Environmental Pollution 20

Mohammad Saghir Khan
Almas Zaidi
Reeta Goel
Javed Musarrat
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Biomanagement of Metal-Contaminated Soils

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Editors
Mohammad Saghir Khan
Department of Agricultural Microbiology
Faculty of Agricultural Sciences
Aligarh Muslim University
Aligarh, Uttar Pradesh, India
khanms17@rediffmail.com

Almas Zaidi
Department of Agricultural Microbiology
Faculty of Agricultural Sciences
Aligarh Muslim University
Aligarh, Uttar Pradesh, India
alma29@rediffmail.com

Reeta Goel
Department of Microbiology
Govind Ballabh Pant University
of Agriculture & Technology
Pantnagar, Uttarakhand, India
rg55@rediffmail.com

Javed Musarrat
Department of Zoology
King Saud University
Riyadh, Saudi Arabia
musarratj1@yahoo.com

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Dedicated in memory of Dr. Meena Zaidi

Preface

The soil environment is a major sink for a multitude of chemicals and heavy metals, which inevitably leads to environmental contamination problems. Indeed, a plethora of different types of heavy metals are used and emanated through various human activities including agricultural, urban or industrial. Millions of tonnes of trace elements are produced every year from mines in demand for newer materials. On being discharged into soil, the heavy metals get accumulated and may disturb the soil ecosystem including microbial compositions and biomass, microbial community structure and their biological activities. Moreover, the excessive concentration of metals in soil can also elicit a wide range of visible and physiological symptoms in plants leading to losses in crop productivity. As a result, heavy metal pollution poses a major threat to human health and environment. Unlike many other pollutants, heavy metals cannot be biologically degraded to more or less toxic products and hence persist in the environment. Toxic metal pollution is, therefore, an enigma for scientists how to tackle this issue that has threatened the environment. Management of metal contaminated environment, especially soils, therefore, becomes important, as these soils usually cover large areas that are rendered unsuitable for sustainable agriculture. The remediation of such soils, in turn, could lead to food security across the globe. To address this environmental threat, conventional remediation approaches have been applied, which, however, do not provide acceptable solutions due either to the technological constraints or to the production of large quantities of toxic products. Therefore, the establishment of efficient, inexpensive and safe and environment friendly methodology and techniques for identifying and limiting or preventing metal pollution, causing threats to the agricultural production systems and human health, is earnestly required. In this regard, the management of contaminated soils using microbes or other biological systems to degrade/transform environmental pollutants under controlled conditions to an innocuous state or to levels below concentration limits established by regulatory authorities is required. Bioremediation in this context, applied in the rehabilitation of heavy-metal-contaminated soil, has been found interesting because it provides an ecologically sound and economically viable method for restoration and remediation of derelict soils. In this regard, biological agents including both heterogeneously distributed microbial

communities and plants of various origins could play a pivotal role in the management of metal polluted soils. Besides their role in protecting the plants from metal toxicity, the microbes are also well known for their biological activities enhancing the soil fertility and promoting plant growth by providing essential nutrients and growth regulators. Use of such microbes possessing multiple properties of metal resistance/reduction and ability to promote plant growth through different mechanisms in metal contaminated soils make them one of the most suitable choices for bioremediation studies. Advances in understanding the role of microorganisms in such processes, together with the ability to fine-tune their activities using the tools of molecular biology, would, therefore, lead to the development of novel or improved metal bioremediation processes. Both plants and microbial strategies for managing contaminated soils could however be different for different agro-ecosystems. The role of non-living microbial communities in controlling the mobility and bioavailability of metal ions is well known. The use of biomass to extract heavy metals is, therefore, an area of current research.

