

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/Biomonitorors | 263 |
| 4.1.1.4 | Comparision 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" (<i>Tillandsia usneoides</i>) | 267 |
| 4.1.1.6 | Conclusion/Outlook: Construction of a Setup for Preventive Healthcare | 276 |
| 4.1.2 | CO ₂ 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 | CO ₂ -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 to 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