

## Contents

|          |   |              |
|----------|---|--------------|
|          | <b>Epigraph</b>   | <i>xv</i>    |
|          | <b>Abbreviations</b>  | <i>xvii</i>  |
|          | <b>Glossary</b>   | <i>xxiii</i> |
|          | <b>Preface</b>  | <i>xxvii</i> |
|          | <b>Acknowledgment</b>                                       | <i>xxix</i>  |
| <b>1</b> | <b>Introduction</b>   | <i>1</i>     |
| 1.1      | Chemistry and Development                                   | <i>1</i>     |
| 1.2      | Pollution and Contamination                                 | <i>3</i>     |
| 1.3      | Chemical pollutants   | <i>4</i>     |
| 1.4      | Pollutants in the Environment                               | <i>6</i>     |
| 1.5      | Concept of Emerging Pollutants                              | <i>7</i>     |
| 1.6      | Historical Background of Emerging Pollutants                | <i>8</i>     |
| 1.7      | Classification of Emerging Pollutants                       | <i>9</i>     |
| 1.8      | Regulations and Normatives                                  | <i>11</i>    |
|          | References  | <i>13</i>    |
| <b>2</b> | <b>Occurrence and Removal of Environmental Pollutants</b>   | <i>19</i>    |
| 2.1      | Introduction  | <i>19</i>    |
| 2.2      | Pollutants in the Atmosphere                                | <i>19</i>    |
| 2.3      | Pollutants in Ground and Surface Waters: Quality Parameters | <i>20</i>    |
| 2.4      | Pollutants in the Ground and Soil                           | <i>23</i>    |
| 2.5      | Sources of Emerging Pollutants or CECs                      | <i>23</i>    |
| 2.5.1    | CECs from WWTPs   | <i>24</i>    |
| 2.5.2    | CECs in Wastewater Biosolids                                | <i>25</i>    |
| 2.5.3    | CECs from Agriculture and Livestock                         | <i>25</i>    |
| 2.5.4    | CECs in Soils   | <i>26</i>    |
| 2.5.5    | CECs in Groundwater   | <i>27</i>    |
| 2.5.6    | CECs in Landfill  | <i>28</i>    |
| 2.5.7    | CECs in Seawater  | <i>29</i>    |
| 2.6      | Treatment of CECs   | <i>30</i>    |
| 2.6.1    | Treatment of CECs in WWTPs                                  | <i>30</i>    |
| 2.6.1.1  | Physical Methods  | <i>30</i>    |
| 2.6.1.2  | Chemical Methods  | <i>31</i>    |

|          |   |           |
|----------|---|-----------|
| 2.6.1.3  | Biological Methods  | 32        |
| 2.6.2    | Treatment of CECs in Landfill Leachates                           | 32        |
| 2.6.3    | Wastewater Reuse  | 33        |
| 2.7      | Toxicity of CECs  | 34        |
|          | References  | 37        |
| <b>3</b> | <b>Detection and Analysis of Chemical Pollutants</b>              | <b>43</b> |
| 3.1      | Introduction  | 43        |
| 3.2      | Sample Preparation  | 43        |
| 3.2.1    | Extraction with Organic Solvents                                  | 44        |
| 3.2.2    | Microwave-Assisted Extraction (MAE)                               | 44        |
| 3.2.3    | Dispersive Liquid–Liquid Microextraction (DLLME)                  | 45        |
| 3.2.4    | Vortex-Assisted Liquid–Liquid Microextraction (VALLME)            | 45        |
| 3.2.5    | Single-Drop Microextraction                                       | 45        |
| 3.2.6    | Solid-Phase Extraction (SPE)                                      | 46        |
| 3.2.7    | Solid-Phase Microextraction (SPME)                                | 47        |
| 3.2.8    | Dispersive Solid Phase Microextraction (DSPE/DSPME)               | 47        |
| 3.2.9    | Matrix Solid-Phase Dispersion (MSPD)                              | 48        |
| 3.2.10   | Passive Sampling  | 48        |
| 3.2.11   | Immunosorbent Extraction  | 49        |
| 3.2.12   | Extraction of Volatile Compounds                                  | 49        |
| 3.2.13   | Online Extraction   | 50        |
