Contents

List of contributing authors ---- XI

Rameshwar Yadav Hiranmai and Murugesan Kamaraj

1 Occurrence, fate, and toxicity of emerging contaminants in a diverse ecosystem ---- 1 1.1 Introduction ---- 1 1.2 Sources and fate of ECs --- 3 1.3 Occurrence and Impacts of EC — 6 1.3.1 Agrochemicals — 6 1.3.2 Personal care products (PCPs) — 8 1.3.3 Pharmaceuticals — 9 1.3.4 Polyaromatic hydrocarbons (PAHs) —— 11 Nanoparticles (NPs) --- 12 1.3.5 1.3.6 Microplastics (MPs) --- 15 1.3.7 Endocrine disruptor chemicals (EDCs) — 17 1.4 Toxicity of ECs --- 18 Conclusion — 19 1.5

Shanmugasundaram Shyamalagowri, Natarajan Shanthi, Jagadeesan Manjunathan, Murugesan Kamaraj, Arumugam Manikandan and Jevaseelan Aravind

2 Techniques for the detection and quantification of emerging contaminants —— 25

- 2.1 Introduction 26
- 2.2 Quality assurance/quality control (QA/QC) in sampling 27
- 2.3 Extraction and cleanup techniques for ECs 29
- 2.3.1 Liquid-liquid extraction (LLE) 30

References — 20

- 2.3.2 Solid-phase extraction (SPE) —— 31
- 2.3.3 Solid-liquid extraction (SLE) 32
- 2.3.4 Ultrasonication assisted extraction (UAE) 33
- 2.3.5 Pressurized liquid extraction (PLE) 34
- 2.3.6 Microwave-assisted extraction (MAE) 34
- 2.3.7 QuEChERS (quick, easy, cheap, effective, rugged, and safe) method —— 35
- 2.4 Instrumental analysis of ECs 35
- 2.4.1 Chromatography and Spectrometry (MS) analysis 35
- 2.4.2 Inductively coupled plasma mass spectrometry (ICP-MS) —— 41
- 2.4.3 Other techniques —— **42**
- 2.5 Conclusion 46
 References 47



| Dayana | ı Priyadharhsini Stephen and Suresh Babu Palanisamy |
|--------|---|
| 3 | Advances in biopolymer composites and biomaterials for the removal of |
| | emerging contaminants — 53 |
| 3.1 | Introduction —— 54 |
| 3.2 | Quantification of biopolymer —— 56 |
| 3.3 | Properties of biopolymers —— 57 |
| 3.4 | Carbon-based biopolymers —— 58 |
| 3.5 | Microalgae based biopolymers —— 58 |
| 3.6 | Chitosan 60 |
| 3.7 | Biopolymers derived from bacterial species — 61 |
| 3.8 | Carbon nanotubes (CNTs) — 62 |
| 3.9 | Application of biopolymers in bioremediation —— 63 |
| 3.9.1 | Biopolymers as biosorbents —— 63 |
| 3.9.2 | Water treatment applications — 63 |
| 3.9.3 | Desalination —— 64 |
| 3.9.4 | Oil-water separation —— 64 |
| 3.9.5 | Removal of heavy metal ions —— 65 |
| 3.9.6 | Removal of evolving contaminants —— 66 |
| 3.9.7 | Removal of dye compounds —— 67 |
| 3.10 | Conclusions —— 68 |
| | References —— 69 |
| Amare | Tiruneh Adugna |
| 4 | Development in nanomembrane-based filtration of emerging |
| • | contaminants — 75 |
| 4.1 | Introduction to nanomembrane-based filtration — 75 |
| 4.2 | Types and fabrication methods of nanomembrane for filtration — 76 |
| 4.2.1 | Types of nanomembrane for filtration —— 76 |
| 4.2.2 | Fabrication methods of nanomembrane for filtration —— 77 |
| 4.3 | Separation mechanisms by the NF membrane — 79 |
| 4.3.1 | Size exclusion —— 81 |
| 4.3.2 | Charge exclusion —— 81 |
| 4.3.3 | Physicochemical interactions —— 82 |
| 4.4 | Recent developments in nanomembrane-based filtration for emerging |
| | contaminants —— 83 |
| 4.4.1 | Removal of antibiotics and pesticides —— 84 |
| 4.4.2 | Removal of pharmaceuticals —— 89 |
| 4.4.3 | Personal care products —— 90 |
| 4.4.4 | Removal of organics pollutants —— 90 |
| 4.5 | Conclusions —— 91 |

