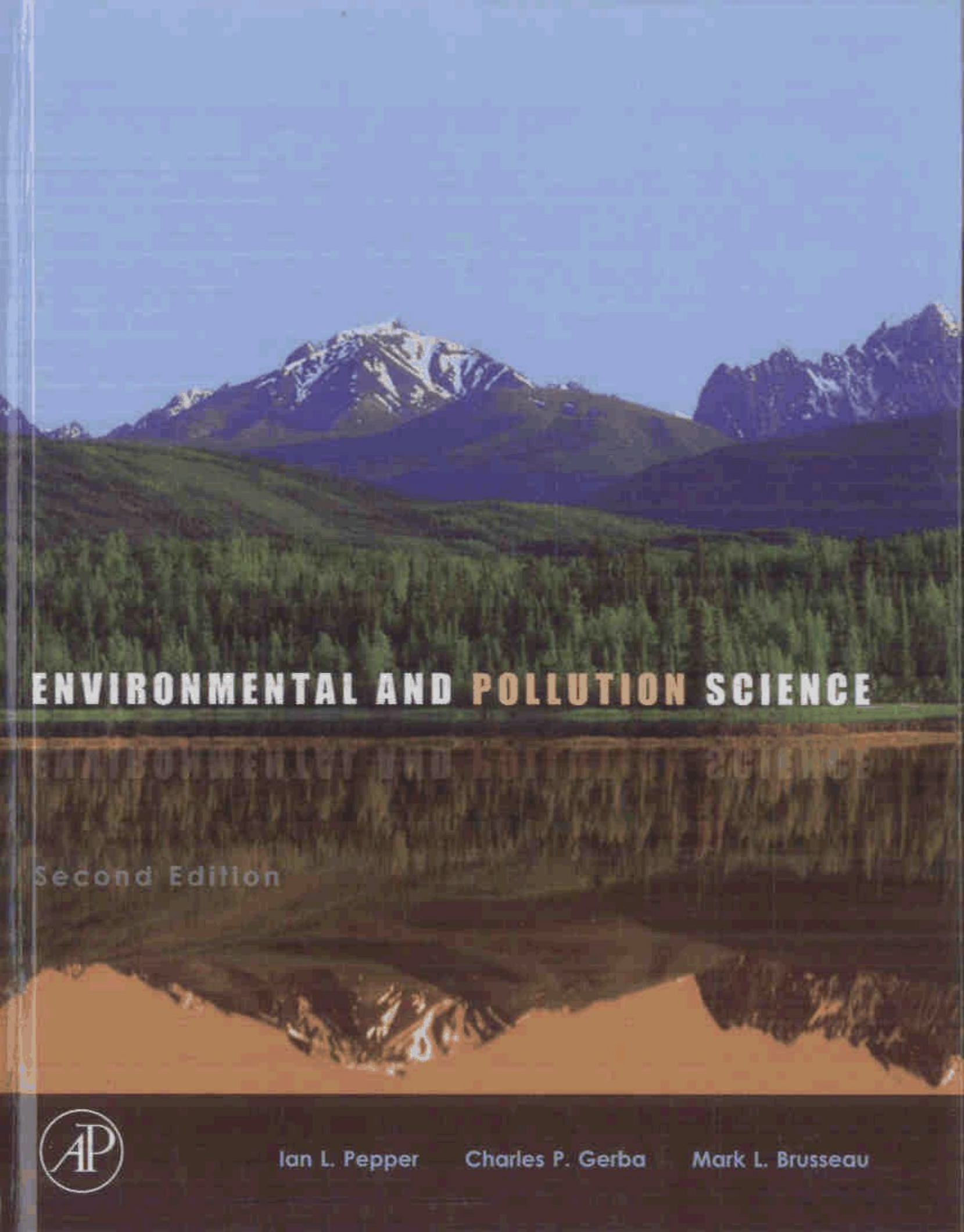




ENVIRONMENTAL AND POLLUTION SCIENCE

Second Edition



Ian L. Pepper

Charles P. Gerba

Mark L. Brusseau

TABLE OF CONTENTS

Preface	xv
The Editors	xvii
Contributing Authors	xviii
The Department of Soil, Water and Environmental Science (SWES)	xx

PART 1

PROCESSES AFFECTING FATE AND TRANSPORT OF CONTAMINANTS

CHAPTER 1

The Extent of Global Pollution 3

J.L. Pepper, C.P. Gerba, and M.L. Brusseau

1.1 Science and Pollution	4
1.2 Global Perspective of the Environment	5
1.3 Pollution and Population Pressures	6
1.4 Overview of Environmental Characterization	8
1.4.1 Soil and the Subsurface	8
1.4.2 Water	8
1.4.3 Air	9
1.5 Advances in Analytical Detection Technology	10
1.5.1 Advances in Chemical Analysis	10
1.5.2 Advances in Biological Analysis	10
1.6 The Risk Based Approach to Pollution Science	10
1.7 Waste Management, Site Remediation, and Ecosystem Restoration	12
References and Additional Reading	12

