Contents

Preface xiii

1 Biotechnology and Various Environmental Concerns: An Introduction 1

۱v

Ravi K. Gangwar, Rajesh Bajpai, and Jaspal Singh

- 1.1 Introduction *1* References *7*
- 2 Plant Biotechnology: Its Importance, Contribution to Agriculture and Environment, and Its Future Prospects 9 Jeny Jose and Csaba Éva
- 2.1 Where do Environment and Biotechnology Meet? 9
- 2.1.1 Introduction 9
- 2.1.2 Chief Applications 10
- 2.2 Understanding Agricultural Biotechnology 11
- 2.2.1 Introduction 11
- 2.2.2 Main Components of Agricultural Biotechnology 12
- 2.2.3 Applications of Agricultural Biotechnology 12
- 2.3 Animal and Plant Biotechnology 13
- 2.3.1 Animal Biotechnology 13
- 2.3.2 Plant Biotechnology 14
- 2.3.2.1 Introduction 14
- 2.3.2.2 Traditional Breeding and Genetic Modification 14
- 2.3.2.3 Creating GMOs 15
- 2.3.2.4 Applications of GM Plants 22
- 2.3.2.5 GMO Controversy 23
- 2.3.2.6 Conclusion 24 References 25

vi Contents

3	Recent Advances in the Remediation of Petroleum		
	Hydrocarbon Contamination with Microbes 31		
	Parvaze A. Wani and Salami O. Rahman		
3.1	Introduction 31		
3.2	Sources of Petroleum Hydrocarbons 32		
3.3	Composition of Petroleum Pollutants 32		
3.4	Toxic Effects of Petroleum Hydrocarbons 33		
3.4.1	Hydrocarbon Toxicity to Microorganisms 33		
3.4.2	Petroleum Toxicity to Soil 34		
3.4.3	Petroleum Toxicity and Plant Growth 34		
3.4.4	Petroleum Toxicity and Human Health 34		
3.5	Hydrocarbon-Degrading Microorganisms 34		
3.6	Mechanism of Petroleum Hydrocarbon Degradation 36		
3.6.1	Enzymatic Degradation of Hydrocarbons 37		
3.6.2	Degradation of Hydrocarbons by Biosurfactants 37		
3.6.3	Petroleum Hydrocarbon Degradation by Immobilized Cells 37		
3.7	Types of Hydrocarbon Degradation 38		
3.7.1	Degradation of Hydrocarbons Under Aerobic Condition 38		
3.7.2	Hydrocarbon Degradation Under Anaerobic Condition 38		
3.8	Factors Affecting Hydrocarbon Degradation by Microorganisms 39		
3.8.1	Hydrocarbon Biodegradation and Temperature 39		
3.8.2	Hydrocarbon Biodegradation and pH 40		
3.8.3	Microbial Population, Microbial Efficiency, and Catabolism 40		
3.8.4	Hydrocarbon Biodegradation and Consortium of Microbes 40		
3.8.5	Hydrocarbon Content and Soil 40		
3.8.6	Salinity and Hydrocarbon Biodegradation 41		
3.8.7	Presence of Dissolved Oxygen in Soil 41		
3.8.8	Nutrient Status of Soil 41		
3.9	Conclusion 41		
	References 42		
4	Remediation of Heavy Metals: Tools and Techniques 47		
	Ankita Singh and Amit Kumar Tripathi		
4.1	Introduction 47		
4.2	Bioremediation 48		
4.3	Organism of Bioremediation 49		
4.3.1	Factors Affecting Microbial Bioremediation 50		
4.3.2	Biotic Factors 50		
4.3.3	Abiotic Factors 50		
4.4	Techniques of Bioremediation 51		
4.4.1	Solid-Phase Bioremediation 51		
4.4.2	Slurry-Phase Bioremediation 51		
4.5	Types of Bioremediation 52		
4.5.1	Biopile 52		
4.5.2	Windrows 52		

- 4.5.3 Land Farming 53
- 4.5.4 Bioreactor 53
- 4.5.4.1 Techniques for In Situ Bioremediation 54
- 4.5.4.2 Types of In Situ Bioremediation 54
- 4.5.5 Bioventing 54
- 4.5.6 Bioslurping 54
- 4.5.7 Biosparging 55
- 4.5.8 Phytoremediation 55
- 4.5.9 Permeable Reactive Barrier (PRB) 55
- 4.6 Prospects of Bioremediation 56
- 4.7 Advantages and Disadvantages of Bioremediation 57
- 4.7.1 Bioremediation's Drawbacks 59
- 4.8 Conclusion 59
 - Acknowledgment 60 References 60