| 3.2.14   | Extraction with Nanomaterials                                     | 50        |
| 3.2.15   | Sampling from Biological Materials                                | 50        |
| 3.3      | Analytical Methods for Identifying EPs                            | 50        |
| 3.3.1    | Separation Methods  | 52        |
| 3.3.2    | Characterization Methods  | 52        |
|          | References  | 53        |
| <b>4</b> | <b>Overview of Pharmaceutical Products as Emerging Pollutants</b> | <b>57</b> |
| 4.1      | Introduction  | 57        |
| 4.2      | Therapeutic Classes of PCs Detected in the Environment            | 59        |
| 4.3      | Sources of PCs in the Environment                                 | 59        |
| 4.4      | Detection and Analysis of PCs in the Environment                  | 61        |
| 4.5      | Occurrence of PCs in the Environment                              | 63        |
| 4.5.1    | Pharmaceuticals in WWTPs  | 64        |
| 4.5.2    | PCs in Hospital Wastewater  | 64        |
| 4.5.3    | PCs in Surface Water and Groundwater                              | 66        |
| 4.5.4    | PCs in Seawater   | 68        |
| 4.5.5    | PCs in Drinking Water   | 68        |
| 4.5.6    | PCs in Soil   | 69        |
| 4.6      | Ecotoxicological Aspects of PCs on Environment                    | 72        |
| 4.7      | Removal of PCs  | 75        |
| 4.7.1    | Conventional Systems for Removing PCs in Water-Treatment Systems  | 76        |
| 4.7.2    | Adsorption on Activated Carbon                                    | 77        |

|          |  |            |
|----------|--|------------|
| 4.7.3    | Technologies Based on Advanced Oxidation Processes (AOPs)                | 77         |
| 4.7.3.1  | AOPs Based on Ozone  | 77         |
| 4.7.3.2  | AOPs Based on UV Radiation   | 77         |
| 4.7.3.3  | AOPs Based on $\gamma$ -Radiation  | 79         |
| 4.7.3.4  | Electro-Oxidation with and without Active Chlorine Generation            | 79         |
| 4.8      | Conclusions  | 79         |
|          | References   | 80         |
| <b>5</b> | <b>Therapeutic Classes of PCs in the Environment</b>                     | <b>103</b> |
| 5.1      | Introduction   | 103        |
| 5.2      | Antibiotics (ABs)  | 105        |
| 5.2.1    | Chemical Classes of Antibiotics  | 105        |
| 5.2.2    | The Problem of the Resistance of Antibiotics                             | 114        |
| 5.2.3    | Antibiotics in the Environment   | 114        |
| 5.2.4    | Degradation/Removal of Antibiotics                                       | 116        |
| 5.2.5    | An Example of ABs in the Environment: Sulfonamides                       | 116        |
| 5.3      | Estrogens and Hormonal Compounds   | 117        |
| 5.3.1    | Estrogens in the Environment   | 117        |
| 5.4      | Drugs with Endocrine Disruption Properties                               | 120        |
| 5.5      | Analgesic, Anti-inflammatory, Antiarthritic, and Antirheumatic Compounds | 124        |
| 5.5.1    | Non-Narcotic Analgesics Drugs  | 124        |
| 5.5.2    | Narcotic Analgesics Drugs  | 125        |
| 5.5.3    | Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)                           | 125        |
| 5.5.3.1  | Diclofenac   | 126        |
| 5.5.3.2  | Ibuprofen  | 127        |
| 5.5.3.3  | Naproxen   | 128        |
| 5.5.3.4  | Ketoprofen   | 128        |
| 5.5.3.5  | Mefenamic Acid   | 128        |
| 5.6      | Psychotropic Drugs   | 128        |
| 5.6.1    | Environmental Impact of Psychotropic Drugs                               | 129        |
| 5.7      | Antiepileptic Drugs  | 131        |
| 5.8      | $\beta$ -Blockers/Diuretics  | 133        |
| 5.8.1    | $\beta$ -Blockers in the Environment                                     | 133        |
| 5.9      | Lipid Regulators   | 135        |
| 5.10     | $\beta_2$ -Sympathomimetic Drugs   | 136        |