CHAPTER 2

Physical-Chemical Characteristics of Soils and the Subsurface 13

J.L. Pepper and M.L. Brusseau

2.1 Soil and Subsurface Environments	14
2.2 Solid Phase	14
2.2.1 Soil Profiles	14
2.2.2 Primary Particles and Soil Texture	16
2.2.3 Soil Structure	16
2.2.4 Cation-Exchange Capacity	18

2.2.5 Soil pH	18
2.2.6 Organic Matter	19
2.2.7 Vadose Zone Solid Phase	20
2.3 Gaseous Phase	20
2.3.1 Constituents of Soil Atmosphere	20
2.3.2 Availability of Oxygen and Soil Respiration	20
2.3.3 Gaseous Phase Within the Vadose Zone	21
2.4 Liquid Phase	21
2.5 Basic Physical Properties	21
2.5.1 Bulk Density	21
2.5.2 Porosity	21
2.5.3 Soil Water Content	22
2.5.4 Soil Temperature	22
Questions and Problems	23
References and Additional Reading	23

CHAPTER 3

Physical-Chemical Characteristics of Waters 24

D.B. Walker, M.L. Brusseau, and K. Fitzsimmons

3.1 The Watery Planet	25
3.1.1 Distribution	25
3.1.2 The Hydrologic Cycle	25
3.2 Unique Properties of Water	26
3.2.1 Structure and Polarity	26
3.2.2 Thermal Properties	26
3.3 Mechanical Properties	27
3.3.1 Interception, Evaporation, Infiltration, Runoff	27
3.4 The Universal Solvent	28
3.4.1 Concentration Terminology	29
3.4.2 Oxygen and Other Gases in Water	29
3.4.3 Carbon Dioxide in Water	30
3.5 Oxidation-Reduction Reactions	32
3.6 Light in Aquatic Environments	33
3.6.1 Light Energy	33
3.6.2 Light at and Below the Water Surface	33
3.7 Oceans	34
3.7.1 Salts	34
3.7.2 Transport and Accumulation of Pollutants	34
3.7.3 Wave Morphology and Currents	34

3.8	Lakes and Reservoirs—The Lentic System	35
3.8.1	Lentic Typology	35
3.8.2	Trophic State	35
3.8.3	Density and Layering	36
3.9	Streams and Rivers—The Lotic System	37
3.9.1	Stream Morphometry	37
3.9.2	Stream Hydraulics	38
3.10	Groundwater—Water in the Subsurface	38
3.10.1	Water in the Subsurface	39
3.10.2	Principles of Subsurface Water Flow	40
3.10.3	Darcy's Law	41
3.10.4	Hydraulic Conductivity	42
3.11	A Watershed Approach	44
	Questions and Problems	44
	References and Additional Reading	45

CHAPTER 4

Physical-Chemical Characteristics of the Atmosphere 46

A.D. Mathias, S.A. Mustl, and H.L. Bohn

4.1	Chemical Composition	47
4.2	Physical Properties and Structure	49
4.2.1	Density, Pressure, and Wind	50
4.2.2	Temperature	51
4.2.3	Water Vapor and Precipitation	55
4.2.4	Radiative Transfer	55
4.2.5	Lower Atmosphere	56
4.2.6	Upper Atmosphere	57
	Questions and Problems	57
	References and Additional Reading	57

CHAPTER 5

Biotic Characteristics of the Environment 58

J.L. Pepper and K.L. Josephson

5.1	Major Groups of Organisms	59
5.2	Microorganisms in Surface Soils	63
5.2.1	Bacteria	63
5.2.1.1	Mode of nutrition	64
5.2.1.2	Type of electron acceptor	65
5.2.1.3	Ecological classification	65
5.2.1.4	Dominant culturable soil bacteria	65
5.2.1.5	Distribution and function	65
5.2.2	Fungi	66
5.2.3	Algae	68
5.2.4	Protozoa	68
5.3	Microorganisms in the Subsurface	69
5.4	Biological Generation of Energy	69
5.5	Soil as an Environment for Microbes	70
5.5.1	Biotic Stress	70
5.5.2	Abiotic Stress	71
5.6	Activity and Physiological State of Microbes in Soil	72
5.7	Enumeration of Soil Bacteria via Dilution and Plating	73
5.8	Microorganisms in Air	73
5.8.1	Incidence of Bioaerosols	73
5.8.2	Fate and Transport of Bioaerosols	74
5.9	Microorganisms in Surface Waters	76
5.9.1	General Characteristics of Microbial Communities in Aquatic Environments	76
	Questions and Problems	77
	References and Additional Reading	77

