

Contents

1. Biotechnology and Bioremediation – An Overview	1
Ajay Singh and Owen P. Ward	
1 Introduction	1
2 Microbial Communities and Bioremediation	3
3 Contaminant Bioavailability	4
4 Microbial Catabolism of Organic Pollutants	5
5 Properties of Some Important Catabolic Enzymes	10
6 Designing Microorganisms for Bioremediation	11
7 Combined Chemical/Physical and Biological Treatments	12
8 Measuring Biodegradation Potential	13
9 Conclusions	14
References	15
2. Microbial Community Dynamics During Bioremediation of Hydrocarbons	19
E. Anne Green and Gerrit Voordouw	
1 Introduction	19
2 Methods for Characterization of Microbial Communities	19
2.1 Non-molecular Methods	22
2.2 Molecular Methods	22
3 Microbial Community Dynamics Following Hydrocarbon Exposure	26
3.1 Monitoring Microbial Strains Added to Environments	26
3.2 Correlation of Hydrocarbon Degradation and Gene Expression	26
3.3 Shifts in Microbial Community Composition Due to Hydrocarbon Exposure	27
4 Conclusions	32
References	32

3. Bioavailability and Biodegradation of Organic Pollutants – A Microbial Perspective	37
Jonathan D. Van Hamme	
1 Why Do Microorganisms Biodegrade Organic Pollutants?	37
2 Microbial Metabolic Capabilities	39
3 Impediments to Microbial Biodegradation	40
4 Chemotaxis	43
5 Cell Surface Properties and Biosurfactants	44
6 Active Uptake and Efflux	47
7 Conclusions: Microbial Communities and Their Neighborhoods	50
References	51
4. Anaerobic Biodegradation of Hydrocarbons	57
John D. Coates	
1 Introduction	57
2 Monoaromatic Compounds	58
2.1 Toluene Biodegradation	59
2.2 Benzene Biodegradation	61
2.3 Ethylbenzene Biodegradation	62
2.4 Xylene Biodegradation	65
3 Polycyclic Aromatic Hydrocarbon Compounds	67
4 Alkanes	71
5 Biomarkers of Anaerobic Hydrocarbon Degradation	72
References	74
5. Biotransformation, Biodegradation, and Bioremediation of Polycyclic Aromatic Hydrocarbons	83
Michael D. Aitken and Thomas C. Long	
1 Introduction	83
2 Relevant Properties of PAHs	84
3 Physical and Chemical Complexity of PAH-Contaminated Systems	87
3.1 PAHs Associate with Nonaqueous Compartments	88
4 Bioavailability and Its Impact on PAH Biodegradation	89
4.1 Bioavailability May Not Be the Only Factor That Limits PAH Biodegradation	91