| 5.11     | Antidiabetic Drugs   | 138        |
| 5.12     | X-Ray Contrast Drugs: Diagnostic Agents                                  | 139        |
| 5.13     | Cytostatic PCs: Antineoplastics  | 140        |
| 5.14     | Veterinary Drugs: Anthelmintics  | 141        |
| 5.14.1   | Classes of Anthelmintics   | 142        |
| 5.14.2   | Anthelmintics in the Environment   | 145        |
|          | References   | 146        |
| <b>6</b> | <b>Illegal Drugs, Occurrence, and Fate in Environment</b>                | <b>167</b> |
| 6.1      | Introduction   | 167        |
| 6.2      | What is an Illicit Drug?   | 168        |

|          |   |            |
|----------|---|------------|
| 6.2.1    | Differences Between Licit and Illicit Drugs as Environmental Contaminants | 169        |
| 6.3      | Classes of Illicit Drugs  | 171        |
| 6.3.1    | Opiates   | 171        |
| 6.3.1.1  | Opiates in the Environment  | 171        |
| 6.3.2    | Other Central Nervous System Depressants                                  | 172        |
| 6.3.3    | Central Nervous System Stimulants: Cocaine                                | 173        |
| 6.3.3.1  | Cocaine in the Environment  | 173        |
| 6.3.4    | Central-Nervous-System Stimulants: Amphetamine-Type Substances (ATs)      | 173        |
| 6.3.4.1  | Amphetamine-Type Substances in the Environment                            | 176        |
| 6.3.5    | Hallucinogens   | 176        |
| 6.3.6    | Cannabis  | 177        |
| 6.3.6.1  | Cannabis and its Metabolites in the Environment                           | 177        |
| 6.4      | Analytical Methods for Detecting of Illicit Drugs                         | 177        |
| 6.5      | Illicit Drugs in the Environmental Compartments                           | 178        |
| 6.5.1    | Illicit Drugs in Wastewater   | 179        |
| 6.5.2    | Illicit Drugs in Surface Water  | 181        |
| 6.5.3    | Illicit Drugs in Seawater   | 182        |
| 6.5.4    | Illicit Drugs in Drinking Water   | 182        |
| 6.5.5    | Illicit Drugs in Soil   | 183        |
| 6.5.6    | Illicit Drugs in Ambient Air  | 184        |
| 6.5.7    | Illicit Drugs on Currency Notes   | 184        |
| 6.6      | Estimation of Drug Consumption in Communities (Sewage-Based Epidemiology) | 185        |
|          | References  | 187        |
| <b>7</b> | <b>Pesticides as Pollutants</b>   | <b>197</b> |
| 7.1      | Introduction  | 197        |
| 7.2      | Classification of Pesticides  | 198        |
| 7.2.1    | Classification of Pesticides by Activity                                  | 199        |
| 7.2.2    | Classification of Pesticides by Toxicity                                  | 199        |
| 7.2.3    | Classification of Pesticides by Chemical Structure                        | 200        |
| 7.3      | Organic Pesticides  | 200        |
| 7.3.1    | Organochlorine Pesticides   | 200        |
| 7.3.2    | Organophosphorus Pesticides   | 202        |
| 7.3.3    | Carbamates  | 203        |
| 7.3.4    | Thiocarbamates  | 204        |
| 7.3.5    | Pyrethrins and Pyrethroids  | 205        |
| 7.3.6    | Phenoxy Carboxylic Acids  | 205        |
| 7.3.7    | Triazines   | 206        |
| 7.3.8    | Uracils and Ureas   | 207        |
| 7.3.9    | Azoles and Related Compounds  | 208        |
| 7.3.10   | Morpholine Derivatives  | 209        |
| 7.3.11   | Bipyridines   | 210        |
| 7.3.12   | Amides  | 211        |
| 7.3.13   | Neonicotinoids  | 211        |

|          |   |            |
|----------|---|------------|
| 7.3.14   | Other Classes of Herbicides   | 213        |
| 7.3.14.1 | Pyridazines and Pyridazinones   | 213        |
| 7.3.14.2 | Nitrile Herbicides  | 213        |
| 7.3.14.3 | Dinitroanilines   | 213        |
| 7.3.14.4 | Pyridine Herbicides   | 214        |
| 7.3.14.5 | Pyrimidines   | 214        |
| 7.4      | Pesticides in the Environment   | 215        |
