

Contents

Preface *xi*

Acknowledgments *xiii*

1	Microplastics Formation	1
	<i>Xinxing Zhang, Qinke Cui, and Zhuo Huang</i>	
1.1	Definition of Microplastics	1
1.2	Types of Microplastics	2
1.2.1	Polyethylene	3
1.2.2	Polypropylene	3
1.2.3	Polystyrene	4
1.2.4	Polyvinyl Chloride	4
1.2.5	Polyester	5
1.3	Generation of Microplastics	5
1.3.1	Primary Microplastics	6
1.3.1.1	Industrial	7
1.3.1.2	Consumer	9
1.3.2	Secondary Microplastics	15
1.3.2.1	Plastics-Derived Microplastics	19
1.3.2.2	Rubbers-Derived Microplastics	37
1.3.2.3	Fibers-Derived Microplastics	56
1.3.2.4	Foam-Derived Microplastics	60
	References	71
2	Migration and Transformation of Microplastics	85
	<i>Xue Yu, Xiaorong Luo, Yuhang Ye, Mengke Zhang, Mengyao Xu, Chenglong Han, and Xueqiang Lu</i>	
2.1	Migration and Transformation of Microplastics in Water	85
2.1.1	Microplastics in the Freshwater Environment	85
2.1.1.1	Distribution of Microplastics in the Freshwater Environment	85
2.1.1.2	Migration and Transformation Processes of Microplastics in the Freshwater Environment	86

2.1.2	Microplastics in the Marine Environment	88
2.1.2.1	Distribution of Microplastics in the Marine Environment	88
2.1.2.2	Migration and Transformation Processes of Microplastics in the Marine Environment	88
2.1.3	Influencing Factors of Migration and Transformation of Microplastics in the Water Environment	96
2.1.3.1	Shape of Microplastics	96
2.1.3.2	Size of Microplastics	97
2.1.3.3	Salinity Gradient	97
2.1.3.4	Water Quality and Hydrodynamic Characteristics	98
2.1.3.5	Windage	98
2.1.3.6	Interaction Between Biofilms and Microplastics	99
2.2	Migration and Transformation of Microplastics in Soil	100
2.2.1	Source and Distribution of Microplastics in Soil	100
2.2.1.1	Source of Microplastics in Soil	100
2.2.1.2	Distribution of Microplastics in Soil	102
2.2.2	Migration Pathways of Microplastics in Soil	104
2.2.3	Influencing Factors of Microplastic Migration in Soil	105
2.2.3.1	Characteristics of Microplastics	105
2.2.3.2	Characteristics of Soil	106
2.2.3.3	Bioturbation and Mechanical Disturbance in Soil	107
2.2.3.4	External Environment	108
2.2.4	Transformation of Microplastics in Soil	109
2.2.4.1	Physical Transformation	110
2.2.4.2	Chemical Transformation	110
2.2.4.3	Biodegradation	111
2.2.5	Transfer of Microplastics in the Terrestrial Food Chain	112
2.3	Migration and Transformation of Microplastics in Atmosphere	112
2.3.1	Sources	112
2.3.1.1	Daily Life use Process	113
2.3.1.2	Industrial and Agricultural Production Processes	113
2.3.1.3	Sea- or Soil-mediated Inputs	113
2.3.1.4	Other Sources	114
2.3.2	Flux and Abundance	114
2.3.2.1	Calculation Method of Settling Flux and Influencing Factors	114
2.3.3	Migration Pathways of Microplastics in the Atmosphere	115
2.3.4	Influencing Factors on the Transport of Microplastics in the Atmosphere	115
2.3.4.1	Physicochemical Characteristics of Microplastics	115
2.3.4.2	Meteorological Factors	116
2.3.4.3	Human Factors	117
2.3.4.4	Geographical Location	117
2.3.5	Human Health and Ecological Risks of Atmospheric Microplastics	118
2.3.5.1	Adsorption of Contaminants	118
2.3.5.2	Human Health Risk	119

- 2.3.5.3 Ecological Risk 120
- 2.3.6 Atmospheric Microplastic Transport Simulation 120
- References 121

3 Toxicity and Health Effects of Microplastics 137

Hanyun Zheng, Quanwei Li, Xiongjie Gu, Yaru Qian, Yunxu Shang, Hong Yu, Lihui An, and Feifei Wang