CHAPTER 6

Physical Processes Affecting Contaminant Transport and Fate 78

M.L. Brusseau

6.1	Contaminant Transport and Fate in the Environment	79
6.2	Contaminant Properties	80
6.3	Advection	81
6.4	Dispersion	82
6.5	Mass Transfer	83
6.6	Transformation Reactions	83
6.7	Characterizing Spatial and Temporal Distributions of Contaminants	83
6.8	Estimating Phase Distributions of Contaminants	85
6.9	Quantifying Contaminant Transport and Fate	86
	Questions and Problems	87
	References and Additional Reading	88

CHAPTER 7

Chemical Processes Affecting Contaminant Transport and Fate 89

M.L. Brusseau and J. Chorover

7.1	Introduction	90
7.2	Basic Properties of Inorganic Contaminants	90
7.2.1	Speciation of Inorganic Pollutants	90
7.2.2	Aqueous Phase Activities and Concentrations	90
7.2.3	Ion Hydration, Ion Hydrolysis, and Acid-Base Reactions	91
7.2.4	Aqueous-Phase Complexation Reactions	93
7.2.5	Precipitation-Dissolution Reactions	93
7.3	Basic Properties of Organic Contaminants	94
7.3.1	Phases: Solids, Liquids, Gases	94
7.3.2	Dissolution and Aqueous Solubilities of Organic Contaminants	95
7.3.3	Evaporation of Organic Contaminants	96
7.3.4	Volatilization of Organic Contaminants	96
7.3.5	Multiple-Component Organic Phases	96
7.4	Sorption Processes	97
7.4.1	Inorganics	97
7.4.2	Organics	98
7.4.3	Magnitude and Rate of Sorption	100
7.5	Abiotic Transformation Reactions	101
7.5.1	Hydrolysis	101
7.5.2	Oxidation-Reduction Reactions	101
7.5.3	Photochemical Reactions	102
7.5.4	Radioactive Decay	103
7.5.5	Quantifying Transformation Rates	103
	Questions and Problems	104
	References and Additional Reading	104

CHAPTER 8

Biological Processes Affecting Contaminant Transport and Fate 105

R.M. Majer

8.1	Biological Effects on Pollutants	106
8.2	The Overall Process of Biodegradation	106

8.3	Microbial Activity and Biodegradation	108
8.3.1	Environmental Effects on Biodegradation	108
8.3.1.1	Oxygen and other terminal electron acceptors	109
8.3.1.2	Microbial populations and organic matter content	111
8.3.1.3	Nitrogen	111
8.3.2	Pollutant Structure	111
8.4	Biodegradation Pathways	112
8.4.1	Biodegradation Under Aerobic Conditions	112
8.4.1.1	Aliphatic hydrocarbons	112
8.4.1.2	Aromatic hydrocarbons	113
8.4.1.3	Alicyclic hydrocarbons	114
8.4.2	Biodegradation Under Anaerobic Conditions	115
8.4.2.1	Aliphatic hydrocarbons	115
8.4.2.2	Aromatic hydrocarbons	116
8.5	Transformation of Metal Pollutants	117
8.5.1	Effects of Metals on Microbial Metabolism	118
8.5.2	Microbial Transformations of Metals	118
	Questions and Problems	120
	References and Additional Reading	120

PART 2

MONITORING, ASSESSMENT, AND REGULATION OF ENVIRONMENTAL POLLUTION

CHAPTER 9

Physical Contaminants 123

J. Walworth and J.L. Pepper

9.1	Particle Origins	124
9.2	Particle Size	124
9.2.1	Nanoparticles	125
9.3	Particles in Air or Aerosols	125
9.3.1	Aerosols of Concern	126
9.3.1.1	Asbestos	126
9.3.1.2	Silica	126
9.3.1.3	Human-made aerosols	127
9.3.1.4	Bioaerosols	128
9.4	Particulates in Water	128
9.4.1	Soil Particles	129
9.4.1.1	Soil particle flocculation	129
9.5	Summary	130
	Questions and Problems	131
	References and Additional Reading	131

CHAPTER 10

Chemical Contaminants 132

M.L. Brusseau, C.M. McColl, G. Famisan, and J.F. Artioli

10.1	Introduction	133
10.2	Types of Contaminants	133
10.3	Sources: Agricultural Activities	133
10.4	Sources: Industrial and Manufacturing Activities	138
10.5	Sources: Municipal Waste	138
10.6	Sources: Service-Related Activities	140
10.7	Sources: Resource Extraction/Production	141
10.8	Sources: Radioactive Contaminants	141