| 7.4.1    | Degradation and Transformation of Pesticides in Environment             | 217        |
| 7.4.2    | Pesticide TPs in the Environment  | 217        |
| 7.4.3    | Analysis of Pesticides  | 218        |
| 7.4.4    | Pesticides in Water   | 220        |
| 7.5      | An Example of National Survey: Pesticides in Italy                      | 221        |
| 7.6      | An Example of Pesticides in the Environment: Neonicotinoid Insecticides | 223        |
|          | References  | 224        |
| <b>8</b> | <b>Lifestyle Products as Emerging Pollutants</b>                        | <b>233</b> |
| 8.1      | Introduction  | 233        |
| 8.2      | Stimulants  | 233        |
| 8.2.1    | Caffeine  | 234        |
| 8.2.1.1  | Caffeine in the Environment   | 234        |
| 8.2.2    | Nicotine  | 236        |
| 8.2.2.1  | Cigarettes in the Environment   | 237        |
| 8.2.2.2  | Nicotine in the Environment   | 237        |
| 8.3      | Food Additives  | 238        |
| 8.3.1    | Toxicology of Food Additives  | 239        |
| 8.3.2    | Global Regulation on Food Additives                                     | 240        |
| 8.4      | Classes of Food Additives   | 241        |
| 8.4.1    | Substances with Nutritive and Other Dietary Effects                     | 241        |
| 8.4.1.1  | Vitamins and Provitamins  | 241        |
| 8.4.1.2  | Amino Acids   | 242        |
| 8.4.1.3  | Minerals and Trace Elements   | 242        |
| 8.4.1.4  | Bulking Agents  | 242        |
| 8.4.2    | Substances with Stabilizing Effects                                     | 242        |
| 8.4.2.1  | Preservatives   | 242        |
| 8.4.2.2  | Antioxidants  | 242        |
| 8.4.2.3  | Synergists and Sequestrants   | 243        |
| 8.4.2.4  | Packaging Gases   | 243        |
| 8.4.2.5  | Stabilizers   | 244        |
| 8.4.3    | Substances with Sensory Effects (Organoleptic Substances)               | 245        |
| 8.4.3.1  | Coloring Agents   | 245        |
| 8.4.3.2  | Color Stabilizers   | 245        |
| 8.4.3.3  | Bleaching Agents  | 246        |
| 8.4.3.4  | Intense Sweeteners  | 246        |
| 8.4.3.5  | Nutritive Sweeteners  | 246        |
| 8.4.3.6  | Acidulants  | 246        |

|          |  |            |
|----------|--|------------|
| 8.4.3.7  | Substances with a Salty Taste                              | 246        |
| 8.4.3.8  | Substances with a Bitter Taste                             | 246        |
| 8.4.3.9  | Substances with an Alkaline Taste                          | 246        |
| 8.4.3.10 | Flavor Enhancers   | 246        |
| 8.4.3.11 | Spices and Flavorings                                      | 247        |
| 8.4.3.12 | Chewing-Gum Bases  | 247        |
| 8.4.4    | Substances as Processing Aids                              | 247        |
| 8.4.4.1  | Extractants  | 247        |
| 8.4.4.2  | Clarifying Agents  | 248        |
| 8.4.4.3  | Filter Aids  | 248        |
| 8.4.4.4  | Propellants  | 248        |
| 8.4.4.5  | Cooling Agents and Cryogenes                               | 248        |
| 8.4.4.6  | Mold-Release Agents  | 248        |
| 8.4.4.7  | Antifoaming Agents   | 248        |
| 8.4.4.8  | Acidity Regulators   | 249        |
| 8.4.4.9  | Emulsifying Salts  | 249        |
| 8.4.4.10 | Dough Conditioners and Flour Improvers                     | 249        |
| 8.4.4.11 | Leavening Agents   | 249        |
| 8.4.4.12 | Enzymes  | 249        |
| 8.4.4.13 | Microbial Cultures   | 249        |
| 8.4.5    | Dietary Supplements  | 249        |
| 8.5      | Food Additives as Emerging Organic Contaminants            | 250        |
| 8.6      | Antioxidants in the Environment                            | 250        |
| 8.7      | Artificial Sweeteners in the Environment                   | 251        |
| 8.7.1    | Metabolism of Artificial Sweeteners                        | 252        |
