

# TABLE OF CONTENTS

---

INTRODUCTORY CHAPTERS . . . . .	1
<b>1: ENVIRONMENTAL SCIENCE AND THE TECHNOLOGICAL CONNECTION . . . . .</b>	<b>3</b>
1.1. What Is Environmental Science? . . . . .	3
1.2. Environmental Science, Technology, and Society . . . . .	6
1.3. Water . . . . .	7
1.4. Air and the Atmosphere . . . . .	7
1.5. Earth . . . . .	8
1.6. Life . . . . .	9
1.7. Ecology . . . . .	9
1.8. Matter and Cycles of Matter . . . . .	10
1.9. Energy and Cycles of Energy . . . . .	11
1.10. Human Impact and Pollution . . . . .	15
1.11. Technology and the Problems It Poses . . . . .	17
1.12. Solutions Offered By Science and Technology . . . . .	18
1.13. Units . . . . .	20
Chapter Summary . . . . .	19
Questions and Problems . . . . .	23
Literature Cited . . . . .	26
Supplementary References . . . . .	26
<b>2: CHEMISTRY AND ENVIRONMENTAL CHEMISTRY . . . . .</b>	<b>29</b>
2.1. Introduction . . . . .	29
2.2. Atoms, the Building Blocks of Matter . . . . .	29
2.3. Elements and the Periodic Table . . . . .	31
2.4. Chemical Bonds and Compounds . . . . .	34
2.5. Quantity of Matter: the Mole . . . . .	37
2.6. Chemical Reactions and Equations . . . . .	38
2.7. Physical Properties and States of Matter . . . . .	38
2.8. Thermal Properties . . . . .	41
2.9. Acids, Bases, and Salts . . . . .	41
2.10. Organic Chemistry . . . . .	43
2.11. Hydrocarbons . . . . .	44
2.12. Functional Groups and Classes of Compounds . . . . .	49
2.13. Environmental Chemistry . . . . .	50
2.14. Aquatic Chemistry . . . . .	50
2.15. The Geosphere and Soil . . . . .	53
2.16. The Atmosphere and Atmospheric Chemistry . . . . .	54
Chapter Summary . . . . .	56
Questions and Problems . . . . .	60
Literature Cited . . . . .	61
Supplementary References . . . . .	61

# Environmental Science and Technology

3: BIOLOGY AND BIOCHEMISTRY.....	63
3.1. Introduction .....	63
3.2. Biology .....	66
3.3. Monera .....	68
3.4. Protista.....	69
3.5. Fungi .....	70
3.6. Plantae .....	72
3.7. Animalia.....	72
3.8. Control In Organisms .....	75
3.9. Nutrition and Metabolism.....	78
3.10. Reproduction and Heredity.....	78
3.11. Biochemistry.....	78
3.12. Proteins.....	82
3.13. Carbohydrates.....	83
3.14. Lipids.....	85
3.15. Enzymes.....	88
3.16. Nucleic Acids .....	91
Chapter Summary.....	93
Questions and Problems.....	94
Supplementary References.....	
4: THE ANTHROSPHERE AND THE ENVIRONMENT.....	95
4.1. Introduction .....	95
4.2. Where Humans Live .....	95
4.3. How Humans Move .....	97
4.4. How Humans Communicate.....	98
4.5. What Humans Consume .....	99
4.6. Infrastructure.....	100
4.7. Technology and Engineering .....	102
4.8. Acquisition of Raw Materials .....	106
4.9. Manufacturing.....	108
4.10 Human Impact and Environmental Pollution .....	112
Questions and Problems.....	115
Literature Cited .....	116
Supplementary References.....	116
WATER .....	117
5: CHARACTERISTICS OF WATER AND BODIES OF WATER.....	119
5.1. Introduction .....	119
5.2. Distribution of Water: the Hydrologic Cycle .....	120
5.3. The Properties of Water, A Unique Substance.....	124
5.4. Standing Bodies of Water.....	126
5.5. Flowing Water.....	128
5.6. Groundwater.....	129
5.7. Water Supply and Resources.....	130
5.8. Impoundment and Transfer of Water.....	132
5.9. Water Use and Consumption.....	133
5.10. Water Technology and Industrial Use.....	134
Chapter Summary.....	137

