Phytoremediation Technology for the Removal of Heavy Metals and Other Contaminants from Soil and Water

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Dedicated to our teachers, and mentors, from whom I continue to learn, and to my family for their support, blessings, motivation, and love. — ***Vineet Kumar***

Dedicated to my family especially my wife without whose support this book would not have been possible. — ***Maulin P. Shah***

This book is dedicated to my daughter and my wife. Their patience and understanding have given me the time and inspiration to research and editing this project. — ***Sushil Kumar Shahi***

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Preface

Environmental pollution with heavy metals and refractory organic chemicals is a global problem that has resulted from rapid mining, military, industrial, agricultural farming, and waste management practices. In addition to their negative effects on aquatic and terrestrial ecosystems and other natural resources, these pollutants accumulate in the food chain through agricultural products or leach into ground water and pose a great harm to humans, animals, plants, and the whole environment of our modern society. There are several evidence that this cocktail of pollutants is a contributor to the global epidemic of cancer and other degenerative diseases. Thus, there is an immediate demand at the regional, local, and global level to decontaminate polluted soil, water, and air to counteract the adverse effects on human health and conserve the environment for our future generations. Since conventional and physicochemical technologies employed for remediating the polluted habitats have many potential drawbacks including expensive and not environment friendly as they generate toxic by-products and large amounts of sludge, which also requires safe disposal and can also cause secondary pollution and lower sustainability. Increased need for the remediation of the heavy metals, organic chemicals, and other contaminants from polluted soil and water has created a demand for improved and newer remediation technologies that are applicable at economical, low waste generation, and environmentally friendly ways to restore the contaminated sites for human rehabilitation and agricultural production in an effective and more sustainable manner, and have a wider scope of waste management.

Phytoremediation in recent years has emerged as an energy-efficient and eco-friendly technology for decontamination of soil, surface and groundwater, air, or other polluted media. Phytoremediation refers to a set of techniques emphasizing the efficient use of plants, their related enzymes, and associated microbes for transportation, sequestration, detoxification, and mineralization of toxicants through complex natural biological, physiological, and chemical processes. This technology can be used to clean up and/or stabilize both inorganic and organic contaminants and has been considered to be the most promising technology due to its minimal site disturbance and low cost and higher public acceptance when compared with conventional remediation methods. It is an emerging green approach where plants are grown in contaminated soil, sediment, and water to increase the decomposition or removal rate of inorganic and organic pollutants *in planta* as well as *ex planta*.

The present book, *Phytoremediation Technology for the Removal of Heavy Metals and Other Contaminants From Soil and Water,* as the title implies, describes the numerous phytoremediation technologies which can be and has been applied to the cleanup of soil, water, and sediment contaminated with various toxic and hazardous *Heavy Metals And Other Contaminant*, to protect the environment and human health for sustainable development. Written for both academics and practitioners, the book provides detailed knowledge of various phytoremediation research, recent development, real-world applicability of that knowledge, and success stories related to phytoremediation of polluted habitats. In this book, we have attempted in several ways to attempt to explore the recent advances in plant-microbes based technologies and their diverse applications to the sustainable development of human life. This whole book is spread over 28 diverse chapters and offers an updated and detailed account of the latest research and development in different aspects of phytoremediation for the removal/remediation of heavy metals and other contaminants from soil and water for safety to public health.

Chapter 1 discusses the numerous bioremediation and phytoremediation technologies for environmental cleanup. Chapter 2 presents a detailed account of the phytoremediation as an ultimate approach for reinstating soil contaminated with heavy metals and other pollutants.