10.9	Natural Sources of Contaminants	143
	Questions and Problems	143
	References and Additional Reading	143

CHAPTER 11

Microbial Contaminants 144

C.P. Gerba and J.L. Pepper

11.1	Water-Related Microbial Disease	145
11.2	Classes of Diseases and Types of Pathogens	146
11.3	Types of Pathogenic Organisms	147
11.3.1	Viruses	147
11.3.2	Bacteria	149
11.3.2.1	Enteric bacteria	149
11.3.2.2	<i>Legionella</i>	151
11.3.2.3	Opportunistic bacterial pathogens	153
11.3.2.4	Indicator bacteria	153
11.3.2.5	The Most Probable Number (MPN) test	153
11.3.2.6	The Membrane Filter (MF) test	154
11.3.2.7	The Presence–Absence (P–A) test	155
11.3.2.8	Fecal streptococci	157
11.3.2.9	Heterotrophic plate count	158
11.3.2.10	Bacteriophage	158
11.3.3	Protozoa	159
11.3.3.1	<i>Giardia</i>	159
11.3.3.2	<i>Cryptosporidium</i>	160
11.3.4	Helminths	161
11.3.5	Blue-Green Algae	163
11.4	Sources of Pathogens in the Environment	163
11.4.1	Sludge	164
11.4.2	Solid Waste	164
11.5	Fate and Transport of Pathogens in the Environment	165
11.6	Standards and Criteria for Indicators	166
	Questions and Problems	168
	References and Additional Reading	168

CHAPTER 12

The Role of Environmental Monitoring in Pollution Science 170

J.F. Artioli and M.L. Brusseau

12.1	Introduction	171
12.2	Sampling and Monitoring Basics	171
12.3	Statistics and Geostatistics	172
12.4	Sampling and Monitoring Tools	173
12.4.1	Maps	173
12.4.2	Remote Sensing	175
12.5	Soil and Vadose Zone Sampling and Monitoring	176
12.6	Groundwater Sampling and Monitoring	177
12.7	Surface Water Sampling and Monitoring	179
12.8	Atmosphere Sampling and Monitoring	179
12.9	Conclusions	181
	Questions and Problems	182
	References and Additional Reading	182

CHAPTER 13

Environmental Toxicology 183

C.P. Gerba

13.1	History of Modern Toxicity in the United States	184
13.2	Toxic Versus Nontoxic	184

13.3	Exposure and Dose	184
13.4	Evaluation of Toxicity	186
13.4.1	Manifestations of Toxicity	187
13.4.2	Toxicity Testing	188
13.4.3	Toxicity Tests for Carcinogenicity	189
13.4.4	Epidemiological Studies	190
13.4.5	Short-Term Tests for Toxicity	192
13.4.6	Threshold Effects	192
13.5	Responses to Toxic Substances	193
13.5.1	Absorption	193
13.5.2	Distribution	194
13.5.3	Excretion	195
13.5.4	Metabolism	195
13.5.5	Biotransformation of Toxicants	195
13.5.6	Phase I Transformations	195
13.5.7	Phase II Transformations	196
13.6	Carcinogens	197
13.7	Mutagens	199
13.8	Teratogens	200
13.9	Chemical Toxicity: General Considerations	201
13.10	Chemical Toxicity: Selected Substances	202
13.10.1	Heavy Metals	202
13.10.2	Inorganic Radionuclides	206
13.10.3	Insecticides	207
13.10.4	Herbicides	208
13.10.5	Halogenated Hydrocarbons	209
	Questions and Problems	211
	References and Additional Reading	211

CHAPTER 14

Risk Assessment 212

C.P. Gerba

14.1	The Concept of Risk Assessment	213
14.2	The Process of Risk Assessment	215
14.2.1	Hazard Identification	215
14.2.2	Exposure Assessment	215
14.2.3	Dose-Response Assessment	217
14.2.4	Risk Characterization	220
14.2.4.1	Cancer risks	220
14.2.4.2	Noncancer risks	221
14.2.4.3	Uncertainty analysis	222
14.2.4.4	Risk projections and management	223
14.2.4.5	Hazardous waste risk assessment	223
14.3	Ecological Risk Assessment	223
14.4	Microbial Risk Assessment	225
	Questions and Problems	231
	References and Additional Reading	231

CHAPTER 15

Environmental Laws and Regulations 233

C.P. Gerba and C. Straub

15.1	Regulatory Overview	234
15.2	The Safe Drinking Water Act	234
15.3	The Clean Water Act	234
15.4	Comprehensive Environmental Response, Compensation and Liability Act	237
15.5	Federal Insecticide and Rodenticide Act	238

15.6	Clean Air Act	238
15.7	Resource Conservation and Recovery Act (RCRA)	239
15.8	The Pollution Prevention Act	239
15.9	Other Regulatory Agencies and Accords	239
	Questions and Problems	240
	References and Additional Reading	240