| 8.7.2    | Occurrence of the Artificial Sweeteners in the Environment | 253        |
| 8.7.3    | Artificial Sweeteners as Pollution Markers                 | 255        |
| 8.7.3.1  | Ecotoxicological Studies on Sucralose                      | 256        |
|          | References   | 257        |
| <b>9</b> | <b>Industrial Chemicals as Emerging Pollutant</b>          | <b>265</b> |
| 9.1      | Introduction   | 265        |
| 9.2      | Perfluorinated Alkyl Substances (PFASs)                    | 266        |
| 9.2.1    | PFASs in the Environment                                   | 268        |
| 9.2.2    | Analysis of PFASs  | 269        |
| 9.2.3    | Toxicology and Regulation of PFASs                         | 270        |
| 9.3      | Plasticizers   | 271        |
| 9.3.1    | Bisphenol A (BPA)  | 271        |
| 9.3.1.1  | BPA in the environment                                     | 272        |
| 9.3.1.2  | Toxicology and regulation of bisphenol A (BPA)             | 273        |
| 9.3.2    | Phthalates   | 274        |
| 9.3.2.1  | Phthalates in the environment                              | 276        |
| 9.3.2.2  | Toxicology and regulation of phthalates                    | 279        |
| 9.3.3    | <i>N</i> -Butylbenzenesulfonamide (NBBSA)                  | 280        |
| 9.3.3.1  | NBBSA in the Environment                                   | 280        |
| 9.4      | Flame Retardants   | 281        |
| 9.5      | Brominated Flame Retardants (BFRs)                         | 281        |

|           |   |            |
|-----------|---|------------|
| 9.5.1     | Polybrominated Diphenyl Ether (PBDE)                                  | 282        |
| 9.5.2     | Tetrabromobisphenol A (TBBPA)   | 289        |
| 9.5.3     | Polybrominated Biphenyls (PBBs)                                       | 291        |
| 9.5.4     | Hexabromobenzene (HBB)  | 291        |
| 9.5.5     | Hexabromocyclododecane (HBCD)   | 292        |
| 9.5.6     | Decabromodiphenyl Ethane (DBDPE)                                      | 292        |
| 9.5.7     | 1,2-Bis(2,4,6-Tribromophenoxy)ethane (BTBPE)                          | 292        |
| 9.6       | Polychlorinated Alkanes (C <sub>10</sub> –C <sub>13</sub> )           | 292        |
| 9.6.1     | Use and Consumption of PCAs   | 293        |
| 9.6.2     | Properties of PCAs  | 294        |
| 9.6.3     | PCAs in the Environment   | 295        |
| 9.6.4     | Toxicology and Regulations of PCAs                                    | 296        |
| 9.7       | Organophosphate Flame Retardants (OPFRs)                              | 297        |
| 9.7.1     | Use and Demand of OPFRs   | 297        |
| 9.7.2     | Properties of OPFRs   | 298        |
| 9.7.3     | OPFRs in the Environment  | 299        |
| 9.7.4     | Toxicology and Regulations of OPFRs                                   | 300        |
| 9.8       | Corrosion Inhibitors: Benzothiazoles and Benzotriazoles               | 302        |
| 9.8.1     | Benzotriazoles  | 302        |
| 9.8.2     | Benzothiazoles  | 303        |
| 9.9       | Polycyclic Aromatic Hydrocarbons (PAHs)                               | 304        |
| 9.10      | Volatile Organic Compounds (VOCs)                                     | 306        |
| 9.10.1    | Hazardous Compounds Originating from Oil Products                     | 308        |
| 9.10.2    | Gasoline Additives: MTBE  | 309        |
| 9.11      | Other Industrial Chemicals  | 310        |
| 9.11.1    | Siloxanes   | 310        |
| 9.11.2    | 1,4-Dioxane   | 311        |
| 9.11.3    | Nitroaromatic Compounds   | 311        |
| 9.11.3.1  | 2,4-Dinitrophenol   | 312        |
| 9.11.4    | Naphthenic Acids  | 312        |
| 9.11.5    | Other Chlorinated Compounds   | 312        |
| 9.11.6    | Perchlorate   | 313        |
|           | References  | 314        |
