TRACE ELEMENTS
in the
ENVIRONMENT
Biogeochemistry, Biotechnology, and Bioremediation

Edited by
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Preface

Plant and soil form an integrated system. Technogenic contamination of soils with potentially toxic trace elements (PTE) are reflected in the functioning of plants and soil biota. Soil contamination by PTE has several implications for human health, as well as for the biosphere. Trace element "biogeogenic cycling" in the environment is an integral function of the ecosystem (aquatic, terrestrial, and atmospheric). Therefore, the aim of this collective work is to deal with the trace elements in the holistic environment, considering advancements in the state-of the-art analytical techniques, molecular biology, and contemporary biotechnology that enhance our knowledge of the behavior of trace elements in the biogeosphere and organismal levels, i.e., at the cellular and molecular levels. Various chapters of this book provide the background with appropriate examples to understanding the trace elements in the biogeosphere on bioavailability, biogeochemistry, biotechnology, bioremediation, and risk assessment.

Trace element behavior and fate depend on their chemistry in soil inorganic and organic phases; their bioavailability depends on a variety of factors concerning the ambient environment, soil, and/or sludge. Trace element enrichment in soil, water, and air may result from natural sources and/or anthropogenic activities such as smelting, mining, agricultural, and waste disposal technologies. For example, coal fly ash application to soils and its effect on boron and other trace element availability to plants; bioavailability of trace elements in relation to root modification in the rhizosphere; and availability through sewage sludge are some important issues discussed in this book. To better explore adaptive physiology of plants exposed to elevated doses of trace elements, knowledge of the behavior of the essential and nonessential elements, aspects related to biogeogenic cycling, accumulation, and exclusion mechanisms by target organisms is a must.

It is generally accepted that the rhizosphere plays an important role in the bioavailability of trace elements. The mechanisms involved in chemical modifications in the rhizosphere, as well as on uptake of trace elements, differ among plant species and soil conditions. The ability to manipulate siderophore production in the rhizosphere to improve plant trace element nutrition will remain a significant challenge for the future to investigate. The importance of mycorrhizal symbiosis for the establishment of a sustainable plant cover on soils with PTE is therefore obvious. Microbial genomics is an integrated tool for developing biosensors for toxic trace elements in the environment, arbuscular mycorrhizal fungi, and the role of arbuscular mycorrhiza and associated microorganisms are increasingly considered in phytoremediation of heavy metal polluted sites. Plant metallothionein genes; genetic engineering for the cleanup of toxic trace elements; and "metallomics," a multidisciplinary metal-assisted functional biogeochemistry — its scope and limitations as the crux of biotechnology and its role in dealing with the PTE in the environment are some of the themes reviewed in different chapters.

Self-cleaning of soils does not take place or, rather, takes place extremely slowly. The toxic metals in top soil, thus get accumulated in plants. Plants can remediate metal pollutants mainly in two ways: (1) phytostabilization, in which plants convert pollutants to a less bioavailable form and/or prevent pollutants' dispersal by wind erosion or leaching; and (2) phytoextraction, in which plants accumulate pollutants in their harvestable tissues, thus decreasing the concentration of the pollutants in the soil. Plants that accumulate and/or exclude toxic trace elements; tolerant plants and biodiversity prospecting to promote phytotechnologies for environmental cleanup; phytomanagement of abandoned mines and biogeochemical prospecting; phytoremediation of contaminated soil with cereal crops; and the role of fertilizers and bacteria in biavailability of metals are reviewed.

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Phytotechnologies using trees; stabilization, remediation, and integrated management of metal-contaminated ecosystems by grasses; applications of weeds more adapted to unfavorable soil conditions such as low moisture; presence of toxic metals easily acclimatized to local situation that would act as sentinels for monitoring trace element pollution; detoxification and defense mechanisms in metal-exposed plants; biogeochemical cycling of trace elements by aquatic and wetland plants and its relevance to phytoremediation; plants that hyperaccumulate PTE and biodiversity prospecting for phytoremediation; phytomanagement of radioactively contaminated sites; phytoextraction of Cd and Zn by willows — advantages and limitations; adaptive physiology; and rhizosphere biotechnology are covered in the sections on biotechnology and bioremediation.

Bacterial biosorption of trace elements; processes and applications of electroremediation of heavy metal-contaminated soils; and application of novel nanoporous sorbents for the removal of heavy metals, metalloids, and radionuclides are some of the emerging areas of research that have been included in this book.

The increasing level of trace elements in the tissues of plants and animals due to bioaccumulation and trophic transfer has adverse effects on ecological and human health. Therefore, the risk assessment, pathways, and trace element toxicity of sewage sludge-amended soils and usage in agroforestry; trophic transfer of trace metals and associated human health issues; and PTE accumulation, movement, and remediation in soils receiving animal manure are also covered.