PART 3

LAND AND WATER POLLUTION MITIGATION

CHAPTER 16

Soil and Land Pollution 243

J.F. Artola, J.L. Watworth, S.A. Musil, and M.A. Crimmins

16.1	Introduction	244
16.2	Surface Mining	244
16.2.1	Mine Tailings	244
16.2.2	Air Emissions	245
16.3	Deforestation	245
16.3.1	Local Land Pollution Impacts of Deforestation	246
16.3.2	Regional Air Quality Impacts of Deforestation	246
16.4	Soil Acidity -Salinity	246
16.4.1	Acid Soils	246
16.4.2	Salinity	247
16.5	Soil Erosion	247
16.5.1	Soil Water Erosion and Control	247
16.5.2	Soil Wind Erosion and Control	249
16.6	Agricultural Activities	249
16.6.1	Fertilizers	249
16.6.2	Pesticides	250
16.6.2.1	Types of pesticides	250
16.6.2.2	Extent of pesticide use	251
16.6.2.3	Fate of pesticides	252
16.7	Animal Wastes	253
16.7.1	Nonpoint Versus Point Source Pollution	253
16.7.2	Specific Pollutants	254
16.8	Industrial Wastes With High Salts and Organics	254
16.8.1	Oil Drilling	254
16.8.2	Coal-Burning Electric Power Plants	254
16.8.3	Industrial Wastes High in Organic Chemicals	255
16.9	Invasive Species	255
16.9.1	Kudzu	256
16.9.2	Salt Cedar	256
	Questions and Problems	257
	References and Additional Reading	258

CHAPTER 17

Subsurface Pollution 259

M.L. Brusseau and G.R. Fick

17.1	Groundwater as a Resource	260
17.2	Groundwater Pollution	261
17.3	Groundwater Pollution Risk Assessment	265

17.4	Point-Source Contamination	267
17.4.1	Hazardous Organic Chemicals	268
17.4.2	Landfills	270
17.5	Diffuse-Source Contamination	272
17.5.1	Agrochemical Pollution of the Subsurface	272
17.5.2	Salt-Water Intrusion	274
17.6	Other Groundwater Contamination Problems	275
17.6.1	Pathogen Contamination of Groundwater	275
17.6.2	Gasoline Additive: Methyl Tertiary-Butyl Ether (MTBE)	276
17.6.3	Solvent Additives: 1,4-dioxane	276
17.6.4	Perchlorate in Groundwater	276
17.6.5	Arsenic in Groundwater	277
17.6.6	Acid-Mine Drainage	277
17.7	Sustainability of Groundwater Resources	277
	Questions and Problems	278
	References and Additional Reading	278

CHAPTER 18

Surface Water Pollution 279

D. Walker, D. Baumgartner, K. Fitzsimmons, and C.P. Gerba

18.1	Surface Freshwater Resources	280
18.2	Marine Water Resources	280
18.2.1	The Coastal Zone	280
18.2.2	Open Ocean Waters	280
18.3	Sources of Surface Water Pollution	281
18.4	Sediments as Surface Water Contaminants	282
18.4.1	Suspended Solids and Turbidity	283
18.5	Metals as Surface Water Contaminants	284
18.5.1	Mercury	284
18.5.2	Arsenic	286
18.5.3	Chromium	286
18.5.4	Selenium	286
18.6	Nutrients and Eutrophication of Surface Waters	286
18.6.1	Harmful Algal Blooms	290
18.6.1.1	Harmful Algal Blooms in Marine Systems	290
18.6.1.2	Harmful Algal Blooms in Freshwater Systems	293
18.7	Organic Compounds in Water	294
18.7.1	Persistent, Bioaccumulative Organic Compounds	294
18.8	Enteric Pathogens as Surface Water Contaminants	296
18.9	Total Maximum Daily Loads (TMDLs)	300
18.10	Quantification of Surface Water Pollution	300
18.10.1	Die-Off of Indicator Organisms	300
18.10.2	Organic Matter and Dissolved Oxygen	303
18.10.3	Measurement of Potential Oxygen Demand Of Organics in Sewage	304
18.10.3.1	COD	304
18.10.3.2	BOD	304
18.11	Determining BOD	304
18.11.1	Impact of BOD on Dissolved Oxygen of Receiving Waters	305
18.12	Dilution of Effluents	306
18.12.1	Dilution in Streams and Rivers	306
18.12.2	Dilution in Large Bodies of Water	307
18.12.2.1	Initial dilution and transport	307
18.12.2.2	Measurements and calculations	307

18.13	Dye Tracing of Plumes	308
18.14	Spatial and Temporal Variation of Plume Concentrations	309
18.15	Compliance Monitoring	310
18.15.1	Mixing Zones	310
18.15.2	Regulatory Use	310
18.15.3	Verification Sampling	310
	Questions and Problems	311
	References and Additional Reading	311