- 3.1 Estuarine and Marine Organisms 137
 - 3.1.1 Plankton 137
 - 3.1.1.1 Enrichment of Microplastics in Plankton 137
 - 3.1.1.2 Toxic Effects of Microplastics on Plankton 138
 - 3.1.2 Benthic Fauna 140
 - 3.1.2.1 Enrichment of Microplastics in Benthic Fauna 140
 - 3.1.2.2 Toxic Effects of Microplastics on Benthic Fauna 141
 - 3.1.3 Marine Fishes 144
 - 3.1.3.1 Enrichment of Microplastics in Marine Fishes 144
 - 3.1.3.2 Toxic Effects of Microplastics on Marine Fishes 144
 - 3.1.4 Marine Mammals 149
 - 3.1.4.1 Enrichment of Microplastics in Marine Mammals 149
 - 3.1.4.2 Toxic Effects of Microplastics on Marine Mammals 150
 - 3.1.5 Seabirds 151
 - 3.1.5.1 Enrichment of Microplastics in Seabirds 151
 - 3.1.5.2 Toxic Effects of Microplastics on Seabirds 152
- 3.2 Freshwater Organisms 153
 - 3.2.1 Plankton 153
 - 3.2.1.1 Phytoplankton 153
 - 3.2.1.2 Zooplankton 157
 - 3.2.2 Freshwater Fishes 161
 - 3.2.2.1 Occurrence of Microplastics in Freshwater Fish 161
 - 3.2.2.2 Ingestion and Excretion of Microplastics 164
 - 3.2.2.3 Toxic Effects of Microplastics on Fish 165
 - 3.2.3 Benthic Organisms 168
 - 3.2.3.1 Occurrence of Microplastics in Benthic Organisms 168
 - 3.2.3.2 Toxic Effects of Microplastics on Benthic Organisms 170
- 3.3 Soil Organisms 172
 - 3.3.1 Effect of Microplastics on Soil Microorganisms 172
 - 3.3.2 Effects of Microplastics on Soil Fauna 174
 - 3.3.3 Effect of Microplastics on Plants 177
- 3.4 Human Health 182
 - 3.4.1 Detection of Microplastics in Human Tissues 182
 - 3.4.1.1 The Detection of Microplastics in Digestive System 182
 - 3.4.1.2 The Detection of Microplastics in Respiratory System 185
 - 3.4.1.3 The Detection of Microplastics in Circulatory System 186
 - 3.4.1.4 The Detection of Microplastics in Reproductive System 186

3.4.2	Health Effects and Toxicity Mechanisms Due to Gastrointestinal Exposures	187
3.4.2.1	The Main Sources of Microplastics Exposure to the Digestive Tract	187
3.4.2.2	Gastrointestinal Exposures and Human Health	191
3.4.2.3	Toxic Mechanisms of Health Damage Caused by Microplastic Gastrointestinal Exposure	192
3.4.3	Health Effects and Toxicity Mechanisms Due to Respiratory Exposures	204
3.4.3.1	Microplastics Accumulation in the Respiratory System	204
3.4.3.2	Respiratory Exposure and Human Health	209
3.4.3.3	Toxic Mechanisms of Health Damage Caused by Microplastic Respiratory Exposure	211
3.4.4	Health Effects and Toxicity in Other Tissues and Cells	219
3.4.4.1	Cell Uptake and Phagocytosis of Microplastics	219
3.4.4.2	Neurotoxicity	221
3.4.4.3	Cytotoxicity and Immune Response	221
3.4.4.4	Germ Cell Toxicity	222
3.4.4.5	Cytotoxicity of Other Tissues	223
3.4.5	Combined Toxicity of Microplastics and Other Pollutants	223
	References	225
4	Solutions to Microplastics Pollution	245
	<i>Li Li, Xuan Wang, Nan Wang, Wu Guo, Quanquan Guo, and Xinkai Li</i>	
4.1	Reduction	246
4.1.1	Legislation and Public Policy	246
4.1.1.1	Restricting Certain Types of Single-use Plastics	247
4.1.1.2	Extending the Producer Responsibility	252
4.1.1.3	Active Use of Post-consumer Recycled Plastic	254
4.1.2	Design	257
4.1.2.1	Design for Reduction	257
4.1.2.2	Design for Reuse	258
4.1.2.3	Design for Recycle	259
4.1.3	Technical Support	260
4.1.3.1	Technologies for High Performance	260
4.1.3.2	Technologies for Optimizing the Apparent Structure	263
4.1.4	Brief Summary	265
4.2	Substitution	265
4.2.1	Biobased Plastics	266
4.2.1.1	Biobased Plastics Derived from Natural Polymers	267
4.2.1.2	Biobased Plastics Polymerized from Natural Monomers	275
4.2.1.3	Plastics Derived from Biosynthesis	278
4.2.1.4	Market Prospects for Biobased Plastics	282
4.2.2	Biodegradable Plastics	282
4.2.2.1	Degradation Mechanisms of Basic Polymers	283
4.2.2.2	Biobased Biodegradable Plastics	284

4.2.2.3	Petrochemical Biodegradable Plastics	287
4.2.2.4	State-of-the-art in Improving Biodegradability of Polymers	291
4.2.2.5	Research Progress in Production of MPs from Biodegradable Plastics	292
4.2.3	Recyclable and Long-life Plastics	292
4.2.3.1	Long-life Polymers	293
4.2.3.2	Closed-loop Recyclable Polymers	296
4.2.4	Brief Summary	297
4.3	Recycling	299
4.3.1	Recyclability Improvement of Plastics	299
4.3.1.1	Strengthening Policy Control	300
4.3.1.2	Design for Recycling	302
4.3.2	Recycling Technologies	304
4.3.2.1	Mechanical Recycling	307
4.3.2.2	Chemical Recycling	321
4.3.2.3	Biocatalytic Recycling	332
4.3.2.4	Energy Recycling	333
4.3.3	Brief Summary	335
4.4	Control in the Environment	336
4.4.1	Strategies and Technologies for Microplastics Remediation	337
4.4.1.1	Physical Methods	337
4.4.1.2	Chemical Methods	347
4.4.1.3	Biological Methods	362
4.4.1.4	Combined Methods	370
4.4.2	Brief Summary	371
4.5	Conclusion	372
	References	373

Index	405
--------------	------------