Questions and Problems . . . . .	138
Literature Cited . . . . .	139
Supplementary References . . . . .	139
<b>6: AQUATIC BIOLOGY, MICROBIOLOGY, AND CHEMISTRY . . . . .</b>	<b>141</b>
6.1. Aquatic Life . . . . .	141
6.2. Life In the Ocean. . . . .	143
6.3. Life At the Interface of Seawater With Fresh Water and With Land . . . . .	143
6.4. Freshwater Life. . . . .	144
6.5. Microorganisms In Water. . . . .	146
6.6. Microorganisms and Elemental Transitions. . . . .	149
6.7. Microbial Degradation of Organic Matter. . . . .	151
6.8. Acid-Base Phenomena In Aquatic Chemistry. . . . .	153
6.9. Phase Interactions and Solubility . . . . .	156
6.10. Oxidation-Reduction . . . . .	160
6.11. Metal Ions and Calcium In Water. . . . .	161
6.12. Complexation and Speciation of Metals . . . . .	163
Chapter Summary. . . . .	164
Questions and Problems. . . . .	167
Supplementary References. . . . .	168
<b>7: WATER POLLUTION . . . . .</b>	<b>169</b>
7.1. Nature and Types of Water Pollutants. . . . .	169
7.2. Elemental Pollutants. . . . .	170
7.3. Heavy Metal. . . . .	171
7.4. Metalloids . . . . .	174
7.5. Organically Bound Metals and Metalloids. . . . .	174
7.6. Inorganic Species. . . . .	175
7.7. Algal Nutrients and Eutrophication. . . . .	176
7.8. Acidity, Alkalinity, and Salinity. . . . .	178
7.9. Oxygen, Oxidants, and Reductants . . . . .	179
7.10. Organic Pollutants . . . . .	179
7.11. Radionuclides In the Aquatic Environment . . . . .	187
Chapter Summary. . . . .	190
Questions and Problems. . . . .	193
Literature Cited . . . . .	195
Supplementary References . . . . .	195
<b>8: WATER TREATMENT. . . . .</b>	<b>197</b>
8.1. Water Treatment and Water Use. . . . .	197
8.2. Municipal Water Treatment . . . . .	197
8.3. Treatment of Water For Industrial Use. . . . .	198
8.4. Sewage Treatment . . . . .	199
8.5. Industrial Wastewater Treatment . . . . .	203
8.6. Removal of Solids . . . . .	204
8.7. Removal of Calcium and Other Metals. . . . .	205
8.8. Removal of Dissolved Organics . . . . .	207
8.9. Removal of Dissolved Inorganics. . . . .	208
8.10. Sludge. . . . .	210

# Environmental Science and Technology

8.11. Water Disinfection . . . . .	212
8.12. Natural Water Purification Processes . . . . .	213
Chapter Summary . . . . .	215
Questions and Problems . . . . .	218
Literature Cited . . . . .	221
Supplementary References . . . . .	221
THE ATMOSPHERE . . . . .	223
9: METEOROLOGY AND CHARACTERISTICS OF THE ATMOSPHERE . . . . .	225
9.1. Importance of the Atmosphere . . . . .	225
9.2. Composition of the Atmosphere . . . . .	227
9.3. Regions and Stratification of the Atmosphere . . . . .	230
9.4. Energy Transfer In the Atmosphere . . . . .	232
9.5. Atmospheric Mass Transfer, Meteorology, and Weather . . . . .	237
9.6. Inversions and Air Pollution . . . . .	238
9.7. Global Aspects of Weather and Climate . . . . .	239
9.8. Microclimate . . . . .	240
9.9. Atmospheric Chemistry . . . . .	241
9.10. Atmospheric Particles . . . . .	242
Chapter Summary . . . . .	245
Questions and Problems . . . . .	246
Supplemental References . . . . .	246
10: ATMOSPHERIC CHEMISTRY . . . . .	247
10.1. Introduction To Atmospheric Chemistry . . . . .	247
10.2. Photochemical Processes . . . . .	248
10.3. Chemical Processes and Chain Reactions In the Atmosphere . . . . .	251
10.4. Oxidation Processes In the Atmosphere . . . . .	252
10.5. Acid-Base Reactions In the Atmosphere . . . . .	254
10.6. Ions In the Atmosphere . . . . .	255
10.7. Evolution of the Atmosphere . . . . .	256
10.8. Reactions of Atmospheric Oxygen . . . . .	257
10.9. Reactions of Atmospheric Nitrogen . . . . .	260
10.10. Atmospheric Carbon Dioxide . . . . .	261
10.11. Atmospheric Water . . . . .	262
10.12. Atmospheric Particles and Atmospheric Chemistry . . . . .	262
Chapter Summary . . . . .	263
Questions and Problems . . . . .	265
Supplemental References . . . . .	266
11: AIR POLLUTION AND ITS CONTROL . . . . .	267
11.1. Introduction . . . . .	267
11.2. Particles In the Atmosphere . . . . .	268
11.3. Carbon Monoxide . . . . .	273
11.4. Sulfur Dioxide and Gaseous Sulfur Compounds . . . . .	273
11.5. Gaseous Nitrogen Compounds In the Atmosphere . . . . .	276
11.6. Fluorine, Chlorine, and Their Gaseous Compounds . . . . .	278
11.8. Pollutant Hydrocarbons . . . . .	280
11.9. Oxygen-Containing Organic Compounds . . . . .	281

