

Contents

The Authors X

Preface XI

1	Definition, History, Discipline	1
1.1	Definition of Environmental Engineering	1
1.2	History and Development of Environmental Engineering	3
1.3	From Environmental Chemistry and Technology to Environmental Engineering: Understanding and Diversifying Anthropogenic Environmental Influences	20
1.3.1	Meaning of Pollutant Degradation	26
1.3.2	Substances and Their Sources	43
1.3.3	Transport and Chemical Alteration of Environmental Chemicals	50
1.3.4	Reactions and Effects	53
1.3.5	Examples of Lipophilic Behavior, Accumulation and Toxicity: Kinds and Reasons of Effects Caused by Organotin Compounds	55
1.3.6	The Term “Heavy Metals” and Its (Purported) Chemical and Toxicological Ramifications	57
1.4	How to Determine Environmental Pollution	59
1.4.1	From Methods of Trace Analysis up to Understanding the Underlying Processes	59
1.4.1.1	Inorganic and Organic Compounds	63
1.4.1.2	Speciation and Concentration	65
1.4.1.3	Quality Control of Analysis	66
1.4.1.4	Accreditation of Laboratories	68
1.4.2	Physical Methods in Chemical and Environmental Analysis, Modeling Ecosystems and the Role of Ecotoxicology in Integrative Environmental Sciences	70
1.4.2.1	Analytical Chemistry	71
1.4.2.2	Geographical Information Systems	72
1.4.2.3	Biotest–Biological and Ecotoxicological Implications	74
1.4.2.4	Locating Soil Pollution Sites by Geoelectric and Other Means	77

1.5	Biological System of the Elements	80
1.5.1	Specificity	85
1.5.2	Essentiality	86
1.5.3	Bioavailability	88
1.5.4	Toxicity	91
1.6	Information and Communication	93
1.6.1	What Is This Thing Called Information?	94
1.6.2	Information Processing and Communication—The Ratio and Relationship between Subjective and Objective Factors in Processes of Recognition	95
1.6.3	Ways of Producing Knowledge Established in Natural Sciences Lead Us Back to Accepting and Integrating Plurality of Views and Opinions	98
1.6.4	Examples from Environmental Research	101
1.6.5	Performance of Brain and Modern Computers; a Comparison—Artificial Intelligence and the Internet	103
1.6.6	Emotional Intelligence	105
1.6.7	How to Shape Dialogic Education Processes (DEP) as a Future Principle of Communication	107
1.7	Ethical Aspects for Society	107
1.7.1	A Market-Based Economy	109
1.7.2	Democracy and Its Limitations	112
1.7.3	Protocol for the Future: Grow along with Your Challenges	114
1.7.3.1	Thoughts on the Future	114
1.7.3.2	International Quality Ends	116
1.7.3.3	Learn How to Learn	117
1.7.3.4	Transborder and International Regions of Education	119
1.7.3.5	Think Tanks Can Be Sites and Means of Smart Conflict Handling and Identify Integrative Solutions for Problems of Society	120
1.7.3.6	How Much Time Is Left for Solutions Taking Care of and Integrating the Present Problems?	120
1.7.3.7	Conclusion	122
2	The Compartments of the Environment—Structure, Function and Chemistry	125
2.1	The Three Environmental Compartments and Their Mutual Interactions: Lessons for Environmental Situation Analysis and Technologies to be Learned from Comparative Planetology	125
2.2	Properties of Earth's Environmental Compartments and Resulting Options to Clean Them	133
2.2.1	Atmosphere	133
2.2.1.1	The Reactor Concept Applied to the Atmosphere	138
2.2.1.2	Structure and Layers of the Atmosphere	140
2.2.1.3	The Atmosphere Acting as a Reactor: the Specific Role(s) of Highly Reactive Species	143
2.2.1.4	Chemical Peculiarities: Acidic and/or Hydrophilic Gases in the Atmosphere	148

2.2.1.5	Air is a Multiphase System	149
2.2.1.6	Catalytic Processes in the Atmosphere	151
2.2.1.7	Chemical Reactivity, Growth and Removal (Precipitation) of Particles from Atmosphere	155
2.2.1.8	Conclusions Concerning Air Quality Integrity	156
2.2.2	Water (Fresh-, Marine-, Groundwater)	156
2.2.2.1	Water as a Medium: Density, Optical and Thermal Properties, and Effects thereof on Biological Processes	157
2.2.2.2	Chemical Properties and Their Variation	161
2.2.2.3	Water as a Multiphase System	163
2.2.2.4	Freshwater, Seawater, Osmotic Pressure, Redox States and Biology	164
2.2.2.5	Non-Equilibria among Different Water Layers Can Promote Chemistry, Biological Processes and Deposition of Materials	169
2.2.2.6	Biogeochemical Cycles in Water, Stoichiometric Ecology and the Design of Sewage Treatment Plants Making Use of Biotechnology	170
2.2.3	Soils and Sediments	173
2.2.3.1	Soil as a Multiphase System	174
2.2.3.2	Important Chemical Features of Soils	177
2.2.3.3	Soil as a Bioreactor	178
2.2.3.4	Gradients Do Form in Soils	180
2.2.3.5	Perturbations of Soil Development	182
2.2.3.6	Implications for Soil Sanitation	183
2.3	A Comparison among Environmental Compartments: Phase Composition, Miscibility toward Key Reactants and Contaminants, Transparency and Biological Activity	190
	Conclusions	195
3	Innovative Technologies	197
3.1	Criteria for Innovation	197
3.1.1	Sustainability	198
3.1.2	National and International Jurisdiction	200
3.1.3	Cost/Benefit Calculations	202
3.2	Examples of Innovative Environmental Technologies	203
3.2.1	Precipitation, Adsorption and Immobilization	205
3.2.1.1	Precipitation	205
3.2.1.2	Adsorption	208
3.2.1.3	Immobilization	211
3.2.2	Redox Potentials, Pourbaix Diagrams and Speciation	212
3.2.3	Reaction Kinetics and Hammett Equation	226
3.2.3.1	When Can Charge Density Patterns Control Kinetics of Entire (Larger) Molecules?	227
3.2.3.2	Chemical Properties of Aromatic Compounds	228
3.2.3.3	Kinetic Modeling of Reactions at Non-aromatic Unsaturated Hydrocarbons by the Taft Equation	235