Chapter 3 describes the prospects of numerous plant species that display expressive mechanisms for efficiently uptake, translocate, and sequester the heavy metals and chemical pollutants from the contaminated environment. Chapter 4 discusses the recent developments in aquatic macrophytes for environmental pollution control with a case study grown on heavy metal removal from lake water and agricultural return wastewater with the use of Duckweed (*Lemnacea*). Chapter 5 provides comprehensive information about the phytoremediation potential of various weed plants belonging to the families Amaranthaceae and Euphorbiaceae grown on heavy metal contaminated soil. Chapter 6 describes the role of oxidoreductase metalloenzymes in the phytoremediation of environmental pollutants. Chapter 7 deals with an updated account of phytoextraction as an effective sustainable green approach to remediate the major environmental pollutants along with its challenges and future perspectives. Chapter 8 discusses and highlights the prospects and potential of various weed plants in phytoremediation and eco-restoration of heavy of metal-contaminated environments. Chapter 9 gives a brief account of the biochemical and molecular events in plants undergoing inorganic stress and the various strategies developed by the plants to ameliorate the metal toxicity. Chapter 10 discusses the monitoring of the process of phytoremediation of heavy metals using spectral reflectance and remote sensing. Chapter 11 emphasizes the environmental and health impacts of mine tailings and a potential method of removal and reduction of leaching toxic metals in mine tailings via phytostabilization as a green remediation technology. Chapter 12 discusses the applicability and drawbacks of phytoremediation along with the strategies for improving and modifying certain traits of plants to ascertain effective phytoremediation of heavy metals, metalloids, and radionuclides. Chapter 13 explains the role of Cress (*Lepidium sativum* L.) in phytoremediation of lithium, a toxic metals. Chapter 14 summarizes the advancement in macrophytes' use for bioremediation of different chemical compounds and the management of the aquatic environment. Chapter 15 provides a summary and discusses the role of PGPR in improving crop productivity and health. It also discusses its influence on other bacterial species, the mechanism involved, role in bioremediation and stress management. Chapter 16 discusses the different approaches for remediation of contaminated soil by using plants and explains role of nanomaterials in phytoremediation of tainted soil. Chapter 17 gives an overview of different classes of pesticides, focuses on the role of phytoremediation technology on pesticide pollution, processes uptaken by plants in eliminating these pollutants, and shedding light on the rhizospheric plant bacterial association for the enhanced degradation. Chapter 19 discusses the role of plat's genes in detoxification and mitigation of heavy metals and organic contaminants pollution abatement. Chapter 20 explains the role of nano-phytoremediation technology in environmental remediation along with future endeavors. Chapter 21 describes the various biosynthesis procedures for the production of nanoparticles from plants, microorganisms and fungi, and their different strategies for the potential application in environmental clean-up, especially heavy metals. Chapter 22 explains the role and potential of constructed wetlands plant treatment system for the treatment and recycling of hazardous wastewater. Chapter 23 gives general and specific information on the ecological characteristics and biological mechanisms involved in the phytoremediation process by aquatic macrophytes. Chapter 24 presents a case study on phytoremediation of trace elements from paper mill wastewater with Pistia stratiotes L. and explains metal accumulation and antioxidant response during remediation. Chapter 25 discusses the role of the coupled phytoremediation-electrokinetic technology in phytoremediation of heavy metals contaminated soils. Chapter 26 presents a comprehensive review of the role of microbes-assisted phytoremediation in remediation of environmental contaminants. Chapter 27 describes the recent progressions application of constructed wetland microbial fuel cell in electricity production and the analysis of the anode microbial community during wastewater treatment. Chapter 28 gives a critical insight about eco-friendly phytocapping technology for sustainable management of landfill sites.

All the chapters in the book are written by authors in a more comprehensive way and are meticulously prepared with fabulous figures, graphs, and tables to make the information easier to understand, and are supported by an extensive list of references and URLs for readers interested in learning further details about the subject matter. The main aim of the book is to focus on the use of phytoemediation technologies in cleanup the polluted environment and make the depleted or degraded fields/water bodies fertile and rejuvenated in order to maintain sustainability.

This book generally brings a contemporary outlook on the modern aspects of environmental decontamination technologies. We are hopeful that this book will be useful to researchers, students, academics, scientists, engineers, government officers, process managers, and practicing professionals, who are interested and/or working in the area of phytoremediation or bioremediation of the environment and related subjects. As an excellent state-of-the-art reference material, the book will contain rich knowledge on the principles and provide them in-depth understanding and comprehensive information of current green technologies, their different environmental applications, recent advantages and disadvantages, critical analysis and modeling of the processes, and future perspective toward research directions and development.

Phytoremediation is still very much an evolving technology; there is a need for more research and development to identify and overcome the limitations and a real need to establish a critical dialogue among scientists, engineers, and environmental

Last but not the least, Dr. Vineet Kumar would like to acknowledge his family members with love and affection in particular his parents (Mr. Niranjan Singh and Mrs. Pawan Devi), younger brother Rohit Chowdhary, and sister Ms. Khushboo.

Finally, I would like to apologize in advance for any errors that may occur in the text, and express my heartfelt embarrassment

We should be pleased to receive any comments on the content and style of *Phytoremediation Technology for the Removal of Heavy Metals and other Contaminants from Soil and Water* from students, professionals, environmentalist, and policy makers, all of which will be given serious consideration for inclusion in any further editions.

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