Biomanagement of Metal Contaminated Soils integrates the frontiers of knowledge on both fundamentals and practical aspects of remediation of metal polluted soils. The book written by experts in the field provide unique, updated and comprehensive information on strategies as to how metal contaminated soils could be remediated, exploited and practiced for increasing the productivity of crops in varied production systems. This book covers a broad area including from sources of heavy-metal pollution to metal toxicity to plants to remediation strategies. Therefore, various bioremediation approaches adopted to remediate contaminated sites and major concerns associated with phytoremediation as a sustainable alternative are reviewed and discussed. Legumes have traditionally been used in soil regeneration, owing to their capacity to increase soil nitrogen due to biological nitrogen fixation. Recently, legumes have also attracted attention for their role in remediation of metal contaminated soils. Given the importance of *Rhizobium*–legume interactions in maintaining soil fertility, attention is paid to explain the role of this symbiosis and approaches employed to genetically engineer legume–*Rhizobium* pairing in order to improve bioremediation. Information relative to the mechanism of metal tolerance and the importance of arbuscular mycorrhizal fungi in the detoxification of metal polluted soils are explored. Research advances in bioremediation of soils and groundwater using plant-based systems, the ecological and evolutionary implications of endophytic bacterial flora of the nickel hyperaccumulator plant *Alyssum bertolonii*, use of biosurfactants of various origins in the removal of heavy metal ions from soils, metal signaling in plants and new possibilities for crop management under cadmium contaminated soils are also broadly covered in this book. Microbial management of highly toxic metals like cadmium and arsenic present in soil, various phytotechnologies employed in remediation of heavy metal contaminated soils and a selective overview of past achievements and current perspective of chromium remediation technologies using promising microorganisms and plants are highlighted separately. Furthermore, the possible genotoxic effects of heavy metals on plants and other organisms and the development and applications of new biomonitoring methodologies for assessment of soil/plant genotoxicity have been sufficiently discussed

in this chapter. The application of biomonitoring protocols in conjunction with the genotoxic assessment of contaminated soil will be advantageous in effective management of heavy metal polluted soils. The mobility and availability of toxic metals after soil washing with chelating agents and decontamination of radioactive-contaminated soils are addressed. Removal of heavy metals by microalgal biomass, the intrinsic and extrinsic factors affecting uptake of metals by microalgae and how these microalgae can be helpful in removing metals from polluted environments are reviewed and highlighted. The transgenic approaches centrally important in metal uptake, compartmentalization and/or translocation to organs, improved production of intracellular metal-detoxifying chelators and (over) production of novel enzymes are discussed. Efforts are also directed to obtain better molecular insights into the metallomics and physiology of hyperaccumulating plants, which are likely to provide candidate genes suitable for phytoremediation. The book further describes how the bioremediation potential of heavy-metal resistant novel actinobacteria, like *Amycolatopsis tucumanensis*, and maize plants could be exploited in detoxifying heavy metals in the polluted soil microcosm. The importance of free-living fungi in metal sorption and plant growth promotion in different agro-ecosystems are dealt separately.

This book collectively involves different bioremediation strategies used in metal removal from contaminated environments and crop production in metal stressed agro-ecosystems. This book contains a wealth of information for the person who needs to remove pollutants from soil or water. It describes the degree of success that can be achieved in removing a variety of metals. The knowledge and methodologies described in this book offer invaluable research tools, which may serve as important and updated source material. This edition provides an authoritative overview for individuals interested in bioremediation technologies. This book will, therefore, be of great interest to research scientists, postgraduate students, bioscience professionals, decision makers and farmers who intend to use natural resources for the abatement of metal contamination. It would also serve as a valuable resource for agronomists, environmentalists, soil microbiologists, soil scientists, biologists and biotechnologists involved in the restoration of contaminated lands. Thus, this book will cover the most interesting and applied aspects of phytoremediation and the role of microbial communities in crop productivity in soils contaminated with heavy metals, written by specialists who provide the scientific community with a critical evaluation of the management of metal contaminated soils.