| <b>10</b> | <b>Surfactants in the Environment</b>                                 | <b>341</b> |
| 10.1      | Introduction  | 341        |
| 10.2      | Structure and Classification  | 342        |
| 10.3      | Nonionic Surfactants  | 343        |
| 10.3.1    | Fatty Alcohols  | 344        |
| 10.3.2    | Alcohol Ethoxylates   | 344        |
| 10.3.3    | Ethylene Oxide/Propylene Oxide-Block Polymers                         | 345        |
| 10.3.4    | Alkylphenol Ethoxylates   | 345        |
| 10.3.5    | Ethoxylated Oils and Fats   | 346        |
| 10.3.6    | Alkanolamides   | 346        |
| 10.3.7    | Esters  | 347        |
| 10.3.8    | Nonionic Surfactants Derived from Carbohydrates and Related Compounds | 347        |

|          |  |     |
|----------|--|-----|
| 10.3.8.1 | Alkyl Polyglucosides   | 348 |
| 10.3.8.2 | Sorbitan Esters  | 348 |
| 10.3.8.3 | Alkyl Carbohydrate Esters  | 349 |
| 10.3.9   | Ester/Ether Surfactants  | 349 |
| 10.3.9.1 | Ethoxylated Glycol and Glycerol Esters   | 350 |
| 10.3.9.2 | Ethoxylated Sorbitan Esters  | 350 |
| 10.3.9.3 | Ethoxylated Pentaerythritol Esters   | 350 |
| 10.3.9.4 | Polyglycerol Monoester   | 350 |
| 10.3.10  | Amine Oxides   | 351 |
| 10.4     | Anionic Surfactants  | 351 |
| 10.4.1   | Carboxylic Acids Derivatives   | 351 |
| 10.4.1.1 | Carboxylic Acid Salts  | 351 |
| 10.4.1.2 | Ether Carboxylic Acids   | 352 |
| 10.4.2   | Sulfuric and Sulfonic Acid Derivatives   | 353 |
| 10.4.2.1 | Alkyl Sulfates   | 353 |
| 10.4.2.2 | Alkyl Sulfonates   | 353 |
| 10.4.2.3 | Alkylbenzene Sulfonates  | 354 |
| 10.4.2.4 | Sulfosuccinates  | 354 |
| 10.4.2.5 | Sulfo Fatty Acid Esters  | 355 |
| 10.4.2.6 | Fatty Acid Isethionates and Taurides   | 355 |
| 10.4.3   | Phosphoric Acid Esters and Salts   | 356 |
| 10.4.4   | Acylamino Acids and Salts  | 356 |
| 10.5     | Cationic Surfactants   | 357 |
| 10.5.1   | Alkyl Amines   | 357 |
| 10.5.2   | Alkylimidazolines  | 358 |
| 10.5.3   | Quaternary Ammonium Compounds  | 358 |
| 10.5.3.1 | Tetraalkyl(-aryl) Ammonium Salts   | 358 |
| 10.5.3.2 | Heterocyclic Ammonium Salts  | 358 |
| 10.5.4   | Ethoxylated Alkyl Amines   | 359 |
| 10.5.5   | Esterified Quaternaries  | 360 |
| 10.6     | Amphoteric Surfactants   | 360 |
| 10.6.1   | Acyl Ethylenediamines and Derivatives  | 360 |
| 10.6.2   | <i>N</i> -Alkyl Amino Acids or Imino Diacids                                       | 361 |
| 10.6.3   | Alkyl Betaines   | 361 |
| 10.7     | Alkoxyated Polysiloxanes   | 362 |
| 10.8     | Fluorosurfactants  | 362 |
| 10.9     | Toxicological Aspects (Environmental Impact) of Surfactants                        | 363 |
| 10.9.1   | Environmental Impact of Alkylphenol Ethoxylates (APEOs)                            | 364 |
| 10.10    | Environmental Occurrence of the Surfactants  | 365 |
| 10.10.1  | Alkylphenol Ethoxylates (APEOs), and Their Degradation Products in the Environment | 366 |
| 10.10.2  | LASs and Their Degradation Products  | 368 |
| 10.11    | Biodegradation of Surfactants  | 368 |
| 10.11.1  | Aerobic Biodegradation   | 371 |
| 10.11.2  | Anerobic Biodegradation  | 371 |
|          | References   | 373 |



|           |  |            |
|-----------|--|------------|
| <b>11</b> | <b>Personal-Care Products</b>                                      | <b>385</b> |
| 11.1      | Introduction   | 385        |
| 11.2      | Musks: Fragrances  | 385        |
| 11.3      | Biocides   | 388        |
| 11.3.1    | Triclosan  | 389        |
| 11.3.2    | Chlorophene and Dichlorophene                                      | 391        |
| 11.3.3    | Parabens   | 392        |
| 11.4      | Sunscreen Agents: UV Filters                                       | 396        |
| 11.4.1    | Analysis of UV-Filters   | 397        |
| 11.4.2    | UV-Filters as Endocrine Disrupters                                 | 398        |
| 11.4.3    | UV Filters in the Environment                                      | 399        |