CHAPTER 19

Soil and Groundwater Remediation 312

M.L. Brusseau

19.1	Introduction	313
19.2	Superfund Process	313
19.3	Site Characterization	314
19.4	Remediation Technologies	318
19.4.1	Containment Technologies	318
19.4.1.1	Physical barriers	319
19.4.1.2	Hydraulic barriers	319
19.4.1.3	Other containment methods	320
19.4.2	Removal	321
19.4.2.1	Excavation	321
19.4.2.2	Pump-and-treat	321
19.4.2.3	Enhanced flushing	322
19.4.2.4	Soil vapor extraction	323
19.4.2.5	Air sparging	323
19.4.2.6	Thermal methods	324
19.4.2.7	Electrokinetic methods	325
19.4.3	<i>In situ</i> Treatment	325
19.4.3.1	Bioremediation	325
19.4.3.2	<i>In situ</i> chemical treatment	328
19.4.4	Other Technologies: Monitored Natural Attenuation	329
19.4.5	Other Technologies: Phytoremediation	329
	Questions and Problems	333
	References and Additional Reading	333

CHAPTER 20

Ecosystem Restoration and Land Reclamation 334

E.P. Glenn, W.J. Waugh, and L.L. Pepper

20.1	Introduction	335
20.2	Site Characterization	335
20.2.1	Conceptual Plan and Site Assessment	335
20.2.2	Plant Surveys	336
20.3	Site Restoration	336
20.4	Site Monitoring	336
20.5	Approaches to Ecosystem Restoration	337
20.5.1	Natural Restoration	337
20.5.2	Passive Ecological Restoration	337
20.5.3	Active Ecological Restoration	338
20.5.4	Ecological Restoration Using Organic Amendment	338
20.5.5	The Invasive Species Problem	339
20.6	Land Reclamation	339
20.6.1	Acidic Soils	347

20.6.2 Saline and Sodic Soils	347
20.6.3 Reforestation	348
Questions and Problems	348
References and Additional Reading	348

PART 4

ATMOSPHERIC POLLUTION

CHAPTER 21

Sensory Pollutants, Electromagnetic Fields and Radiofrequency Radiation 351

J.F. Artale and C.M. McColl

21.1 Introduction	352
21.2 Heat	352
21.2.1 Sources of Heat Islands	352
21.2.2 Effects of Heat Islands	352
21.2.3 Controlling Heat Islands	353
21.2.4 Summary	353
21.3 Light	354
21.3.1 Sources of Light Pollution	354
21.3.2 Effects of Light	354
21.3.3 Controlling Light Pollution	355
21.3.4 Summary	356
21.4 Noise Pollution	356
21.4.1 The Physics of Sound	356
21.4.2 How We Hear Noise	356
21.4.3 Sources of Noise	358
21.4.4 Effects of Noise	358
21.4.5 Summary	358
21.5 Odor as a Sensory Pollutant	359
21.5.1 Odor Response	359
21.5.2 Odor Perceptions	359
21.5.3 Sources of Odor	359
21.5.4 Regulations	360
21.5.5 Summary	360
21.6 Electromagnetic Fields and Radiofrequency Radiation	360
21.6.1 Effects and Levels of EMF	361
21.6.2 Effects and Levels of RF	361
21.6.3 Summary	362
Questions and Problems	364
References and Additional Reading	364

CHAPTER 22

Indoor Air Quality 365

K.A. Reynolds

22.1 Fundamentals of Indoor Air Quality	366
22.2 Sources of Indoor Air Pollutants	366
22.2.1 Volatile Organic Compounds	367
22.2.1.1 Pesticides	367
22.2.1.2 Construction Materials and Furnishings	367
22.2.2 Combustion Products	368
22.2.2.1 Carbon Monoxide and Nitrogen Dioxide	368
22.2.2.2 Environmental Tobacco Smoke (ETS)	368

22.2.3 Lead and Radon	368
22.2.4 Biological Pollutants	369
22.2.4.1 Mold	369
22.2.4.2 Endotoxin	369
22.2.4.3 Viruses and Bacteria	370
22.2.4.4 Animal Allergens	370
22.2.4.5 Arthropod Allergens	370
22.2.4.6 Plant Allergens	371

22.3 Factors Influencing Exposure to Indoor Air Pollution	371
22.3.1 Source Prevalence	371
22.3.2 Building Maintenance and Operation	372
22.3.3 Building Design	373
22.3.4 Sensitive Populations	373
22.4 Monitoring IAQ	374
Questions and Problems	375
References and Additional Reading	376

CHAPTER 23

Atmospheric Pollution 377

A.D. Matthias, A.C. Comrie, and S.A. Musil

23.1 Air Pollution Concepts	378
23.2 Sources, Types, and Effects of Air Pollution	379
23.2.1 Primary Pollutants	380
23.2.1.1 Carbon monoxide	381
23.2.1.2 Hydrocarbons	381
23.2.1.3 Particulate matter	381
23.2.1.4 Sulfur dioxide	382
23.2.1.5 Nitrogen oxides (NO _x)	383
23.2.1.6 Lead	383
23.2.2 Secondary Pollutants	383
23.2.3 Toxic and Hazardous Air Pollutants	385
23.2.4 Pollutants With Radiative Effects	385
23.2.4.1 Greenhouse gases	385
23.2.4.2 Stratospheric pollution	386
23.2.4.2.1 NO _x /O ₃ destruction cycle	387
23.2.4.2.2 H ₂ O/O ₃ destruction cycle	388
23.2.4.2.3 CFC/O ₃ destruction cycle	388
23.3 Weather and Pollutants	388
23.3.1 Stability and Inversions	388
23.3.2 Wind and Turbulence in Relation to Air Pollution	389
23.3.3 Pollutant Transformation and Removal	391
23.4 Pollution Trends in the United States	392
Questions and Problems	393
References and Additional Reading	393