5 Complexity of PAH Transformation and Degradation by Microorganisms 92

5.1 Outcomes of PAH Metabolism 93

5.1.1 Growth on PAHs 94

5.1.2 PAH Mineralization in the Absence of Growth 94

5.1.3 Incomplete Metabolism 96

5.2 Substrate Ranges of PAH-Degrading Bacteria 99

5.2.1 Substrate Interactions in Pure Cultures 100

5.3 Diversity of PAH Metabolism 102

6 Prospects for Bioremediation of PAH-Contaminated Systems 105

6.1 Mass Transfer Limitations 105

6.2 Bioaugmentation 106

6.3 Removal Kinetics 107

6.4 Supplemental Carbon Sources 107

6.5 Other Considerations 108

7 Conclusions 109

References 110

6. Biodegradation and Bioremediation of Halogenated Organic Compounds 125
 William W. Mohn

1 Introduction: The Problem with Halo-organic Compounds 125

2 Biodegradation 126

2.1 Some Generalizations About Halo-organic Biodegradation 126

2.2 Co-metabolic Processes 127

2.2.1 Aerobic Polychlorinated Biphenyl Biodegradation 127

2.2.2 Aerobic Trichloroethene Biodegradation 130

2.3 Specifically Evolved Aerobic Processes 131

2.3.1 Aerobic Pentachlorophenol Biodegradation and Patchwork Evolution 131

2.3.2 Aerobic Hexachlorocyclohexane Biodegradation 133

2.4 Dehalorespiration 134

2.4.1 Probable Dehalorespiration with Polychlorinated Biphenyls 135

2.4.2 Dehalorespiration with Perchloroethene 136

2.5 Ligninase Systems 137

3	Bioremediation	138
3.1	The Current State of Halo-organic Bioremediation	138
3.2	Composting of PCP-Contaminated Soil	139
3.3	In Situ Treatment of Chlorinated Ethenes	140
3.4	The Promise of PCB Bioremediation	142
3.5	The Potential of Exploiting Mobile Genetic Elements	144
	References	144
7.	Biodegradation of N-Containing Xenobiotics	149
	Jing Ye, Ajay Singh, and Owen P. Ward	
1	Introduction	149
2	Overview of Key N-Containing Xenobiotics	150
3	Nitroaromatics	151
4	Nitrate Esters	159
5	Compounds Containing Nitrogen-Heterocyclic Ring Structures	162
6	Conclusions	166
	References	167
8.	Aromatic Hydrocarbon Dioxygenases	175
	Rebecca Parales and Sol M. Resnick	
1	Role and Significance of Aromatic Hydrocarbon Dioxygenases in Biodegradation	175
2	Isolation of Aromatic Hydrocarbon Dioxygenases from the Environment	177
3	Classification and Relationships of Aromatic Ring-Hydroxylating Dioxygenases	178
4	Enzymology of Aromatic Hydrocarbon Dioxygenases ...	180
4.1	General Reaction Catalyzed	180
4.2	The Structure of NDO and Electron Transport Proteins	181
4.3	Roles of the α and β Subunits of the Oxygenase ...	183
4.4	Enzyme Mechanism	183
5	Substrate Range, Applications and Enzyme Engineering	185
5.1	Range of Reactions Catalyzed	185
5.2	Enzyme Engineering and Applications	187
6	Conclusions	189
	References	189

9. Bacterial Reductive Dehalogenases	197
Marc B. Habash, Jack D. Trevors, and Hung Lee	
1 Introduction	197
2 Reductive Dehalogenases Involved in Carbon Metabolism	203
2.1 Tetrachlorohydroquinone Reductive Dehalogenase	205
2.1.1 General Characteristics	205
2.1.2 Reaction Mechanism	206
2.1.3 Molecular Characterization	207
2.1.4 Structural Characterization: Comparison to Other GSTs	209
2.2 Dichloromethane (DCM) Dehalogenase	211
2.2.1 Enzyme Characteristics	212
2.2.2 Molecular Characterization	213
2.2.3 Structural Characterization	214
3 Reductive Dehalogenases Involved in Energy Conservation	215
3.1 3-Chlorobenzoate Dehalogenase	215
3.2 3-Chloro-4-Hydroxyphenylacetate Reductive Dehalogenase	218
3.2.1 General Characterization	218
3.2.2 Molecular Characterization	220
3.3 3-Chloro-4-Hydroxybenzoate Reductive Dehalogenase	221
3.4 Tetrachloroethene and Trichloroethene Reductive Dehalogenases	222
3.4.1 General Characteristics	222
3.4.2 Molecular Characterization	225
4 Conclusions	226
References	228
10. Engineering of improved Biocatalysts in Bioremediation	235
Wilfred Chen and Ashok Mulchandani	
1 Introduction	235
2 Engineering Microbes for Improved Bioremediation	236
2.1 Bioadsorbents for Heavy Metal Removal	236
2.2 Metal Precipitation	239
2.3 Enzymatic Transformation of Metals and Metalloids	239
2.4 Designing Strains for Enhanced Biodegradation	240

3 Protein Engineering for Improved Bioremediation	243
4 Conclusions	246
References	246
11. Combined Biological and Abiological Degradation of Xenobiotic Compounds	251
Roland Crawford, Thomas F. Hess, and Andrzej Paszczyński	
1 Introduction	251
2 Chemical Agents for Pretreatment of Recalcitrant Contaminants	252
2.1 Fenton's Reagent	252
2.2 Ozone	252
2.3 Permanganate	253
2.4 Ferrate (FeVI)	254
2.5 Zero-Valent Iron (Fe ⁰)	254
2.6 Chlorine	255
2.7 Other Pretreatment Approaches	255
3 Fenton-Like Systems for Soil and Water	256
3.1 Combined Remediation Technologies	256
3.2 Combined Remediation Technologies for TNT Destruction	257
4 Other Treatment Systems	261
4.1 Ferrate	261
4.2 Permanganate	262
4.3 Zero-Valent Iron	264
5 Brown-Rot Fungi: Nature's Example of Organisms Employing Fenton-Like Reactions	266
5.1 Brown-Rot Decay Mechanisms	266
5.2 Secretion of Organic Acids	268
5.3 Fenton-Like Reactions for Degradation of Man-Made Chemicals	269
5.4 Additional Evidence for Fungal Fenton-Like Reactions	271
6 Conclusions	272
References	272
12. Methods for Monitoring and Assessment of Bioremediation Processes	279
Ajay Singh, Ramesh C. Kuhad, Zarook Shareefdeen, and Owen P. Ward	
1 Introduction	279
2 Biodegradation Estimation Methods	280

3	Conventional Plating and Microbial Enumeration	283
4	Biochemical/Physiological Methods	286
4.1	Phospholipid Fatty Acid Analysis	286
4.2	Soil Enzyme Assay	288
4.3	BIOLOG	289
4.4	Immunochemical Methods	290
5	Molecular Biology-Based Methods	291
5.1	Molecular Techniques	291
5.2	Bacterial Biosensors	293
6	Toxicological Risk Assessments	296
7	Conclusions	297
	References	298
Subject Index		305