| 11.4.3.1  | Benzophenone Derivatives in the Environment                        | 401        |
| 11.4.3.2  | 3-Benzylidene- and 4-Methylbenzylidene-Camphor in the Environment  | 402        |
| 11.5      | Insect Repellents: <i>N,N</i> -diethyl- <i>m</i> -toluamide (DEET) | 403        |
| 11.6      | Other PCPs   | 405        |
|           | References   | 407        |
| <br>      |  |            |
| <b>12</b> | <b>Water Disinfectant By-Products</b>                              | <b>423</b> |
| 12.1      | Introduction   | 423        |
| 12.2      | Wastewater Treatments  | 424        |
| 12.2.1    | Water Reuse  | 425        |
| 12.2.2    | Drinking Water Treatments  | 425        |
| 12.2.3    | Water Disinfection   | 425        |
| 12.3      | Disinfection Methods   | 426        |
| 12.3.1    | Chlorination   | 426        |
| 12.3.2    | Chlorine Dioxide   | 427        |
| 12.3.3    | Chloramination   | 428        |
| 12.3.4    | Sodium Dichloroisocyanurate  | 428        |
| 12.3.5    | Ozonization  | 429        |
| 12.3.6    | UV Irradiation   | 429        |
| 12.3.7    | Other Methods of Disinfection                                      | 429        |
| 12.4      | Water DPBs   | 430        |
| 12.4.1    | DBPs from Chlorination   | 430        |
| 12.4.2    | Other Halogenated DBPs   | 432        |
| 12.4.3    | Nitrogenous DBPs   | 433        |
| 12.4.4    | Carbonaceous DPBs from Ozonation                                   | 435        |
| 12.5      | Methods of Analysis of DBPs  | 435        |
| 12.6      | Disinfection By-Products (DBPs) in Drinking Water                  | 437        |
| 12.7      | Disinfection By-Products in Swimming Pools                         | 438        |
| 12.8      | Changes in Oxidation/Disinfection Strategies                       | 439        |
| 12.9      | Toxicological Studies on DBPs                                      | 441        |
| 12.10     | Regulations/Guidelines of DBPs in Drinking Water                   | 442        |
|           | References   | 444        |
| <br>      |  |            |
| <b>13</b> | <b>Other Contaminants of Emerging Concern</b>                      | <b>453</b> |
| 13.1      | Introduction   | 453        |

|          |   |            |
|----------|---|------------|
| 13.2     | Nanotechnology as a Pollution Source                          | 453        |
| 13.2.1   | Detection of NMs  | 454        |
| 13.2.2   | NMs in the Environment  | 456        |
| 13.2.3   | Toxicity of NMs   | 457        |
| 13.3     | Microplastics (MPs)   | 458        |
| 13.4     | Toxic Elements and Elemental Species                          | 460        |
| 13.4.1   | Arsenic (As)  | 462        |
| 13.4.2   | Cadmium (Cd)  | 462        |
| 13.4.3   | Lead (Pb)   | 463        |
| 13.4.4   | Mercury (Hg)  | 464        |
| 13.4.5   | Manganese (Mn)  | 465        |
| 13.4.6   | Antimony (Sb)   | 466        |
| 13.4.7   | Technology-Critical Elements                                  | 466        |
| 13.4.8   | Radionuclides   | 467        |
| 13.5     | Biotoxins   | 467        |
| 13.5.1   | Mycotoxins  | 468        |
| 13.5.2   | Algal Toxins  | 469        |
| 13.5.3   | Other Marine Toxins   | 472        |
| 13.5.3.1 | Cyclic Imines   | 472        |
| 13.5.3.2 | Ciguatoxins   | 472        |
| 13.5.3.3 | Azaspiracids (AZAs)   | 472        |
| 13.5.3.4 | Tetrodotoxin (TTX)  | 472        |
| 13.5.3.5 | Palitoxins  | 473        |
| 13.5.4   | Bacterial Toxins  | 473        |
| 13.5.5   | Naturally Occurring Toxins in Vegetable Foodstuffs            | 473        |
| 13.6     | Microorganisms  | 473        |
| 13.7     | Contaminants on the Horizon: Ionic Liquids and Prions         | 474        |
|          | References  | 475        |
| <b>A</b> | <b>InChI Key for the Most Relevant Compounds in this Book</b> | <b>487</b> |
|          | <b>Index</b>  | <b>493</b> |