5 Soil Biodiversity and Environmental Sustainability 69

- Tsedekech G. Weldmichael
- 5.1 Introduction 69
- 5.1.1 Biodiversity in the Soil 69
- 5.1.2 Environmental Sustainability 70
- 5.2 Importance of Soil Biodiversity in Supporting Terrestrial Life and Diversity 71
- 5.2.1 Nutrient Acquisition and Retention 71
- 5.2.2 Pest and Disease Control 73
- 5.3 Soil Biodiversity and Climate Change 75
- 5.4 Soil Biodiversity and Hydrological Cycle 77
- 5.5 Soil Biodiversity and Environmental Remediation 79
- 5.6 Conclusion 80 References 81
- 6 Plant Growth-Promoting Rhizobacteria: Role, Applications, and Biotechnology 89

Induja Mishra, Pashupati Nath, Namita Joshi, and Bishwambhar D. Joshi

- 6.1 Introduction 89
- 6.2 Functions and Role of PGPR 90
- 6.3 Range and Different Diversity of PGPR 91
- 6.3.1 Rhizosphere: Focal Point of PGPR 91
- 6.3.2 Characteristics of an Ideal PGPR 92
- 6.3.3 Growth-Enhancing Activities 93
- 6.3.4 PGPR Over the Period of Time 93
- 6.4 Mechanisms of Plant Growth Promotion by PGPR 94
- 6.5 Biotechnological Effects of PGPR 95
- 6.5.1 Biological Fixation of Nitrogen 95
- 6.5.2 Solubilization of Phosphorus 95

- 6.5.3 Antagonistic Activity and Biocontrol Agents 96
- 6.5.4 Synthesis of Hydrolytic Enzymes 97
- 6.5.5 Production of Siderophores 97
- 6.5.6 Production of Antibiotics 98
- 6.5.7 Production of Ethylene 98
- 6.5.8 Production of Gibberellins and Cytokinin (Stimulators of Plant Growth) 99
- 6.5.9 Production of Bacteriocins 99
- 6.5.10 Induced Systemic and Systemic Acquired Resistance (ISR and SAR) 100
- 6.6 PGPR Cometabolism 100
- 6.7 Classification and Assortment of PGPR Strains 101
- 6.8 Commercial Significance of PGPR 101
- 6.8.1 Restrains with PGPR 102
- 6.9 Future Prospects of PGPR 102
- 6.10 Concluding Remarks of PGPR *103* References *103*
- 7 A Green Approach for CO₂ Fixation Using Microalgae Adsorption: Biotechnological Approach 115

Priyanka Raviraj and Syed Atif Ali

- 7.1 Introduction 115
- 7.2 Effect of CO₂ Emissions on Environment 116
- 7.3 Advanced CO₂-Capturing Methods *117*
- 7.3.1 Absorption *117*
- 7.3.2 Adsorption 118
- 7.3.3 Membrane Separation 118
- 7.4 Biological Methods for CO₂ Capturing 118
- 7.5 Earlier Technologies of Carbon Dioxide Capturing 119
- 7.6 Natural Carbon Capture Technology: Photosynthesis *120*
- 7.7 Microalgae as the Modern Tool to Capture CO₂ 121
- Biology of Microalgae as Photosynthetic Organisms and CO₂
 Absorbers 122
- 7.9 Conclusion 123 References 123

 8 Assessment of *In-Vitro* Culture as a Sustainable and Eco-friendly Approach of Propagating Lichens and Their Constituent Organisms for Bioprospecting Applications 129 Amrita Kumari, Himani Joshi, Ankita H. Tripathi, Garima Chand, Penny Joshi, Lalit M. Tewari, Yogesh Joshi, Dalip K. Upreti, Rajesh Bajpai, and Santosh K. Upadhyay
 8.1 Lichens and Their Structural Organization 129

- 8.1.1 Structural Organization *129*
- 8.1.2 Role of Mycobionts and Phycobionts in the Symbiotic Association 130
- 8.2 Lichens and Bioprospection 131
- 8.3 Lichens as Sources of Unique Metabolites 132

