

Preface

The volume *Soil Heavy Metals* duly edited by Irena Sherameti and Ajit Varma, published in 2010, was a success story. This was nicely celebrated in typical German style in the house of Professor Dr. Ralf Oelmüller, Institute of General Botany and Plant Physiology, University of Jena. Over a glass of wine I proposed to Irena to edit a volume on detoxification of heavy metals in soil. After a short discussion, we agreed to work together on this volume.

This volume summarises the ongoing scientific activities in the field of detoxification of heavy metals in soils, plants and microorganisms. The chapters are arranged in such a way that first we get an introduction about the art of detoxification of heavy metals and the heavy metal plants. The second group of chapters deals with the phytoremediation in general and phytoremediation of special ions. The next section describes several aspects of plant responses to heavy metals and the responses of special organisms/groups to heavy metals. At last different methodologies for detoxification of heavy metals in soils and plants are discussed.

Soil, one of the most important natural resources, is becoming degraded due to anthropogenic activities such as mining, agricultural activities, sewage sludge, fossil fuel combustion, metallurgical and chemical industries and electronics. As described in Chap. 1 written by Jyoti Agrawal, Irena Sherameti and Ajit Varma each source of contamination has its own damaging effects to plants, animals and humans, but the pollution from heavy metals is of serious concern and a big potential threat to the environment and human health. This chapter gives a general overview of some of the sources of heavy metal contaminants in soil, soil–plant relationships regarding heavy metals and heavy metal tolerance mechanism(s) in plants. In Chap. 2, Hermann Bothe directs us to the heavy metal soils and heavy metal plants (Metallophytes) of Central Europe showing that the adaptations of these metallophytes to the adverse conditions of heavy metal soils differ from one plant species to the next. Further we get introduced to some strategies employed by the metallophytes to cope with high concentrations of heavy metals at the whole plant level and gene expressions upon heavy metal stress in plants. Functional significance of metal ligands in hyperaccumulating plants is analysed by Marjana Regvar and Katarina Vogel-Mikuš in Chap. 3. This chapter focuses on ligands (organic acids, histidine, metallothioneins, low-molecular-weight thiols, etc.) that

have roles in the immobilisation, transport and/or storage of accumulated metals in plant organs, tissues and cells.

Chapter 4, written by Shao Hongbo, Chu Liye, Xu Gang, Yan Kun, Zhang Lihua and Sun Junna is a progress in phytoremediating heavy metal-contaminated soils, that introduces the latest development in the field of phytoremediation as one of the main methods for removing hazardous heavy metal from contaminated soils. Using plants and microbes is preferred because of its cost-effectiveness, environmental friendliness and fewer side effects. So far all plant species recognised as useful for phytoremediation belong to angiosperm phylogeny group that is classified into 63 orders and 413 families. The authors of Chap. 5, Stanislaw W. Gawronski, Maria Greger and Helena Gawronska, show that among all only species from 8 orders and 18 families are identified as well-tolerating pollutants and useful for phytoremediation having advantages and limitations in their usefulness as phytoremediants. The authors of Chap. 6, Dora M. Carmona, Raúl Zornoza, Ángel Faz, Silvia Martínez-Martínez and Jose A. Acosta, describe the environmental impacts of mining activities in Southeast Spain. A field trial was established and experimental plots were designed, using marble wastes, pig manure and sewage sludge as amendments to reclaim the mine soils. The authors monitored the dynamics of heavy metals, soil properties and vegetation along 5 years after reclamation.

Zinc is an essential micronutrient with various cellular functions, but excess Zn in plants is toxic and causes chlorosis and growth disorders. To ensure Zn homeostasis the transport machinery is responsible for uptake and export of Zn that includes members of the metal tolerance protein (MTP), ZRT1/IRT1-like protein (ZIP) and heavy metal ATPase (HMA) families. Their roles in the acquisition, distribution, homeostasis and signalling of Zn are described in Chap. 7 by Miki Kawachi, Yoshihiro Kobae, Rie Tomioka and Masayoshi Maeshima. Copper, trace amounts of which are required to sustain plant life (so-called essential elements), in high concentrations causes plant death. Discussing current methods and approaches used for quantification of apoplastic and symplastic copper pools has a significant place in Chap. 8 written by Valentina P. Kholodova, Elena M. Ivanova and Vladimir V. Kuznetsov. The role of arbuscular mycorrhizal fungi producing an extraradical mycelium in metal ion immobilisation is also considered in this chapter. Arsenic is a ubiquitously distributed and an extremely toxic metalloid affecting the health of many people in more than 23 countries. On land arsenic is relatively immovable through binding of soil particle; however, most arsenic can readily dissolve in water and in soluble form may leach into surface and ground waters. Chapter 9, written by Dharmendra K. Gupta, Sudhakar Srivastava, H.G. Huang, Maria C. Romero-Puertas and Luisamaria M. Sandalio, focuses on arsenic contamination, accumulation, tolerance and detoxification mechanisms in plants. Chapter 10 of Kavita Shah presents an overview of the research information on sources and effects of cadmium metal on plants in particular. The knowledge of metal hyperaccumulation physiology and the molecular and genetic basis of Cd tolerance and detoxification in plants forms a major part of this chapter. The prospects and the future applications of hyperaccumulators in phytoremediation of Cd metal are also discussed. Dieter Rehder deals in Chap. 11 with the transport, accumulation and physiological effects of vanadium. Industrial