CHAPTER 24

Global Change 395

E.P. Glenn and A.D. Matthias

24.1 Introduction	396
24.2 Global Warming and the Greenhouse Effect	397
24.2.1 The Greenhouse Effect	397
24.2.2 Effects of Greenhouse Gas Emissions on the Global Climate	401

24.3	Other Global Changes	403
24.3.1	Acid Rain	403
24.3.2	Atmospheric Ozone	404
24.3.3	Deforestation	405
24.3.4	Desertification	406
24.3.5	Depletion of Ocean Fish Stocks	407
24.3.6	Coastal Degradation	408
24.4	Solutions to the Problems of Global Environmental Change	409
	Questions and Problems	411
	References and Additional Reading	411

PART 5

WASTE AND WATER TREATMENT AND MANAGEMENT

CHAPTER 25

Industrial and Municipal Solid Waste Treatment and Disposal 415

J.F. Artola

25.1	Introduction	416
25.2	Relevant Regulations for Industrial and Municipal Solid Wastes	417
25.3	Major Forms of Industrial Wastes	417
25.4	Treatment and Disposal of Industrial Wastes	419
25.4.1	Gas and Particulate Emissions	419
25.4.2	Chemical Precipitation	419
25.4.3	Flocculation, Coagulation, Dewatering, Filtration-Decanting, Drying	420
25.4.4	Stabilization (Neutralization) and Solidification	420
25.4.5	Oxidation	420
25.4.6	Landfilling	421
25.4.7	Landfarming of Refinery Sludges and Oilfield Wastes	421
25.4.8	Deep-Well Injection of Liquid Wastes	421
25.4.9	Incineration	422
25.4.10	Stockpiling, Tailings, and Muds	423
25.5	Reuse of Industrial Wastes	423
25.5.1	Metals Recovery	423
25.5.2	Energy Recovery	423
25.5.3	Industrial Waste Solvents	423
25.5.4	Industrial Waste Reuse	423
25.6	Treatment and Disposal of Municipal Solid Waste	424
25.6.1	Municipal Solid Waste	424
25.6.2	Modern Sanitary Landfills	425
25.6.3	Reduction of MSW	426
25.7	Pollution Prevention	426
	Questions and Problems	427
	References and Additional Reading	428

CHAPTER 26

Municipal Wastewater Treatment 429

C.P. Gerba and J.L. Pepper

26.1	The Nature of Wastewater (Sewage)	430
26.2	Modern Wastewater Treatment	432

26.2.1	Primary Treatment	432
26.2.2	Secondary Treatment	432
26.2.2.1	Trickling filters	432
26.2.2.2	Conventional activated sludge	435
26.2.2.3	Nitrogen removal by the activated sludge process	436
26.2.2.4	Phosphorus removal by activated sludge process	436
26.2.3	Tertiary Treatment	437
26.2.4	Removal of Pathogens by Sewage Treatment Processes	437
26.2.5	Removal of Organics and Inorganics by Sewage Treatment Processes	439
26.3	Oxidation Ponds	439
26.4	Septic Tanks	441
26.5	Land Application of Wastewater	443
26.6	Wetlands and Aquaculture Systems	445
26.7	Sludge Processing	446
26.7.1	Stabilization Technologies	447
26.7.1.1	Aerobic digestion	447
26.7.1.2	Anaerobic digestion	447
26.7.2	Sludge Processing to Produce Class A Biosolids	448
26.7.2.1	Composting	448
26.7.2.2	Lime and heat treatment	449
	Questions and Problems	449
	References and Additional Reading	450

CHAPTER 27

Land Application of Biosolids and Animal Wastes 451

J.L. Pepper and C.P. Gerba

27.1	Biosolids and Animal Wastes: A Historical Perspective and Current Outlook	452
27.2	The Nature of Wastewater (Sewage)	452
27.3	Wastewater (Sewage) Treatment	453
27.3.1	Class A versus Class B Biosolids	453
27.4	Methods of Land Application of Biosolids	453
27.5	Benefits of Land Application of Biosolids	456
27.5.1	Biosolids as a Source of Plant Nutrients	456
27.5.2	Biosolid Impact on Soil Physical and Chemical Properties	456
27.5.3	Reduced Pollution	457
27.6	Hazards of Land Application of Biosolids	457
27.6.1	Site Restrictions	457
27.6.2	Nitrates and Phosphates	457
27.6.3	Metals and Organics	457
27.6.4	Emerging Chemicals of Concern	459
27.6.5	Pathogens	460
27.6.5.1	Exposure via air	460
27.6.5.2	Exposure via groundwater	460
27.6.5.3	Exposure via soil	460
27.7	Sources of Animal Wastes	464
27.8	Nonpoint Versus Point Source Pollution	465
27.9	Benefits of Land Application of Animal Wastes	465
27.10	Hazards of Land Application of Animal Wastes	466
27.11	Public Perceptions of Land Application	466
	Questions and Problems	467
	References and Additional Reading	467