Contents ix

- 8.4 Need of *In Vitro* Culture of Lichen and Lichen Components and Its Utility in Environment Conservation 134
- 8.5 In Vitro Culture of Lichens/Constituent Organisms 135
- 8.5.1 Efforts Carried Out on Lichen Culture 135
- 8.5.2 Mycobiont Culture 136
- 8.5.3 Endolichenic Fungal Culture *138*
- 8.6 Use of *In Vitro* Lichen Culture for Bioprospecting 139
- 8.6.1 lichen Symbiont/Mycobiont Culture 139
- 8.6.2 Endolichenic Fungal Culture 141
- 8.7 Challenges Associated 145
- 8.8 Conclusion 145 Acknowledgment 145 References 146
- 9 Bioprospection Potential of Indian Cladoniaceae Together with Its Distribution, Habitat Preference, and Biotechnological Prospects 155

Rajesh Bajpai, Upasana Pandey, Brahma N. Singh, Veena Pande, Chandra P. Singh, and Dalip K. Upreti

- 9.1 Introduction 155
- 9.2 Materials and Methods 159
- 9.3 Results and Discussion 160
- 9.4 Conclusions 182 Acknowledgments 183 References 183

10 Biotechnological Approach for the Wastewater

Management 193

Anamika Agrawal, Sameer Chandra, Anand K. Gupta, Rajendra Singh, and Jaspal Singh

- 10.1 Introduction 193
- 10.1.1 Sources of Water Pollution 194
- 10.1.2 Water Pollutants 194
- 10.1.2.1 Sewage Pollutants 194
- 10.1.2.2 Industrial Pollutants 194
- 10.1.2.3 Agriculture Pollutant 194
- 10.1.3 Physical Pollutants 195
- 10.1.3.1 Radioactive Waste 195
- 10.1.3.2 Thermal Sources 195
- 10.1.3.3 River Streams and Mountain Springs Sediments 195
- 10.1.3.4 Petroleum Products 195
- 10.2 Effects of Water Pollution 195
- 10.3 Role of Biotechnology to Control Water Pollution 196
- 10.3.1 Genetically Engineered Microorganisms (GEMs) in Remediation of Pollution 196

x Contents

- 10.3.1.1 Biotechnological Approaches for Water Pollution Remediation 198
- 10.3.1.2 Aerobic Biological Treatment 198
- 10.3.1.3 Activated Sludge Process 198
- 10.3.1.4 Constructed Wetlands 199
- 10.3.1.5 Biological Filters-Fixed Film Systems 199
- 10.3.1.6 Rotating Biological Contactors 199
- 10.3.1.7 Fluidized Bed Reactor 200
- 10.3.1.8 Expanded Bed Reactor (EBR) 200
- 10.3.2 Anaerobic Biological Treatment 200
- 10.3.2.1 Membrane Bioreactors (MBRs) 201
- 10.3.2.2 Bioremediation 201
- 10.3.2.3 Bioremediation of Industrial Effluent Using Biotechnology 202
- 10.3.2.4 Bioremediation of Pulp and Paper Mill Effluent 202
- 10.3.2.5 Bioremediation of Spilled Oil and Grease Deposits 202
- 10.3.2.6 Bioremediation of Textile Industry Effluent Through Biotechnology 203
- 10.3.2.7 Bioremediation of Distillery Effluent Using Biotechnology 203
- 10.3.2.8 Phytoremediation 204
- 10.4 Role of Biotechnology in Phytoremediation 205
- 10.4.1 Bioaugmentation 205
- 10.4.2 Biosorption 206
- 10.4.3 Advantages 207
- 10.5 Conclusion 207 References 207
- 11The Application of Biotechnology in the Realm of Bioenergy
and Biofuels209

Manvi Singh, Namira Arif, and Anil Bhatia

- 11.1 Introduction 209
- 11.2 Bioenergy (Biomass Energy) 210
- 11.2.1 Biomass and Its Sources 211
- 11.2.2 Biomass to Energy 211
- 11.2.2.1 Biomass to Biogas 212
- 11.2.2.2 Biomass to Biofuels 214
- 11.2.3 Agri-biomass (Biochar) to Energy 217
- 11.3 Conclusions 217 References 218
 - References 218
- 12 Nanotechnological Approach for the Abatement of Environmental Pollution: A Way Forward Toward a Clean Environment 221 Manzari Kushwaha, Anuradha Mishra, Divya Goel, and Shiv Shankar
- 12.1 Introduction 221
- 12.2 Nanoparticles: Properties, Types, and Route of Synthesis 222
- 12.2.1 Properties of Nanoparticles 223

