

Contents

Preface XI

List of Contributors XIII

1	Pollution Prevention and Treatment Using Nanotechnology	1
	<i>Bernd Nowack</i>	
1.1	Introduction	1
1.2	More Efficient Resource and Energy Consumption	3
1.3	Pollution Detection and Sensing	4
1.4	Water Treatment	4
1.4.1	Adsorption of Pollutants	4
1.4.2	Magnetic Nanoparticles	6
1.4.3	Nanofiltration	6
1.4.4	Degradation of Pollutants	6
1.4.5	Zeravalent Iron	7
1.5	Soil and Groundwater Remediation	9
1.6	Environmental Risks	10
1.6.1	Behavior in the Environment	10
1.6.2	Ecotoxicology	11
1.7	Conclusions	11
	References	12
2	Photocatalytic Surfaces: Antipollution and Antimicrobial Effects	17
	<i>Norman S. Allen, Michele Edge, Joanne Verran, John Stratton, Julie Maltby, and Claire Bygott</i>	
2.1	Introduction to Photocatalysis: Titanium Dioxide Chemistry and Structure–Activity	17
2.2	Applications	26
2.3	Photocatalytic Chemistry	26
2.4	Photoactivity Tests for 2-Propanol Oxidation and Hydroxyl Content	31

2.5	Self-Cleaning Effects: Paints/Cementitious Materials	33
2.5.1	Antibacterial Effect	38
2.5.2	Depollution: NO _x /VOC Removal	42
2.6	Conclusions	48
	References	49
3	Nanosized Photocatalysts in Environmental Remediation	51
	<i>Jess P. Wilcoxon and Billie L. Abrams</i>	
3.1	Introduction	51
3.1.1	Global Issues	51
3.1.2	Scope	53
3.2	General Field of Environmental Remediation	54
3.3	Photocatalysis	57
3.3.1	History and Background	57
3.3.2	Definitions	58
3.3.3	Well-Known Example – Water Splitting Reaction	59
3.4	Design Issues for Environmental Remediation Photocatalysts	60
3.4.1	Introduction	60
3.4.2	Charge Separation	61
3.4.3	pH of Solution	62
3.4.4	Charge Transfer	62
3.4.5	Presence of Simple and Complex Salts	62
3.4.6	Effect of Surfactants	64
3.4.7	Effect of Solvent and Dissolved Oxygen	65
3.4.8	Light Intensity	66
3.5	Potential for Nanomaterials in Environmental Remediation	66
3.5.1	Introduction	66
3.5.2	Nanomaterials and Advantages in Photocatalysis	68
3.5.2.1	Semiconductor Nanoclusters	68
3.5.2.2	Quantum Confinement	68
3.5.2.3	Surface Chemistry	71
3.5.2.4	Other Unique Materials Properties	71
3.5.2.5	Importance of Nanocluster Photostability	72
3.6	Nanoparticle Synthesis and Characterization	73
3.6.1	Introduction	73
3.6.2	Characterization	74
3.6.3	Detailed Examples of Nanocluster Synthesis and Photocatalysis	77
3.6.3.1	Semiconductor Nanoclusters	77
3.6.3.2	TiO ₂	78
3.6.3.3	Alternative Photocatalytic Materials	83
3.6.3.4	MoS ₂ and Other Metal Dichalcogenides	86
3.7	Current and Future Technological Applications of Photocatalysts for Environmental Remediation	112
3.7.1	Indoor Air Purification	113
3.7.2	Outdoor Air Purification	115

3.8	Conclusion	117
	References	119
4	Pollution Treatment, Remediation and Sensing	125
	<i>Abhilash Sugunan and Joydeep Dutta</i>	
4.1	Introduction	125
4.2	Treatment Technologies to Remove Environmental Pollutants	127
4.3	Remediation Technologies to Clean Up Environmental Pollutants Effectively	131
4.4	Sensors	133
4.4.1	Biosensors	134
4.4.2	Electrochemical Sensors	134
4.4.3	Mass Sensors	135
4.4.4	Optical Sensors	137
4.4.5	Gas Sensors	138
4.4.6	Novel Sensing Technologies and Devices for Pollutant and Microbial Detection	140
4.4.6.1	Real-Time Chemical Composition Measurements of Fine and Ultrafine Airborne Particles	140
4.4.6.2	Ultrasensitive Detection of Pathogens in Water	140
4.4.6.3	Detection of Heavy Metals in Water	141
4.5	Conclusions	143
	References	143
5	Benefits in Energy Budget	147
	<i>Ian Ivar Suni</i>	
5.1	Introduction	147
5.2	Nanomaterials in Fuel Cells	148
5.2.1	Low-Temperature Fuel Cell Technology	148
5.2.2	Nanoparticle Catalysts in Low-Temperature Fuel Cells	150
5.2.3	Fuel Cell Catalyst Support Materials	151
5.2.4	Carbon Nanotubes: Science and Technology	152
5.2.5	Carbon Nanotubes within Operating PEMFCs	153
5.3	Hydrogen Storage	157
5.3.1	Hydrogen Storage Using Carbon Nanomaterials	158
5.4	Solar Cells	159
5.4.1	Solar Energy Basics, Including Quantum Confinement	159
5.4.2	Nanocrystalline Dye-Sensitized Solar Cells	161
5.4.3	Nanomaterials in Solar Cell Counter Electrodes	164
5.5	Lithium Ion Battery Anode Materials	165
5.5.1	Lithium Ion Batteries	165
5.5.2	Nanomaterials for Lithium Ion Storage: Sn Nanoparticles	166
5.5.3	Nanomaterials for Lithium Ion Storage: Si Nanocomposites	169
5.5.4	Nanomaterials for Lithium Ion Storage: Carbon Nanotubes and Carbon Nanotube-Based Composites	170