11.10. Organohalide Compounds . . . . .	283
11.11. Organosulfur Compounds . . . . .	285
11.12. Organonitrogen Compounds . . . . .	285
Chapter Summary . . . . .	287
Questions and Problems . . . . .	289
Literature Cited . . . . .	290
Supplementary References . . . . .	290
<b>12: THE ENDANGERED GLOBAL ATMOSPHERE . . . . .</b>	<b>293</b>
12.1. Anthropogenic Change In the Atmosphere. . . . .	293
12.2. Greenhouse Gases and Global Warming . . . . .	294
12.3. Drought and Desertification. . . . .	297
12.4. Acid Rain. . . . .	298
12.5. Ozone Layer Destruction. . . . .	301
12.6. Photochemical Smog . . . . .	303
12.7. Nuclear Winter . . . . .	310
12.8. Visitors From Space . . . . .	312
12.9. What Is To Be Done? . . . . .	313
Chapter Summary . . . . .	316
Questions and Problems. . . . .	319
Literature Cited . . . . .	320
Supplementary References. . . . .	321
<b>EARTH. . . . .</b>	<b>323</b>
<b>13: THE GEOSPHERE . . . . .</b>	<b>324</b>
13.1. Introduction. . . . .	324
13.2. The Nature of Solids In the Geosphere . . . . .	327
13.3. Physical Form of the Geosphere . . . . .	331
13.4. Internal Processes. . . . .	333
13.5. Surface Processes . . . . .	335
13.6. Sediments. . . . .	337
13.7. Interaction With the Atmosphere and Hydrosphere. . . . .	337
13.8. Life Support By the Geosphere. . . . .	339
13.9. Soil . . . . .	339
13.10. Geochemistry. . . . .	340
13.11. Water On and In the Geosphere . . . . .	342
13.12. Economic Geology. . . . .	344
13.13. Engineering Geology . . . . .	345
Chapter Summary . . . . .	346
Questions and Problems. . . . .	348
Literature Cited . . . . .	349
Supplementary References. . . . .	349
<b>14: SOIL . . . . .</b>	<b>351</b>
14.1. Soil and Agriculture . . . . .	351
14.2. The Nature of Soil . . . . .	352
14.3. Acid-Base and Ion Exchange Reactions In Soils . . . . .	357
14.4. Macronutrients In Soil. . . . .	357
14.5. Nitrogen, Phosphorus, and Potassium In Soil. . . . .	358

