

Shree N. Singh
Rudra D. Tripathi
(Eds.)

Environmental Bioremediation Technologies

With 58 Figures, 1 in colour

 Springer

Contents

Foreword	V
Preface	VII
Contributors	XVII
1. Bioremediation of Organic and Metal Co-contaminated Environments: Effects of Metal Toxicity, Speciation, and Bioavailability on Biodegradation	1
Todd R. Sandrin and Douglas R. Hoffman	
1. Introduction	1
2. Metal Toxicity to Microorganisms	2
3. Metal Speciation and Bioavailability	4
4. Metal Inhibition of Biodegradation	19
5. Strategies to Enhance Biodegradation in Co-contaminated Environments	25
6. Conclusions and Future Directions	28
2. New Bioremediation Technologies to Remove Heavy Metals and Radionuclides using Fe(III)-, Sulfate- and Sulfur- Reducing Bacteria	35
Mireille Bruschi and Florence Goulhen	
1. Introduction	35
2. Microbial Reduction of Metals by Fe(III)-reducing Bacteria	36

3.	Microbial Interaction with Toxic Metals by Sulfate-reducing Bacteria	40
4.	Development of Biosensors	45
5.	Development of Bioreactors	46
6.	Conclusion	48
3.	Bioremediation of Soils Polluted with Hexavalent Chromium using Bacteria: A Challenge	57
	Carlo Viti and Luciana Giovannetti	
1.	Introduction	57
2.	Chromium Toxicity	59
3.	Chemical Transformations of Chromium in Soil: Mobility and Bio-availability	61
4.	Interaction Between Chromium and Bacteria	62
5.	Soil Bioremediation Strategies	67
6.	Conclusion	70
4.	Accumulation and Detoxification of Metals by Plants and Microbes	77
	Rutchadaporn Sriprang and Yoshikatsu Murooka	
1.	Introduction	77
2.	Phytoremediation	78
3.	Microbial Remediation of Metal-polluted Soils	88
4.	Heavy Metal Bioremediation using “Symbiotic Engineering”	91
5.	Conclusion	94
5.	Role of Phytochelatins in Phytoremediation of Heavy Metals	101
	Erwin Grill, Seema Mishra, Sudhakar Srivastava and R.D. Tripathi	
1.	Introduction	101

2.	Phytochelatin	103
3.	<i>Biosynthesis of Phytochelatins</i>	113
4.	Mechanism of Action of Phytochelatins	121
5.	Characterization and Regulation of Phytochelatin Synthase Gene	124
6.	Evolutionary Aspects of Phytochelatin Synthase	126
7.	Genetic Engineering for Enhancing Phytoremediation Potential	130
8.	Phytochelatin as a Biosensor	135
9.	Conclusion	135
6.	Metal Resistance in Plants with Particular Reference to Aluminium	147
	B.P. Shaw, V.K. Jha and B.B. Sahu	
1.	Introduction	147
2.	Phytotoxicity of Al and Agricultural Losses	152
3.	Aluminum Tolerant Crop Plants	153
4.	Conclusion	166
7.	Bioremediation of Metals: Microbial Processes and Techniques	173
	K. Ramasamy, Kamaludeen and Sara Parwin Banu	
1.	Introduction	173
2.	Metals and Microbes	173
3.	Microbial Processes Affecting Bioremediation of Metals	177
4.	Bioremediation Options for Metal Contaminated Sites	179
5.	Bioremediation of Chromium Contaminated Soils	181
6.	Future Thrust – Do We Really Need to Do More?	184
7.	Conclusion	185
8.	Phytoremediation of Metals and Radionuclides	189
	Susan Eapen, Shraddha Singh and S.F. D’Souza	
1.	Introduction	189

2.	Metals in Soils	190
3.	Radionuclides	192
4.	Phytoextraction	195
5.	Rhizofiltration	197
6.	Phytostabilization	198
7.	Phytovolatilization	199
8.	Design of Phytoremediation System	199
9.	Challenges for Phytoremediation	201
10.	Companies Developing Phytoremediation	203
11.	Regulatory Acceptance and Public Acceptance	204
12.	Conclusion	204
9.	Nanotechnology for Bioremediation of Heavy Metals	211
	P. Rajendran and P. Gunasekaran	
1.	Introduction	211
2.	Nanotechnology - A New Scientific Frontier	211
3.	Unique Properties of Nanoparticles	212
4.	Synthesis of Nanophase Materials	212
5.	Instrumentation for Nanotechnology	213
6.	Application and Current Status of Nanotechnology	214
7.	Metal Pollution and its Impact	214
8.	Current Strategies for Metal Remediation	215
9.	Bioremediation through Nanotechnology	215
10.	Case Studies	217
11.	Magnetotactic Bacteria	218
12.	Comparison of Current Strategies with Nanotechnology	218
13.	Future Prospects	219
14.	Conclusion	219
10.	Biotechnological Approaches to Improve Phytoremediation Efficiency for Environment Contaminants	223
	Rana P. Singh, Geeta Dhanias, Asha Sharma and Pawan K. Jaiwal	
1.	Introduction	223