- 3.2.3.4 Partition of Volatile Aromatics and Their Respective Oxidation Kinetics between Air and Water: Practical Examples from Environmental Chemistry 237
- 3.2.4 Activation Barriers versus Catalysis 240
 - 3.2.4.1 Reaction Kinetics and Mutual Repulsion among Molecules 240
 - 3.2.4.2 Kinetics, Catalysis, Equilibrium 242
 - 3.2.4.3 Homogeneous versus Heterogeneous Catalysis 244
- 3.2.5 Throughflow Equilibria and How to Run a Process 248
 - 3.2.5.1 Equilibrium, Equilibrium Constant and Reaction Kinetics 248
 - 3.2.5.2 From Equilibrium Thermodynamics into Flow Systems: Which Are the Effects by Adding and Removing Substances Steadily? 249
 - 3.2.5.3 Nonlinear Chemical Kinetics Can Occur in Throughflow Systems 251
 - 3.2.5.4 Flow Equilibria in Biology: The Blueprint and Precondition for Biomimetic Processes 252
 - 3.2.5.5 The Hard Way into Flow Equilibrium 254
- 4 Specific Studies 257**
 - 4.1 Atmosphere 258
 - 4.1.1 Bioindication and Biomonitoring 258
 - 4.1.1.1 The Problem 259
 - 4.1.1.2 Definitions 260
 - 4.1.1.3 Using Plants as Bioindicators/Biomonitors 263
 - 4.1.1.4 Comparison of Instrumental Measurements and the Use of Bioindicators with Respect to Harmonization and Quality Control 266
 - 4.1.1.5 Examples of Bioindication/Biomonitoring: Controlling the Atmospheric Deposition of Chemical Elements by Using Mosses and Spanish “Moss” (*Tillandsia usneoides*) 267
 - 4.1.1.6 Conclusion/Outlook: Construction of a Setup for Preventive Healthcare 276
 - 4.1.2 CO₂ Reduction 276
 - 4.1.2.1 The Problem 276
 - 4.1.2.2 Applicable Principles and Technical Solutions 285
 - 4.1.2.3 A Practical Example 291
 - 4.1.2.4 CO₂-based Radiative Forcing versus Other Sources and Distributions of Waste Heat: What about Nuclear Energy? 294
 - 4.1.2.5 Conclusion 295
 - 4.2 Soils and Sediments 296
 - 4.2.1 Phytoremediation 296
 - 4.2.1.1 The Problem 296
 - 4.2.1.2 Purposes of Mitigation of Noxious Effects 297
 - 4.2.1.3 The Use of Certain Plants and Trees to Clean up Soil 299
 - 4.2.1.4 The Efficacy of Bioremediation Has Been Determined Chemically 302
 - 4.2.1.5 Conclusion 304
 - 4.2.2 Ethylenediamine Tetraacetic Acid—Its Chemical Properties, Persistence, Ecological Hazards and Methods of Removal 305

4.2.2.1	The Problem	305
4.2.2.2	Fields and Amounts of EDTA Application	306
4.2.2.3	The Compound and Its Properties: Why a Complexing Agent Makes Trouble	309
4.2.2.4	Principles of Action (Pathways of EDTA Degradation) and Technical Remediation: A Survey of Chances and Obstacles	314
4.2.2.5	Practical Experience	320
4.2.2.6	Conclusion	321
4.3	Water	322
4.3.1	Reactive Walls	322
4.3.1.1	The Problem	322
4.3.1.2	Principles of Action and Practical Solutions	324
4.3.1.3	Conclusion	335
4.3.2	Pharmaceuticals in the Environment—Special Emphasis on Diclofenac (Voltaren™)—An Analgetic Agent with Difficult and Interesting Properties	335
4.3.2.1	The Problem	335
4.3.2.2	Toxicological Effects to Animals	337
4.3.2.3	Novel Methods of Removing Diclofenac	339
4.4	Energy—One of the Biggest Challenges of the Twenty-first Century. The Need for Renewable Energy	342
4.4.1	The Problems	342
4.4.1.1	Energy Depletion of Fossil Fuels	342
4.4.1.2	Climate Protection	346
4.4.1.3	The Role of Nuclear Power	348
4.4.2	Rethinking the Way for Ecological Economics	354
4.4.2.1	Global View of Renewable Energy	355
4.4.2.2	Renewable Energy in Germany and the Planned Nuclear Exit	366
4.4.2.3	The Growth Region Ems Axis, Lower Saxony (Northwestern Germany)	367
4.4.3	Conclusion	371
	Glossary	373
	References	391
	Periodic Table of Elements	415
	Index	417