## **Contents**

## Preface ix

4.7

4.8

Steroids 91

1	Usage of Pharmaceutical and Personal Care Products 1		
1.1	Pharmaceutical Consumption Trends 9		
	Study Questions 11		
	References 12		
2	Most Prescribed Pharmacouticals and Polated Endnoints 15		
2.1	Most Prescribed Pharmaceuticals and Related Endpoints 15 Antihypertensive and Cardiovascular 16		
2.1	7.2		
2.2	Analgesics and Anti-inflammatory Drugs 29		
2.5	Study Questions 33		
	References 33		
	References 55		
3	Usage of Antimicrobial Agents and Related Endpoints 39		
3.1	Cell Wall Synthesis Inhibiting Antibiotics 41		
3.2	Inhibitors of Protein Synthesis 46		
3.3	Nucleic Acid Synthesis Inhibitors 60		
3.4	Antagonism to Metabolic Processes 67		
3.5	Antibiotics that Disrupt Membrane Integrity 68		
3.6	Other Antimicrobials 69		
	Study Questions 70		
	References 70		
4	Usage of Other Groups of Pharmaceuticals and Related Endpoints 75		
4.1	Gastrointestinal Drugs 76		
4.2	Antidiabetic Drugs 78		
4.3	Diuretics and Electrolytes 79		
4.4	Thyroid System Medication 81		
4.5	Respiratory Drugs 82		
4.6	Oral Contraceptive and Reproductive Therapeutics 84		

Biophosphonates and Other Skeletal Ailment Drugs

90

vi	Contents	
	4.9	Hematologic Drugs 94
	4.10	Nutritional Drugs 94
	4.11	Triptans 95
	4.12	Anesthetics 96
	4.13	Antineoplastics and Immunosuppressants 97
		Study Questions 98
		References 98
	5	Personal Care Products of Environmental Concern 103
	5.1	Fragrances and Musks 104
	5.2	Ultraviolet Light Filters 111
	5.3	Detergents 111
	5.4	Disinfectants 114
		Study Questions 115
		References 116
	6	Detection and Occurrence of PPCPs in the Environment 119
	6.1	Detection of PPCPs in the Environment 123
	6.1.1	Detection Using Instrumentation 126
	6.1.2	Detection Using Bioassays 127
	6.2	Occurrence of PPCPs in Various Environments 131
	6.2.1	Aquatic Systems 133
	6.2.1.1	PPCPs in Wastewater 133
	6.2.1.2	PPCPs in Surface Water 141
	6.2.1.3 6.2.1.4	PPCPs in Groundwater 146 PPCPs in Potable Water 149
	6.2.1.4	Occurrence of PPCPs in Sediments 152
	6.2.3	Occurrence of PPCPs in Soil 152
	6.2.4	PPCPs in Aerial Environments 154
	6.3	Excretion as a Driver of Pharmaceutical Occurrence
		in the Environment 158
		Study Questions 162
		References 163
	7	Ecopharmacokinetics and Ecopharmacodynamics of PPCPs 177
	7.1	Overview of Pharmacokinetics and Pharmacodynamics 178
	7.1.1	PPCP Sorption and Bioavailability in the Environment 188
	7.1.2	Compound Half-life and Clearance 192
	7.2	Degradation of PPCPs in the Environment 196