## Environmental Science and Technology

14.6. Micronutrients In Soil . . . . .	362
14.7. Wastes and Pollutants In Soil . . . . .	363
14.8. <i>Soil Loss and Deterioration</i> . . . . .	365
14.9. Genetic Engineering and Agriculture . . . . .	367
14.10. Agriculture and Health . . . . .	369
Chapter Summary. . . . .	370
Questions and Problems. . . . .	372
Literature Cited . . . . .	373
Supplementary References. . . . .	373
<b>15: ENVIRONMENTAL GEOLOGY AND GEOSPHERIC POLLUTION . . . . .</b>	<b>375</b>
15.1. Introduction. . . . .	375
15.2. Earthquakes . . . . .	376
15.3. Volcanoes . . . . .	378
15.4. Surface Earth Movement. . . . .	379
15.5. <i>Stream and River Phenomena</i> . . . . .	381
15.6. Phenomena At the Land/Ocean Interface. . . . .	382
15.7. Phenomena At the Land/Atmosphere Interface . . . . .	384
15.8. Effects of Ice . . . . .	386
15.9. Effects of Human Activities. . . . .	386
15.10. <i>Air Pollution and the Geosphere</i> . . . . .	388
15.11. Water Pollution and the Geosphere. . . . .	389
15.12. <i>Waste Disposal and the Geosphere</i> . . . . .	390
15.13. The Geosphere and Health. . . . .	392
15.14. Land Use. . . . .	393
Chapter Summary. . . . .	395
Questions and Problems. . . . .	397
Literature Cited. . . . .	398
Supplementary References. . . . .	398
<b>16: GEOSPHERIC RESOURCES . . . . .</b>	<b>399</b>
16.1. Introduction. . . . .	399
16.2. Geospheric Sources of Useful Minerals. . . . .	400
16.3. Evaluation of Mineral Resources . . . . .	402
16.4. Extraction and Mining . . . . .	402
16.5. Metals . . . . .	404
16.6. Nonmetal Mineral Resources . . . . .	407
16.7. How Long Will Essential Minerals Last? . . . . .	409
16.8. What Can Be Done About Mineral Shortages? . . . . .	410
Chapter Summary. . . . .	412
Questions and Problems . . . . .	414
Supplementary References. . . . .	415
<b>LIFE . . . . .</b>	<b>417</b>
<b>17: ECOSYSTEMS AND BIOLOGICAL COMMUNITIES. . . . .</b>	<b>419</b>
17.1. Life and the Biosphere . . . . .	419
17.2. Ecology and Life Systems . . . . .	421
17.3. What Is A Biological Community? . . . . .	423
17.4. Physical Characteristics and Conditions . . . . .	424

17.6. Species . . . . .	426
17.7. Populations . . . . .	427
17.8. Survival of Life Systems, Productivity, Diversity, and Resilience . . . . .	429
17.9. Relationships Among Species . . . . .	431
17.10. Changing Communities . . . . .	433
17.11. Human Effects . . . . .	435
17.12. Human Actions To Preserve and Improve Life On Earth . . . . .	436
17.13. Laws and Regulations . . . . .	438
Chapter Summary . . . . .	439
Questions and Problems . . . . .	441
Literature Cited . . . . .	442
Supplementary References . . . . .	442
<b>18: BIOTRANSFORMATIONS AND BIODEGRADATION . . . . .</b>	<b>445</b>
18.1. Introduction . . . . .	445
18.2. Bioconcentration . . . . .	446
18.3. Bioconcentration and Biotransfer Factors . . . . .	447
18.4. Biodegradation . . . . .	449
18.5. Enzymatic Processes In Biodegradation . . . . .	452
18.6. Biodegradation of Wastes In Water and Soil . . . . .	454
Chapter Summary . . . . .	456
Questions . . . . .	458
Literature Cited . . . . .	459
Supplementary References . . . . .	459
<b>19: BIOGEOCHEMICAL CYCLES . . . . .</b>	<b>461</b>
19.1. Matter and Cycles of Matter . . . . .	461
19.2. The Carbon Cycle . . . . .	464
19.3. The Nitrogen Cycle . . . . .	466
19.4. The Oxygen Cycle . . . . .	468
19.5. The Phosphorus Cycle . . . . .	469
19.6. The Sulfur Cycle . . . . .	471
Chapter Summary . . . . .	472
Questions and Problems . . . . .	474
Literature Cited . . . . .	474
Supplementary References . . . . .	475
<b>20: TOXICOLOGY AND TOXICOLOGICAL CHEMISTRY . . . . .</b>	<b>477</b>
20.1. Introduction To Toxicology and Toxicological Chemistry . . . . .	477
20.2. Dose-Response Relationships . . . . .	480
20.3. Relative Toxicity . . . . .	481
20.4. Reversibility and Sensitivity . . . . .	482
20.5. Xenobiotic and Endogenous Substances . . . . .	483
20.6. Toxicological Chemistry . . . . .	483
20.7. Kinetic Phase and Dynamic Phase . . . . .	485
20.8. Teratogenesis, Mutagenesis, Carcinogenesis, Immune System Effects, and Reproductive Effects . . . . .	488
20.9. Health Hazards . . . . .	494
Chapter Summary . . . . .	496
Questions and Problems . . . . .	498