We are highly thankful to our well qualified and proficient colleagues from across the world for providing the state-of-the-art scientific information to make this book a reality. All chapters are well exemplified with appropriate tables and figures, and enriched with extensive and the latest literature. The help and support provided by research scholars in designing and preparing the illustrations presented in this book are greatly acknowledged. We are indeed very grateful to our family members for their untiring and sustained support during the processing of this book. And most of all, we are extremely thankful to our adorable children, Zainab and Butool, for their patient and helpful attitude all through the project. We appreciate the great efforts of book publishing team at Springer-Verlag, the Netherlands, in responding to all our

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Mohammad Saghir Khan
Almas Zaidi
Reeta Goel
Javed Musarrat

Contributors

Carlos M. Abate Planta Piloto de Procesos Industriales y Microbiológicos (PROIMI-CONICET), Tucumán, Argentina

Universidad Nacional de Tucumán, Avenida Belgrano y Pasaje Caseros, 4000 Tucumán, Argentina

Mamdoh F. Abdel-Sabour Nuclear Research Center, Atomic Energy Authority, P.O. 13759, Cairo, Egypt, freemfs73@yahoo.com

Reda Abd El-Aziz Ibrahim Abou-Shanab Environmental Biotechnology Department, Genetic Engineering and Biotechnology Research Institute (GEBRI), City of Scientific Research and Technological Applications, New Borg El Arab City, Alexandria 21934, Egypt, redaabushanab@yahoo.com

Yeşim Sağ Açıkel Department of Chemical Engineering, Hacettepe University, 06800 Beytepe, Ankara, Turkey, yesims@hacettepe.edu.tr

Ees Ahmad Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh 202002, Uttar Pradesh, India

Virginia H. Albarracín Planta Piloto de Procesos Industriales y Microbiológicos (PROIMI-CONICET), Tucumán, Argentina

Universidad Nacional de Tucumán, Avenida Belgrano y Pasaje Caseros, 4000 Tucumán, Argentina

Sas-Nowosielska Aleksandra Institute for Ecology of Industrial Areas, Kossutha 6 Street, Katowice, Poland, sas@ietu.katowice.pl

Abdulaziz A. Al-Khedhairy Department of Zoology, College of Science, King Saud University, Riyadh 11451, Saudi Arabia

María J. Amoroso Planta Piloto de Procesos Industriales y Microbiológicos (PROIMI-CONICET), Tucumán, Argentina

Universidad del Norte Santo Tomás de Aquino, Tucumán, Argentina

Universidad Nacional de Tucumán, Avenida Belgrano y Pasaje Caseros, 4000 Tucumán, Argentina

K.K.I.U. Aruna Kumara Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka, kkiuaruna@crop.ruh.ac.lk

Marco Bazzicalupo Department of Evolutionary Biology, University of Firenze, via Romana 17, I-50125 Florence, Italy

Claudia S. Benimeli Planta Piloto de Procesos Industriales y Microbiológicos (PROIMI-CONICET), Tucumán, Argentina

Universidad del Norte Santo Tomás de Aquino, Tucumán, Argentina, cbenimeli@yahoo.com.ar

Paula M.L. Castro CBQF/Escola Superior de Biotecnologia, Universidade Católica Portuguesa, Rua Dr. António Bernardino de Almeida, P-4200-072, Porto, Portugal

Miguel Ángel Caviedes Departamento de Microbiología y Parasitología, Facultad de Farmacia, Universidad de Sevilla, Profesor García González, 2, Sevilla 41012, Spain

Nilanjana Das School of Biosciences and Technology, VIT University, Vellore 632014, Tamil Nadu, India, nilanjana00@lycos.com

Andrew Agbontalor Erakhrumen Department of Forest Resources Management, University of Ibadan, Ibadan, Nigeria, erakhrumen@yahoo.com

Etelvina Figueira Centre for Cell Biology, Biology Department, University of Aveiro, Universidade de Aveiro, Aveiro, Portugal, efigueira@ua.pt

Reeta Goel Department of Microbiology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar 263145, Uttarakhand, India, rg55@rediffmail.com

Abhishek Gupta Department of Microbiology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar 263145, Uttarakhand, India

Marya Hashmatt Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand

Arshad Javaid Institute of Agricultural Sciences, University of the Punjab, Quai-e-Azam Campus, Lahore, Pakistan, arshadjpk@yahoo.com

Anthea Johnson Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand

Anil Kapri Department of Microbiology, College of Basic Sciences & Humanities, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar 263145, Uttarakhand, India

Mohammad Saghir Khan Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh 202002, Uttar Pradesh, India