5.5.5	Lithium Ion Storage: Further Considerations	171
	References	172
6	An Industrial Ecology Perspective	177
	<i>Shannon M. Lloyd, Deanna N. Lekas, and Ketra A. Schmitt</i>	
6.1	Introduction	177
6.1.1	Industrial Ecology	177
6.1.2	Applying Industrial Ecology to Nanotechnology	178
6.2	Life Cycle Assessment	179
6.2.1	Background on Life Cycle Assessment	179
6.2.2	Life Cycle Implications for Nanotechnology	180
6.2.3	Life Cycle Studies Conducted to Date	181
6.3	Substance Flow Analysis	184
6.3.1	Background on Substance Flow Analysis	184
6.3.2	Substance Flow Analysis Implications for Nanotechnology	185
6.3.3	Summary of Substance Flow Analysis Work Conducted to Date	185
6.4	Corporate Social Responsibility	186
6.4.1	Background on Corporate Social Responsibility	186
6.4.2	Corporate Social Responsibility Implications for Nanotechnology	187
6.4.3	Summary of Work Conducted to Understand Nanofirm EHS Concerns and Actions	188
6.5	Conclusions	189
	References	190
7	Composition, Transformation and Effects of Nanoparticles in the Atmosphere	195
	<i>Ulrich Pöschl</i>	
7.1	Introduction	195
7.2	Composition	199
7.2.1	Carbonaceous Components	199
7.2.2	Primary and Secondary Organic Components	202
7.3	Transformation	205
7.3.1	Chemical Transformation of Carbonaceous Aerosol Components	208
7.3.2	Restructuring, Phase Transitions, Hygroscopic Growth and CCN/IN Activation of Aerosol Particles upon Interaction with Water Vapor	212
7.4	Climate and Health Effects	216
7.5	Summary and Outlook	219
	References	221
8	Measurement and Detection of Nanoparticles Within the Environment	229
	<i>Thomas A.J. Kuhlbusch, Heinz Fissan, and Christof Asbach</i>	
8.1	Introduction	229
8.2	Occurrence of Nanoparticles in Environmental Media	233

8.2.1	Ambient Environment	233
8.2.1.1	Water and Soils	233
8.2.1.2	Air	234
8.2.2	Workplace Environment	234
8.3	Nanoparticle Detection and Measurement Techniques	235
8.3.1	Soil	235
8.3.2	Water and Liquids	235
8.3.2.1	Coulter Counter	235
8.3.2.2	Light Scattering	236
8.3.3	Air	238
8.3.3.1	Basics	238
8.3.3.2	Online Physical Characterization	243
8.3.3.3	Online Physical–Chemical Characterization	256
8.3.3.4	Offline Physical Characterization	258
8.4	Nanoparticle Detection and Measurement Strategies	259
	References	262
9	Epidemiological Studies on Particulate Air Pollution	267
	<i>Irene Bröske-Hohlfeld and Annette Peters</i>	
9.1	Introduction	267
9.1.1	Outline of the Chapter	267
9.1.2	A Short Definition of Particle Sizes	268
9.1.3	A Brief Comment on Epidemiological Study Design	269
9.2	Potential Entry Routes for Nanoparticles into the Human Body	270
9.2.1	Inhalation and Metabolism of Airborne Particles	270
9.3	Studies of Environmental Air Pollution in the USA and Europe	271
9.3.1	PM ₁₀ and PM _{2.5}	271
9.3.1.1	Short-Term Studies	272
9.3.1.2	Long-Term Studies	272
9.3.2	Ultrafine Particles (UFP)	273
9.4	Cardiovascular Disease	275
9.5	Respiratory Disease	276
9.5.1	Deterioration of Lung Function and Respiratory Symptoms	276
9.5.2	Asthma and Allergies	277
9.5.3	Lung Cancer	278
9.6	Diseases of the Central Nervous System	279
9.7	Particulate Air Pollution at the Workplace	281
	References	286
10	Impact of Nanotechnological Developments on the Environment	291
	<i>Harald F. Krug and Petra Klug</i>	
10.1	Problem	291
10.2	Risk Management	292
10.3	Sources of Nanoparticles: New Products	294
10.4	Production and Use of Nanomaterials	296

x | *Contents*

10.5	Workplace and the Environment: Effects and Aspects of Nanomaterials	297
10.6	Distribution of Nanoparticles in Ambient Air	298
10.7	Distribution of Nanoparticles in Water	299
10.8	Conclusions	302
	References	303

	Index	307
--	--------------	-----