References — 91

Vaanmathy Pandiyaraj, Ankita Murmu, Saravana Kumari Pandy, Murugan Sevanan, and Shanamitha Arjunan

| 5 | Metal nanoparticles and its application on phenolic and heavy metal |
|----------|--|
| | pollutants — 101 |
| 5.1 | Introduction — 101 |
| 5.1.1 | Metal nanoparticles —— 103 |
| 5.2 | Heavy metals —— 104 |
| 5.2.1 | Application of metal nanoparticles on heavy metals —— 105 |
| 5.3 | Phenolic pollutants — 109 |
| 5.3.1 | Effect of metal nanoparticles on phenolic pollutants — 110 |
| 5.3.2 | Photocatalytic degradation of phenol using nanoparticles — 110 |
| 5.3.3 | Electrocatalytic degradation of phenol using nanoparticles — 113 |
| 5.3.4 | Biocatalytic degradation of phenol using nanoparticles —— 113 |
| 5.3.5 | Microgel – nanoparticles based remediation —— 114 |
| 5.4 | Conclusions —— 115 |
| | References —— 115 |
| Smilin E | Bell Aseervatham G, Arul Ananth Devanesan and Doulathunnisa Jaffar Ali |
| 6 | Nanobiocatalysts and photocatalyst in dye degradation —— 121 |
| 6.1 | Introduction —— 121 |
| 6.2 | Nanoparticles in dye degradation —— 123 |
| 6.3 | Hybrid and heterogeneous photocatalyst —— 126 |
| 6.4 | Photocatalysts and nano photocatalyst in dye degradation — 127 |
| 6.5 | Nanocatalyst in industrial effluents — 129 |
| 6.6 | Biocatalyst and nanobiocatalyst as dye degrading agent —— 130 |
| 6.7 | Green synthesis of biopolymer nanobiocatalyst — 132 |
| 6.8 | Conclusions —— 136 |
| | References —— 137 |
| Bhuvan | eswari Meganathan, Thirumalaisamy Rathinavel and Suriyaprabha Rangaraj |
| 7 | Trends in microbial degradation and bioremediation of emerging |
| | contaminants —— 145 |
| 7.1 | Introduction —— 145 |
| 7.2 | Persistence of emerging contaminant in the environment —— 147 |
| 7.3 | Conventional methods of treatment and its disadvantages — 148 |
| 7.4 | Microbial sources for degradation of ECs —— 149 |
| 7.4.1 | Microbial biofilms —— 149 |
| 7.4.2 | Microbial consortia —— 151 |
| 7.4.3 | Extremophiles —— 151 |
| 7.4.4 | Microbes as energy source —— 151 |
| 7.4.5 | Bioreactors — 152 |
| 7.4.6 | Microbial immobilization with nanoparticles and |

nanobiomolecules --- 153

VIII — Contents

| 7.4.7 | Genetically modified microbes (GMOs) —— 153 |
|-------|--|
| 7.5 | Microbial process of degrading the emerging pollutants —— 154 |
| 7.5.1 | Bioremediation of ECs —— 154 |
| 7.5.2 | Biodegradation using various types of microbes —— 155 |
| 7.5.3 | Biosorption —— 156 |
| 7.5.4 | Biostimulation, biopiling, and bioaugmentation — 158 |
| 7.5.5 | Rhizoremediation —— 159 |
| 7.6 | Necessity of microbial degradation —— 159 |
| 7.7 | Challenges in microbial degradation —— 160 |
| 7.8 | Scope of microbial degradation of emerging contaminants —— 160 |
| 7.9 | Conclusions —— 161 |
| | References —— 162 |
| | |