Contents | xi

- 12.2.2 Classification of Nanoparticles 223
- 12.2.3 Synthesis of Nanoparticles 225
- 12.2.3.1 Top-Down Approach 225
- 12.2.3.2 Bottom-Up Approach 226
- 12.2.4 Environmental Applications of nanoparticles 226
- 12.3 Nanoremediation for Environment Cleanup 227
- 12.3.1 Nanoremediation of Air 228
- 12.3.1.1 Nanoadsorption 229
- 12.3.1.2 Degradation by Nanocatalysis 229
- 12.3.1.3 Nanofiltration 230
- 12.3.2 Nanoremediation of Water 231
- 12.3.2.1 Adsorption 231
- 12.3.2.2 Membrane Process 231
- 12.3.2.3 Photocatalysis 232
- 12.3.3 Nanoremediation of Soil 233
- 12.3.4 Nanomaterial for Control of Environmental Pathogens 233
- 12.4 Challenges in Nanoremediation of the Environment and Solution 236
- 12.5 Conclusion and Future Prospects 238 Acknowledgments 238 References 239
- 13 Role of Fatty Acids and Proteins in Alteration of Microbial Cell Surface Hydrophobicity: A Regulatory Factor of Environmental Biodegradation 249

Babita Kumari, Kriti Kriti, and Gayatri Singh

- 13.1 Introduction 249
- 13.2 Cell Surface Fatty Acids and Alteration in CSH 250
- 13.2.1 Saturated and Unsaturated Fatty Acid 251
- 13.3 Proteins/Genes Responsible in CSH Modulation 253
- 13.3.1 Flo Mannoprotein 253
- 13.3.2 CyoC 255
- 13.3.3 LapF 255
- 13.3.4 CSH1 255
- 13.3.5 A-protein 255
- 13.3.6 BslA 256
- 13.3.7 Foam-Forming Gene 256
- 13.3.8 Cpx-Signaling Pathway 256
- 13.4 Eicosapentaenoic Acid (EPA) 256
- 13.5 Factors that Influence Cell Surface Hydrophobicity 257
- 13.5.1 Chemicals 257
- 13.5.1.1 Hydrocarbons 257
- 13.5.1.2 Surfactants 258
- 13.5.1.3 Antimicrobial Chemicals 258
- 13.5.2 Environmental Condition 259

xii Contents

13.6	Conclusion 260)
	Acknowledgmen	t 260
	References 260	

14 Chemical Sustainability for a Nontoxic Environment - A Healthy Future 269

Puneet Khare, Shashi K. Tiwari, and Lakshmi Bala

- 14.1 Introduction 269
- 14.2 Basis of Sustainable Chemistry 271
- Challenges in Front of Sustainable Chemistry 272 14.3
- 14.4 Green Chemistry: A Sustainable Approach at a Minor Level 273
- Research and Education in Green and Sustainable Chemistry 274 14.5
- Scope of the Concerned Field 274 14.6
- 14.7 Role of OECD Toward Sustainable Chemistry 275
- Difference Between Green and Sustainable Chemistry 275 14.8
- 14.9 The 12 Principles of Green Chemistry (EPA) 276
- 14.10 Applications and Innovations of Sustainable Chemistry 277
- 14.11 In the Pharmaceutical Industry 277
- 14.12 Intense Use of Renewable Resources 278
- 14.13 Improvement in Catalytic Methods 278
- 14.14 Encouragement of the Use of Biomass 278
- 14.15 Improvement of Lignocellulose Extraction Technology 278
- 14.16 Improvement in Solvents 278
- 14.17 Biocatalyst Advancement 279
- 14.18 Improvement in Plastic Technology 279
- Techniques for Assessing Environmentally Friendly Chemical Processes 14.19 and Products 280
- 14.20 R&D in Sustainable Chemical Fields 280
- 14.21 Benefits of Sustainable Chemistry 280
- 14.22 Conclusion 281
 - Acknowledgment 281
 - References 281

Index 285