2.	Phytoremediation: The Processes, Potentials and Limitations	226
3.	Commercial Viability of Phytoremediation Projects	233
4.	Rhizosphere Manipulations for Enhanced Bioavailability of the Toxic Substances	234
5.	Molecular Mechanisms of Uptake, Detoxification, Transport and Accumulation of Toxic Substances by Plants and Genetic Engineering for Enhanced Phytoremediation	238
6.	Conclusion	249
11.	Aquatic Plants for Phytotechnology	259
	M.N.V. Prasad	
1.	Introduction	259
2.	Phytotechnologies	259
3.	Conclusion	273
12.	Phytomonitoring of Air Pollutants for Environmental Quality Management	275
	Jeetendra K. Upadhyay and Nobuyuki Kobayashi	
1.	Introduction	275
2.	Plants as Bioindicators of Air Pollutants	279
3.	Phytoremediation and Urban Air Quality Management	283
4.	Phytoremediation and Indoor Air Quality (IAQ)	285
5.	Conclusion	287
13.	Phytoremediation of Air Pollutants: A Review	293
	S.N. Singh and Amitosh Verma	
1.	Introduction	293
2.	Phytotoxicity of Air Pollutants	295
3.	Absorption and Assimilation of Pollutants	297
4.	Phytofiltration of Particulate Matter	299
5.	Plant Tolerance to Ambient Pollutants	301
6.	Factors Controlling Plant Tolerance	302

7.	A Case Study	304
8.	Conclusion	309
14.	Phytoremediation: Role of Plants in Contaminated Site Management	315
	Rajiv K. Sinha, Sunil Herat and P.K. Tandon	
1.	Introduction	315
2.	Plant Species Involved in Phytoremediation	316
3.	Phytoremediation: The Biophysical and Biochemical Mechanisms	317
4.	The Vetiver Grass Technology (VGT)	320
5.	Role of VGT in Environmental Management	323
6.	Stabilization and Rehabilitation of Mining Overburdens	324
7.	Rehabilitation of Waste Landfills: Leachate Retention and Purification	326
8.	Removal of Nutrients and Heavy Metals and Prevention of Eutrophication in Streams and Lakes by VGT	327
9.	Wastewater / Storm water Treatment by VGT in Constructed Wetlands	328
10.	Conclusion	329
15.	The Role of Macrophytes in Nutrient Removal using Constructed Wetlands	331
	Margaret Greenway	
1.	Introduction	331
2.	Role of Macrophytes in Nutrient Removal	339
3.	Conclusion	348
16.	Nitrate Pollution and its Remediation	353
	U.N. Dwivedi, Seema Mishra, Poorinima Singh and R.D. Tripathi	

1.	Introduction	353
2.	Methods for Estimation of Nitrate Pollution	354
3.	Sources of Nitrate Pollution	356
4.	Landscape Physiology Affecting Nitrate Flux	361
5.	Role of Nitrifying and Denitrifying Microbes in Nitrate Pollution	362
6.	Nitrate Assimilation by Plants	364
7.	Biological Toxicity Due to Nitrate Pollution	368
8.	Problem Areas for Nitrate Pollution	369
9.	Management Options for Nitrate	372
10.	Conclusion	378
17.	Bioremediation of Petroleum Sludge using Bacterial Consortium with Biosurfactant	391
	K.S.M. Rahman, T.J. Rahman, I.M. Banat, R. Lord and G. Street	
1.	Introduction	391
2.	Methods	392
3.	Results and Discussion	395
4.	Conclusion	407
18.	Diversity, Biodegradation and Bioremediation of Polycyclic Aromatic Hydrocarbons	409
	Sumeet Labana, Manisha Kapur, Deepak K. Malik, Dhan Prakash and R.K. Jain	
1.	Introduction	409
2.	Natural Sources of PAHs in the Environment	410
3.	Anthropogenic Sources of PAHs in the Environment	411
4.	Biodegradation of PAHs	411
5.	Bioremediation Studies	421
6.	Diversity of PAHs Degrading Bacteria	424
7.	Diversity of PAHs Metabolic Genes	426
8.	Conclusion	431

19.	Environmental Applications of Fungal and Plant Systems: Decolourisation of Textile Wastewater and Related Dyestuffs	445
	Albino A. Dias, Ana Sampaio and Rui M. Bezerra	
1.	Introduction	445
2.	Environmental Fate of Textile Dyeing and Treatment Difficulties	446
3.	Overview of Biological Treatments	448
4.	Extracellular Oxidoreductases Useful in Pollution Abatement	449
5.	Textile Dyes Decolourisation by Fungi and their Enzymes	455
6.	New Tendencies in Textile Wastewater Treatments	455
7.	Conclusion	457
20.	Fungal-Based Remediation: Treatment of PCP contaminated Soil in New Zealand	465
	J.M. Thwaites, R.L. Farrell, S.D. Duncan, R.T. Lamar and R.B. White	
1.	Introduction	465
2.	Fungal-based Remediation	465
3.	Conclusion	475
21.	Biofilms in Porous Media: Mathematical Modeling and Numerical Simulation	481
	Benito M. Chen-Charpentier and Hristo V. Kojouharov	
1.	Introduction	481
2.	The Physical System	482
3.	The Mathematical Model	484
4.	Numerical Solution Techniques	488
5.	Simulations	497
6.	Conclusion	508
	Index	513