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Editors

M.N.V. Prasad is a professor of environmental biology at the University of Hyderabad, India. The author, coauthor, editor, or coeditor for 6 books; Dr. Prasad has published more than 140 research papers in the broad area of environmental botany and heavy metal stress in plants. From 2000 to 2004, Dr. Prasad served as head of the Department of Plant Sciences, School of Life Sciences; during 2001-2003, he functioned as a coordinator for the M.Sc. Biotechnology programme of the School of Life Sciences (sponsored by the Department of Biotechnology, Government of India); also as coordinator since 1995, and post graduate diploma in Environmental Education and Management, Centre for Distance Education. He is an elected fellow of the Linnean Society of London, England, and the National Institute of Ecology, New Delhi, India, and a member of the International Allelopathy Society; the National Institute of Ecology; the Bioenergy Society of India; and the Indian Network for Soil Contamination Research. He received B.Sc. (1973) and M.Sc. (1975) degrees from Andhra University, India, and a Ph.D. degree (1979) in botany from the University of Lucknow, India.

Academic distinctions:

- 2003: Academy of Finland, visiting scientist, Department of Biology/Botany, University of Oulu, Finland
- 2000: Swedish International Development Cooperation Agency (SIDA) visiting fellowship, Institute of Botany Stockholm University
- 1998: Elected fellow, Linnean Society of London
- 1998: Fundacao para a Ciencia e a Technologia (FCT), Portugal visiting professorship at the Departamento de Botanica, Universidade de Coimbra, Coimbra, Portugal
- 1996: Indo–Polish Cultural Exchange Program, visiting fellowship, Institution of Molecular Biology, Jagiellonian University, Krakow, Poland
- 1996: Elected fellow, National Institute of Ecology, New Delhi
- 1994: Natural and Engineering Research Council (NSERC), Canada, Foreign Researcher Award

Professor Ravi Naidu is foundation professor and the inaugural director of the Australian Research Centre for Environmental Risk Assessment and Remediation. He has researched environmental contaminants, bioavailability, and remediation for over 20 years. Naidu has co-authored over 300 technical publications and co-edited 8 books in the field of soil and environmental sciences including remediation of contaminated sites. Since 1994, he has worked with scientists from the Asia region on environmental contamination, including the recent arsenic poisoning of people in Bangladesh, India, and China. In recognition of his contribution to environmental research, he was awarded the Gold Medal in environmental science in 1998 by Tamil Nadu Agricultural University, elected to the Fellow of Soil Science Society of America in 2000, and also elected Fellow of the Soil Society of New Zealand in 2004. Naidu is the chair of the Standards Australia–New Zealand Technical Committee on Sampling and Analyses of Contaminated Soils; chair of the International Committee on Bioavailability and Risk Assessment; chair of the International Union of Soil Sciences' Commission for Soil Degradation Control, Remediation, and Reclamation; president of the International Society on Trace Element Biogeochemistry; and sitting member of the Victorian EPA Contaminated Sites Auditor Panel.

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Kenneth S. Sajwan is a professor and director of the environmental science program in the department of natural sciences and mathematics at Georgia's Savannah State University. Dr. Sajwan earned a B.S. degree in agriculture and animal husbandry, an M.S. degree in agronomy, and Ph.D. degrees in science from the Indian Institute of Technology, Kharagpur and in soil chemistry and plant nutrition from Colorado State University. Dr. Sajwan joined the faculty of Savannah State University in 1992 as an associate professor and was promoted to full professor in 1996. Prior to joining the faculty of Savannah State University, he was an assistant professor at the University of Georgia's Savannah River Ecology Laboratory in Aiken, South Carolina. His previous work experience includes a World Bank consultancy to Colombia, South America, and research associateships at the universities of Wisconsin and Kentucky. Dr. Sajwan holds adjunct professorship appointments at Alabama Agricultural & Mechanical University and the University of South Carolina at Aiken, and a faculty affiliate appointment at the Institute of Ecology at the University of Georgia.

Dr. Sajwan has been recognized as a devoted and talented teacher and his accomplishments are reflected in his ability to motivate, challenge, and inspire his students to excel in the classroom and beyond. Dr. Sajwan has received several awards for his outstanding contribution to teaching and research. He is a recipient of the Richard Nicholson National Award for Excellence in Science Teaching (2005); the National Science Teacher's Association Distinguished Science Teacher Award (2004); the Ernest L. Boyer International Award for Teaching, Learning, and Technology (2003); the Board of Regents' University System of Georgia Teaching Excellence Award (2002); and the White House Millennium Award for Teaching and Research Excellence (2001). In addition, he is the recipient of the Board of Regents' University System of Georgia Distinguished Professor of Teaching and Learning Award for the 1998-1999 academic year at Savannah State University and is the recipient of the 1999 International Award for Innovative Excellence in Teaching, Learning, and Technology.

Dr. Sajwan has edited four books, *Coal Combustion Products and Environmental Issues, Chemistry of Trace Elements in Fly Ash, Biogeochemistry of Trace Elements in Coal and Coal Combustion Byproducts,* and *Trace Elements in Coal and Coal Combustion Residues*. In addition, he has published two laboratory manuals and over 100 articles in peer reviewed journals, serials, conference proceedings, and symposia. Dr. Sajwan's primary research areas of interest include biogeochemistry of trace elements, environmental chemistry, ecotoxicology, and chemical equilibria in soils.

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