Degradation of Antibiotics in the Environment 197

Fate of Other Important Groups of Antibiotics 203

Degradation of Quinolone Compounds

Degradation of Tetracyclines 201 Degradation of Macrolides 203

Fate of β-Lactams and Cephalosporins 199

7.2.1

7.2.1.1

7.2.1.2 7.2.1.3

7.2.1.4

7.2.1.5

7.2.2	Degradation of Analgesics and Anti-inflammatory Drugs 204
7.2.3	Degradation of Estrogens and Other Reproductive Hormones 207
7.2.4	Degradation of Other Important Pharmaceuticals 210
7.2.5	Degradation of Surfactants 210
7.3	Role of Physicochemical Factors in the Fate of PPCPs
	in the Environment 211
7.3.1	Molecular Size as an Attribute to Absorption and Persistence 211
7.3.2	Solubility and Hydrolysis 212
7.3.3	Effects of Dissociation, Partitioning, and Lipophilicity
	on Degradability 214
7.3.4	Effects of Moisture and Oxygen to the Fate of PPCPs
	in the Environment 217
7.3.5	Effects of Temperature in PPCP Dynamics and Degradation
	in the Environment 218
7.3.6	Other Determinants of PPCP Fate and Persistence
	in the Environment 219
7.3.6.1	Presence of Other Compounds 219
7.3.6.2	Photolysis of PPCPs 221
	Study Questions 225
	References 226
8	Ecotoxicity of Pharmaceuticals and Personal Care Products 239
8.1	Conventional Assessment of the Risk 245
8.2	Ecological Impact of PPCPs on Microorganisms and Microbial
	Processes 250
8.2.1	Antibiotic Resistance 250
8.2.1.1	Acquisition of Antibiotic Resistance 256
8.2.1.2	Mechanisms of Antibiotic Resistance 256
8.2.2	Biogeochemical Perturbations 257
8.3	Effects of PPCPs on Invertebrates 259
8.4	PPCP Ecotoxicity on Aquatic Organisms 261
8.4.1	Endocrine Disrupters in the Aquatic System 264
8.4.2	Effects of Antibiotic Resistance to Aquatic Organisms 269
8.4.3	Ecotoxicological Effects of Cosmetics on Aquatic Organisms 269
8.4.4	Ecotoxicity of Other PPCPs in Aquatic Organisms 270
8.5	Ecotoxicity of PPCPs on Terrestrial Wildlife 272
8.6	Livestock and Human Health 276
8.6.1	Clinical Antibiotic-resistance Cases 277
8.6.2	PPCP-related Allergic Reactions 282
8.6.3	Endocrine Disruption in Humans and Livestock 283
8.6.4	Is There an Association Between PPCPs in the Environment
	and Some Cancers? 284
8.6.5	Other PPCPs of Concern to Humans and Livestock
	in the Environment 286
8.7	Ecotoxicity of PPCPs on Vegetation 286

/iii	Content

•		
	8.8	General Considerations in Long-term PPCP Toxicity 287 Study Questions 289 References 290
	9	Technologies for Removing and Reducing PPCPs
	0.4	in the Environment 313
	9.1	Conventional Treatment Systems 316
	9.1.1	Primary Treatment 316
	9.1.2	Secondary Treatment 317
	9.1.2.1	· ·
	9.1.2.2	•
	9.1.2.3	± '
	9.2	Advanced Treatment Processes 320
	9.2.1	Advanced Filtration Systems 321
	9.2.1.1	
		Filtration Membranes 328
	9.2.2	
		Chlorination 338
		Ozonation 340
	9.2.3	
	9.2.4	Electrolysis 342
	9.2.5	Advanced Oxidation Processes 344
	9.3	Effect of Wastewater Retention Time on PPCP Removal 346
	9.4	Formulation and Regimen Design for Reduced Environmenta
		Impact 347
	9.5	Source Separation of Urine and Decentralization Needs 348
	9.6	Future Technological Trends 348
		Study Questions 349
		References 350
	10	Guidelines for a Regulatory Framework on PPCPs
	10	in the Environment 357
	10.1	Improving Assessment of the Risks from PPCPs
	10.1	in the Environment 359
	10.2	Effect of Mixtures 363
	10.2	
	10.3	r
	10.4	Use of Quantitative Structure–Activity Relationships in Ecotoxicology 364
	10 5	· · · · · · · · · · · · · · · · · · ·
	10.5	Toxicogenomic Approaches for Guiding Regulations 365 Social Responsibility in Legislation and Making Policy 366
	10.6	7 8
	10.7	Drug Approval and Advertising 371
	10.8	Use of Prescription Records for Mapping PPCPs 372
		Study Questions 373 References 374
		KPIPIPICPS 5/4