# Environmental Science and Technology

Literature Cited . . . . .	500
Supplementary References . . . . .	500
TECHNOLOGY . . . . .	503
21: TECHNOLOGY, MANUFACTURING, TRANSPORTATION, AND COMMUNICATION . . . . .	505
21.1. Introduction . . . . .	505
21.2. Technology . . . . .	506
21.3. Agriculture—the Most Basic Industry . . . . .	507
21.4. Raw Materials and Mining . . . . .	508
21.5. Materials Science . . . . .	510
21.6. Automation . . . . .	511
21.7. Robotics . . . . .	512
21.8. Computers and Technology . . . . .	513
21.9. Transportation . . . . .	514
21.10. Information and Communication . . . . .	516
21.11. High Tech . . . . .	518
21.12. Closing the Loop: Industrial Ecology and Sustainable Development . . . . .	520
Questions and Problems . . . . .	526
Literature Cited . . . . .	527
Supplementary References . . . . .	527
22: ENERGY AND RESOURCE UTILIZATION . . . . .	529
22.1. Introduction . . . . .	529
22.2. Economics: the Broader View Including Environment and Resources . . . . .	530
22.3. Mining and Mineral Resources . . . . .	532
22.4. Wood — A Major Renewable Resource . . . . .	532
22.5. The Energy Problem . . . . .	534
22.6. World Energy Resources . . . . .	534
22.7. Energy Conservation . . . . .	535
22.8. Energy Conversion Processes . . . . .	536
22.9. Petroleum and Natural Gas . . . . .	537
22.10. Coal . . . . .	540
22.11. Nuclear Fission Power . . . . .	543
22.12. Nuclear Fusion Power . . . . .	546
22.13. Geothermal Energy . . . . .	547
22.14. The Sun: An Ideal Energy Source . . . . .	547
22.15. Energy From Biomass . . . . .	549
22.14. Future Energy Sources . . . . .	551
Chapter Summary . . . . .	552
Questions and Problems . . . . .	554
Literature Cited . . . . .	555
Supplementary References . . . . .	555
23: WASTES FROM THE ANTHROSPHERE . . . . .	557
23.1. Introduction . . . . .	557
23.2. Classification of Hazardous Substances and Wastes . . . . .	559



23.3. Flammable and Combustible Substances . . . . .	561
23.4. Reactive Substances. . . . .	564
23.5. Corrosive Substances. . . . .	566
23.6. Toxic Substances . . . . .	567
23.7. Physical Forms and Segregation of Wastes . . . . .	567
23.8. Hazardous Wastes In the Environment . . . . .	568
23.9. Hazardous Wastes In the Geosphere . . . . .	571
23.10. Hazardous Wastes In the Hydrosphere . . . . .	573
23.11. Hazardous Wastes In the Atmosphere . . . . .	575
23.12. Hazardous Wastes In the Biosphere. . . . .	577
Chapter Summary. . . . .	580
Questions and Problems. . . . .	584
Literature Cited . . . . .	586
Supplemental References . . . . .	586
<b>24: WASTE MINIMIZATION, TREATMENT, AND DISPOSAL . . . . .</b>	<b>589</b>
24.1. Introduction . . . . .	589
24.2. Waste Reduction and Minimization . . . . .	590
24.3. Recycling . . . . .	591
24.4. Physical Methods of Waste Treatment . . . . .	593
24.5. Chemical Treatment: An Overview . . . . .	597
24.7. Thermal Treatment Methods . . . . .	602
24.8. Biodegradation of Wastes . . . . .	606
24.9. Land Treatment and Composting . . . . .	607
24.10. Preparation of Wastes For Disposal . . . . .	608
24.11. Ultimate Disposal of Wastes . . . . .	611
24.12. Leachate and Gas Emissions. . . . .	614
24.13. <i>In Situ</i> Treatment. . . . .	615
Chapter Summary. . . . .	618
Questions and Problems . . . . .	622
Literature Cited . . . . .	624
Supplementary References . . . . .	624