Pavel Kotrba Department of Biochemistry and Microbiology, Institute of Chemical Technology, Prague, Technická 5, Prague 166 28, Czech Republic, pavel.kotrba@vscht.cz

Alejandro Lafuente Departamento de Microbiología y Parasitología, Facultad de Farmacia, Universidad de Sevilla, Profesor García González, 2, Sevilla 41012, Spain

Domen Lestan Department of Agronomy, Biotechnical Faculty, Centre for Soil and Environmental Science, University of Ljubljana, Jamnikarjeva 101, Sl-1000 Ljubljana, Slovenia, Domen.Lestan@bf.uni-lj.si

Ana Lima Centre for Cell Biology, Biology Department, University of Aveiro, Universidade de Aveiro, Aveiro, Portugal

Tomas Macek Department of Biochemistry and Microbiology, Institute of Chemical Technology, Prague, Technická 5, Prague 166 28, Czech Republic

IOCB & ICT Joint laboratory, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic, Flemingovo sq. 2, 166 10 Prague, Czech Republic

Martina Mackova Department of Biochemistry and Microbiology, Institute of Chemical Technology, Prague, Technická 5, Prague 166 28, Czech Republic

F. Xavier Malcata ISMAI – Instituto Superior da Maia, Avenida Carlos Oliveira Campos, Castelo da Maia, Avioso S. Pedro P-4475-690, Portugal

CIMAR/CIIMAR – Centro Interdisciplinar de Investigação Marinha e Ambiental, Rua dos Bragas no 289, P-4050-123, Porto, Portugal, fmalcata@ismai.pt

Lazar Mathew School of Biosciences and Technology, VIT University, Vellore 632014, Tamil Nadu, India, lazarmathew@rediffmail.com

Alessio Mengoni Department of Evolutionary Biology, University of Firenze, via Romana 17, I-50125 Florence, Italy, alessio.mengoni@unifi.it

Ali Seid Mohammed Department of Biology, Bahir Dar University, Bahir Dar, Ethiopia

Cristina M. Monteiro CBQF/Escola Superior de Biotecnologia, Universidade Católica Portuguesa, Rua Dr. António Bernardino de Almeida, P-4200-072 Porto, Portugal

Javed Musarrat Al-Jeraisy Chair for DNA Research, Department of Zoology, College of Science, King Saud University, Riyadh 11451, Saudi Arabia

Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh 202002, Uttar Pradesh, India, musarratj1@yahoo.com

Mohammad Oves Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh 202002, Uttar Pradesh, India

Eloísa Pajuelo Departamento de Microbiología y Parasitología, Facultad de Farmacia, Universidad de Sevilla, Profesor García González, 2, Sevilla 41012, Spain, epajuelo@us.es

Francesco Pini Department of Evolutionary Biology, University of Firenze, via Romana 17, I-50125 Florence, Italy

Marta A. Polti Planta Piloto de Procesos Industriales y Microbiológicos (PROIMI-CONICET), Tucumán, Argentina

Universidad Nacional de Tucumán, Avenida Belgrano y Pasaje Caseros, 4000 Tucumán, Argentina

Jai Prakash Narain Rai Ecotechnology Laboratory, Department of Environmental Sciences, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar 263145, Uttarakhand, India, jamesraionline@gmail.com

Ignacio David Rodríguez-Llorente Departamento de Microbiología y Parasitología, Facultad de Farmacia, Universidad de Sevilla, Profesor García González, 2, Sevilla 41012, Spain

Bhoomika Saluja Department of Microbiology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar 263145, Uttarakhand, India

Shweta Saraswat Ecotechnology Laboratory, Department of Environmental Sciences, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar 263145, Uttarakhand, India

Maqsood Ahmad Siddiqui Department of Zoology, College of Science, King Saud University, Riyadh 11451, Saudi Arabia

Naresh Singhal Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand, n.singhal@auckland.ac.nz

Metka Udovic Department of Agronomy, Biotechnical Faculty, Centre for Soil and Environmental Science, University of Ljubljana, Jamnikarjeva 101, Sl-1000 Ljubljana, Slovenia

Almas Zaidi Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh 202002, Uttar Pradesh, India, alma29@rediffmail.com

Contents