CHAPTER 28

Drinking Water Treatment and Water Security 468

C.P. Gerba, K.A. Reynolds, and J.L. Pepper

28.1	Water Treatment Processes	469
28.2	Disinfection	471
28.3	Factors Affecting Disinfectants	472
28.4	Halogens	473
28.4.1	Chlorine	473
28.4.2	Chloramines	474
28.4.3	Chlorine Dioxide	474
28.4.4	Ozone	475
28.4.5	Ultraviolet Light	475
28.5	Disinfection By-Products	477
28.6	Residential Water Treatment	478
28.6.1	Residential Water Contamination	479
28.6.2	Treatment Deficiencies	479
28.6.3	Point-of-Use Water Treatment Technology	481
28.7	Water Security	482
28.7.1	Potential Terrorist Attacks	482
28.7.2	Real-Time Monitoring	482
28.8	Monitoring Community Water Quality	485
	Questions and Problems	485
	References and Additional Reading	486

PART 6

EMERGING ISSUES IN POLLUTION SCIENCE

CHAPTER 29

Genetically Engineered Crops and Microbes 489

C. Reusing, G. Grass, and J.L. Pepper

29.1	Introduction to Nucleic Acids	490
29.2	Recombinant DNA Technology	490
29.3	Transfer of Nucleic Acid Sequences from One Organism to Another (Cloning)	490
29.4	Chemical Synthesis, Sequencing and Amplification of DNA	492
29.4.1	DNA Synthesis	492
29.4.2	DNA Sequencing	493
29.4.3	PCR Amplification	493
29.5	Heterologous Gene Expression in Pro- and Eukaryotes	493
29.6	Genetically Engineered Plants for Agriculture	494
29.6.1	Insect Resistance	494
29.6.2	Virus Resistance	495
29.6.3	Herbicide Resistance	495
29.6.4	Fungus and Bacterial Resistance	495
29.7	Genetically Engineered Plants for Remediation	495
29.7.1	Metal Remediation via Plants	495
29.7.2	Organic Remediation via Plants	496
29.8	Microbial-Assisted Remediation	496
29.8.1	Genetic Engineering of Biodegradative Pathways	497
29.8.2	Radiation Resistant Degraders	497
29.9	Potential Problems Due to Genetically Modified Organisms	497

29.10	Summary	498
	Questions and Problems	498
	References and Additional Reading	498

CHAPTER 30

Antibiotic-Resistant Bacteria and Gene Transfer 499

C. Reusing and J.L. Pepper

30.1	Why Are Antibiotics An Issue?	500
30.2	Classification and Function of Antibiotics	500
30.3	Development of Bacterial Antibiotic Resistance	501
30.4	Transfer of Genetic Material by Horizontal Gene Transfer	501
30.5	Prevalent Environments Favoring HGT	501
30.6	Isolation and Detection of Antibiotic-Resistant Bacteria	502
30.7	Incidence of Antibiotic-Resistant Bacteria in Various Environments	502
30.7.1	Environmental Samples and Food	502
30.7.2	Hospitals	503
30.7.3	Feedlots	504
30.8	Gene Transfer Between Bacteria—How Prevalent Is It?	504
30.8.1	Environmental Samples	504
30.9	Summary and Conclusions	505
	Questions and Problems	505
	References and Additional Reading	505

CHAPTER 31

Pharmaceuticals and Endocrine Disruptors 506

R. Arnold, D. Quattrud, C.P. Gerba, and J.L. Pepper

31.1	Endocrine Disruptors and Hormones	507
31.2	Significance of EDCs in Water	507
31.3	Incidence of EDCs in Water	508
31.4	Fate and Transport of Estrogenic Compounds in Municipal Wastewater	511
31.5	Methods for Measuring Estrogenic Activity in Water	512
31.6	What are the Risk of EDCs?	514
	Questions and Problems	515
	References and Additional Reading	515

CHAPTER 32

Epilogue: Is the Future of Pollution History? 516

J.L. Pepper, C.P. Gerba, and M.L. Brusseau

32.1	The Role of Government in Controlling Pollution	517
32.2	Research Priorities Necessary to Protect Human Health	517
32.3	Pollution Prevention of Earth, Air, and Water	517
32.4	Is the Future of Pollution History?	518
	References and Additional Reading	520

Index 521