamination with metals, different aspects of phytoremediation, evaluation of plants in phytoremediation, radioactive waste treatment and radionuclides in plants, plant–microbe interactions, pollution status of soils from different countries, heavy metal remediation, spatial mapping of metal-contaminated soils, organic amendments, soils polluted with oil hydrocarbons, role of serpentine flora and soil organic carbon.

A discussion on the different mechanisms plants adapt for remediation of metal-contaminated soils has been outlined at the start stressing the fact that an understanding of the inherently complex mechanisms is a prerequisite for developing suitable remediation techniques. This is followed by potential risks of heavy metals in soils, the role of plants in remediation, main limitations of phytoremediation and future prospects, and the sources and types of metal contamination in agricultural soils and the implications for the biosphere. Arsenic (As) is one of the oldest and most important poisons in the global environment and is becoming a serious threat for crop production. The chapter on this subject has summarized the work on As toxicity in relation to plants and environment. Authors have also discussed the progress made during last few decades to remediate the toxicity in soil, water, plant and food chains through different remediation technologies. Similarly studies on cadmium (Cd), being a promising ecotoxic metal, have been discussed at length because it poses inhibitory effects on plant metabolism, biodiversity, soil biological activity, and human and animal health. The strategies for the restriction of Cd entrance in grain crops by using different chemicals have been outlined. The role of Copper (Cu) as one of the most hazardous pollutants, particularly at higher concentrations has been included in the book, followed by the studies carried out in Malaysia which present results of assessing the phytoremediation potential of *Jatropha curcas*, *Acacia mangium*, *Dyera costulata* and *Hopea odorata* for Cu-contaminated soil. Soil contamination due to lead (Pb) warrants special attention because of its long-term retention in soil and hazardous effects on plant and human health. The role of synthetic chelators in the remediation of Pb-contaminated soils is given with a critical assessment of the risks and limitations associated with this technology. A chapter discussing the mechanisms of and factors affecting phytoremediation has also been included in the book.

A review of the role of phytoremediation in radioactive waste treatment has been presented as well as radionuclides in plants. Innovative new methodologies in this field and the different categories of phytoremediation techniques which may treat and control radioactive contaminated waste are addressed. The other chapter elaborates the scope and limitations of phytoremediation for radioactive contaminated soils. The authors have reviewed major sources of radioactive contaminants to soil and environment, possible role of phytoremediation, and post-remediation activities. This chapter concludes with implications for remediation of areas of extensive surface contamination. The transfer of heavy metals and radionuclides from soil to vegetables and plants in terms of transfer factor has been presented in a separate chapter. This factor is commonly used to estimate the food chain transfer of different elements and possible phytoremediation measures.

The extent of soil pollution in Turkey and the possible remediation measures and effective phytoremediation technology for cleaning soils polluted with oil hydrocarbons in Georgia have been discussed at length. The technology mentioned in the chapter from Georgia can be used to eliminate the pollution caused by accidental oil spills, which can be the result of oil transportation. Another chapter deals with the current status of soil pollution and nutrient deficiencies in the soils of Nepal. It has been concluded that plant-growth-promoting *Rhizobacteria* are beneficial for combating heavy metal stress. A chapter reviewing plant–microbe interactions in phytoremediation with a particular reference to the microbial dynamics in the rhizosphere of plants grown on contaminated soils has been added. Sufficient information has been given on the recent approaches in phytoremediation and how genetic engineering can play its role in improving the potential of phytoremediation in plants. The role of organic amendments to immobilize metals, improve plant growth and subsequent release of metals due to decomposition of organic matter has been discussed. Finally the spatial mapping of metal-contaminated soils using GIS techniques has been discussed and the fate of pig slurry application in a temperate region and its implications for sustainable agriculture and control of soil pollution evaluated.

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