Ebrahim M. Abda, Atsede Muleta, Mesfin Tafesse, Sundramurthy Venkatesa Prabhu, and Afework Aemro

| 8 | Recent endeavors in micropial remediation of micro- and |
|-------|---|
| | nanoplastics —— 169 |
| 8.1 | Introduction —— 170 |
| 8.2 | Synthetic plastics and types —— 171 |
| 8.3 | Formation, properties, and analysis of microplastics and |
| | nanoplastics —— 171 |
| 8.4 | Environmental and health implications of micro- and |
| | nanoplastics —— 173 |
| 8.5 | Microbial mediated-degradation mechanisms of microplastics and |
| | nanoplastics pollutants —— 175 |
| 8.6 | Recent endeavors in micro- and nanoplastic microbial |
| | remediation —— 176 |
| 8.6.1 | Exemplary microbes and enzymatic degradation of micro- and |
| | nanoplastics — 176 |
| 8.6.2 | Merits, demerits, and biodegradation assessment — 181 |
| 8.6.3 | The insights into the composition of Epiplastic Organisms: Omics |
| | approach —— 182 |
| 8.6.4 | Technologies for the remediation of micro-nanoplastics waste —— 185 |
| 8.7 | Practical snags and the future direction of research — 188 |
| 8.8 | Concluding remarks —— 189 |
| | References —— 189 |

Prasanth Bhatt, Swamynathan Ganesan, Infant Santhose and Thirumurugan Durairaj

| 9 | Phytoremediation as an effective tool to handle emerging |
|-----|--|
| | contaminants —— 195 |
| 9.1 | Introduction —— 196 |
| 9.2 | Transportation and manufacturing by-products —— 197 |
| 9.3 | Pharmaceutical products —— 201 |
| 9.4 | Personal care products —— 202 |
| 9.5 | Nanomaterials —— 203 |
| 9.6 | Food processing and packaging materials —— 204 |
| 9.7 | Mining by-products —— 205 |
| 9.8 | Batteries and E-waste —— 206 |

9.9 Radioactive elements — 207

Lithium —— 206

9.8.1

9.10 Conclusion and future prospects — 207

Future prospects — 229

Conclusions — 230 References — 230

References —— 208

Venkatesa Prabhu Sundramurthy, Thirumullaivoyal G. Nithya, Chandran Masi, Chinnasamy Gomadurai, and Ebrahim M. Abda

10 Recent advances and prospects for industrial waste management and product recovery for environmental appliances: a review —— 215

| 10.1 | Introduction —— 215 |
|--------|--|
| 10.2 | Classification and characteristics of wastes — 216 |
| 10.3 | Industrial waste —— 217 |
| 10.4 | Waste management practices —— 217 |
| 10.4.1 | Recycling —— 218 |
| 10.4.2 | Techniques for solid waste management —— 218 |
| 10.4.3 | Techniques for liquid waste management —— 220 |
| 10.5 | Exploitation of microorganisms for waste management —— 221 |
| 10.6 | Decomposition —— 223 |
| 10.7 | Valorization of food processing waste by biorefinery technology —— 224 |
| 10.7.1 | Biorefinery from brewer's spent grain (BSG) —— 224 |
| 10.7.2 | Biorefinery from olive waste —— 224 |
| 10.7.3 | Biorefinery from potato peels —— 226 |
| 10.8 | Nutrients recovery from dairy product industries waste —— 226 |
| 10.9 | Energy production from the waste —— 227 |
| 10.10 | Recovery of resources from waste —— 228 |
| 10.11 | Legislation on waste management —— 228 |

10.12

10.13