and volcanic exhalation of vanadium oxides can cause locally a vanadium overload in soil surface areas. Soil bacteria such as *Geobacter metallireducens* and *Shewanella oneidensis* reduce vanadate to insoluble and comparatively harmless vanadium (IV) hydroxide. The remobilization of vanadium (IV) can occur by strong chelators excreted by other bacteria such as *Azotobacter*. Tapan Jyoti Purakayastha deals in Chap. 12 with the remediation of arsenic-contaminated soil. The use of engineered microbes as selective biosorbents is an attractive green cure technology for the low-cost and efficient removal of arsenic from soil. Fate of cadmium in calcareous soils under salinity conditions is discussed in Chap. 13 by Ali Khanmirzaei. The chemistry of calcareous and saline soils, the application of fractionation and speciation analysis for investigating the mobility and environmental ecotoxicity of this element in calcareous soils and some examples on Cd detoxification in carbonate rich soils are outlined in this chapter.

The current status of organellar proteomics as a high-throughput approach for obtaining a better understanding of heavy metal accumulation and detoxification in plants is analysed in detail in Chap. 14 by Nagib Ahsan, Byung-Hyun Lee and Setsuko Komatsu. To identify the proteins involved in organ-specific heavy metal response pathways is a fundamental step in the process of understanding the molecular mechanisms leading to accumulation and detoxification of toxic heavy metals in plant cells. Chapter 15, written by Laura A. Hardulak, Mary L. Preuss and Joseph M. Jez, provides an overview of sulfur metabolism in plants, how it plays a critical role in heavy metal tolerance and how efforts to engineer these pathways may improve bioremediation efforts. Metabolically, sulfur metabolism is a core pathway for the synthesis of molecules required for heavy metal tolerance in plants. Etsuro Yoshimura in Chap. 16 discusses Cd(II)-activated synthesis of phytochelatins. Phytochelatins are implicated in heavy metal tolerance in higher plants, algae, and a fungal species. Synthesis of the peptides is mediated by an enzyme designated as PC synthase (PCS) from the tripeptide glutathione (GSH).

Elsholtzia splendens has been proven to be a Cu-tolerant plant and can remarkably influence the behaviour of Cu in root–soil interface by root exudates, rhizosphere bacteria and arbuscular mycorrhizal fungi. *E. splendens* has evolved a series of defensive strategies against Cu stress such as Cu compartmentation and speciation transformation, which are discussed in detail in Chap. 17 by Yingxu Chen, Mingge Yu and Dechao Duan.

The role of aquatic macrophytes in biogeochemical cycling of heavy metals, the relevance to soil-sediment continuum detoxification and ecosystem health is presented in Chap. 18 by Przemysław Malec, Beata Mysliwa-Kurdziel, M.N.V. Prasad, Andrzej Waloszek and Kazimierz Strzałka. The wetland sediments and soils of flood plains play an important role in the biogeochemical cycling of heavy metals. The role of both photosynthetic activity and competitive/synergistic effects of the elements available to aquatic macrophytes in the circulation and deposition of metals are discussed in terms of the functioning of wetland ecosystems and phytoremediation. To stimulate phytoremediation, fast growing plants with high metal uptake and high biomass are required. Alternatively, soil microorganisms such as fungi and bacteria are used in heavy metal detoxification. The recent advances in effect and significance of fungi

and rhizobacteria in heavy metal detoxification is reviewed in Chap. 19 by Sema Camci Cetin, Ayten Karaca, Ridvan Kizilkaya and Oguz Can Turgay. The same group of authors contributed Chap. 21 in which the detoxification of heavy metals using earthworms is discussed. Earthworms can effect either available or total metal concentrations in soil because of their capability for accumulating heavy metals in their tissues and hence reduce their involvement in soil food chain. D.V. Yadav, Radha Jain and R.K. Rai, authors of Chap. 20, deal with the phytoremediation/detoxification of heavy metals from soils through sugar crops, especially sugar cane, sugar beet and sweet sorghum. The potential of these sugar crops is presented. At Chap. 22, Roberto Terzano and Matteo Spagnuolo discuss the stabilisation of heavy metals by promoting zeolite synthesis in soil which can be easily done at low temperatures by adding Si- and Al-containing materials in alkaline conditions. This methodology is a promising one and in combination with other physico-chemical or biological remediation processes can effectively stabilise heavy metals in polluted sites.

This volume promises to be useful for researchers, students and other academicians involved in understanding the basics of detoxification of heavy metals in soils.

We are very thankful to all authors for contributing to this volume and we hope that their contribution will stimulate further high-quality teaching and research. It has been a pleasure to edit this book, primarily due to the stimulating cooperation of the contributors.

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