

FUNDAMENTALS OF ECOTOXICOLOGY

The Science of Pollution

FOURTH EDITION

Michael C. Newman



CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

Contents

List of Vignettes.....	xiii
Preface.....	xv
Acknowledgments.....	xix
Author	xxi
Guest Authors	xxiii
Chapter 1	
Introduction.....	1
1.1 Historic Need for Ecotoxicology	1
1.2 Current Need for Ecotoxicology Expertise.....	6
1.3 Ecotoxicology.....	22
1.4 Ecotoxicology: A Synthetic Science	23
1.4.1 Introduction.....	23
1.4.2 Science, Technology, and Practice.....	25
1.4.2.1 Scientific Goal.....	26
1.4.2.2 Technological Goal	28
1.4.2.3 Practical Goal.....	29
1.5 Summary.....	30
Suggested Readings	31
Chapter 2	
Major Classes of Contaminants	33
2.1 Introduction.....	33
2.2 Major Classes of Contaminants	34
2.2.1 Inorganic Contaminants.....	34
2.2.1.1 Metals and Metalloids.....	35
2.2.1.2 Organometallic Compounds	39
2.2.1.3 Inorganic Gases.....	40
2.2.1.4 Anionic Contaminants Including Nutrients	40
2.2.2 Organic Contaminants.....	43
2.2.2.1 Hydrochlorofluorocarbons and Chlorofluorocarbons	43
2.2.2.2 Organochlorine Alkenes	44
2.2.2.3 Polycyclic Aromatic Hydrocarbons.....	45
2.2.2.4 Polyhalogenated Benzenes, Phenols, and Biphenyls.....	46
2.2.2.5 Polychlorinated Naphthalenes	47
2.2.2.6 Polychlorinated Dibenzodioxins and Dibenzofurans.....	48
2.2.2.7 Pesticides	48
2.2.2.8 Herbicides.....	70
2.2.2.9 Oxygen-Demanding Compounds	71
2.2.2.10 Other Important Compounds	71
2.2.2.11 Additional Emerging Organic Contaminants of Concern	79
2.2.3 Radiations	83
2.2.3.1 Expressing Radioactivity.....	85
2.2.3.2 Radionuclides	86
2.2.3.3 Ultraviolet Radiation	88
2.2.3.4 Infrared Radiation	89

2.2.4	Genetic Contaminants	89
2.2.5	Nanomaterials	90
2.2.6	Thermal Pollution	92
2.3	Summary	94
2.4	Background Chemistry Concepts and Definitions.....	94
	Suggested Readings	98
 Chapter 3		
	Uptake, Biotransformation, Detoxification, Elimination, and Accumulation	99
3.1	Introduction	99
3.2	Uptake	101
3.2.1	Introduction.....	101
3.2.2	Reaction Order.....	104
3.3	Biotransformation and Detoxification.....	105
3.3.1	General.....	105
3.3.2	Metals and Metalloids.....	105
3.3.3	Organic Compounds	108
3.4	Elimination.....	109
3.4.1	Elimination Mechanisms	109
3.4.2	Modeling Elimination.....	112
3.5	Accumulation	117
3.6	Summary	126
	Suggested Readings	126
 Chapter 4		
	Factors Influencing Bioaccumulation	129
4.1	Introduction	129
4.1.1	General.....	129
4.1.2	Bioavailability	130
4.2	Chemical Qualities Influencing Bioavailability.....	133
4.2.1	Inorganic Contaminants.....	133
4.2.1.1	Bioavailability from Water.....	133
4.2.2	Bioavailability from Solid Phases.....	138
4.2.3	Organic Contaminants	146
4.2.3.1	Bioavailability from Water.....	146
4.2.3.2	Bioavailability from Solid Phases	149
4.3	Biological Qualities Influencing Bioaccumulation	150
4.3.1	Temperature-Influenced Processes	150
4.3.2	Allometry	151
4.3.3	Other Factors.....	154
4.4	Summary	155
	Suggested Readings	155
 Chapter 5		
	Bioaccumulation from Food and Trophic Transfer.....	157
5.1	Introduction	157
5.2	Quantifying Bioaccumulation from Food.....	165
5.2.1	Assimilation from Food.....	165

5.2.2	Trophic Transfer.....	166
5.2.2.1	Defining Trophic Position	166
5.2.2.2	Estimating Trophic Transfer.....	169
5.3	Inorganic Contaminants.....	172
5.3.1	Metals and Metalloids.....	172
5.3.2	Radionuclides.....	176
5.4	Organic Compounds	177
5.5	Summary.....	179
	Suggested Readings	180
 Chapter 6		
	Molecular Effects and Biomarkers	181
6.1	Introduction.....	181
6.2	Organic Compound Detoxification	182
6.2.1	Phase I Transformations	183
6.2.2	Phase II Transformations	192
6.3	Metallothioneins	193
6.4	Stress Proteins	200
6.5	Oxidative Stress and Antioxidant Response	201
6.6	DNA Modification.....	204
6.7	Enzyme Dysfunction and Substrate Pool Shifts	206
6.8	Summary.....	208
	Suggested Readings	208
 Chapter 7		
	Cells, Tissues, and Organs.....	209
7.1	Introduction	209
7.2	General Cytotoxicity and Histopathology	210
7.2.1	Necrosis and Apoptosis.....	211
7.2.2	Inflammation.....	214
7.2.3	Other General Effects	215
7.3	Gene and Chromosome Damage	217
7.4	Cancer	222
7.5	Gills as an Example	225
7.6	Liver as an Example	226
7.7	Summary.....	233
	Suggested Readings	234
 Chapter 8		
	Sublethal Effects to Individuals	235
8.1	General.....	235
8.2	Selyean Stress.....	236
8.3	Growth	237
8.4	Development.....	243
8.4.1	Developmental Toxicity and Teratology	243
8.4.2	Sexual Characteristics.....	246
8.4.3	Developmental Stability.....	252
8.5	Reproduction	259

8.6	Physiology	260
8.7	Immunology	263
8.8	Behavior	263
8.9	Detecting Sublethal Effects.....	267
8.9.1	Conventional Approach	267
8.9.2	Fundamental Issue to Resolve	271
8.10	Summary.....	273
	Suggested Readings	274
 Chapter 9		
	Acute and Chronic Lethal Effects to Individuals	275
9.1	General	275
9.1.1	Overview.....	275
9.1.2	Acute, Chronic, and Life Stage Lethality	275
9.1.3	Test Types	276
9.2	Dose–Response	279
9.2.1	Basis for Dose–Response Models.....	279
9.2.2	Fitting Data to Dose–Response Models	281
9.2.3	Incipency.....	286
9.2.4	Mixture Models	286
9.3	Survival Time.....	292
9.3.1	Basis for Time–Response Models	292
9.3.2	Fitting Survival Time Data	293
9.3.3	Incipency.....	296
9.3.4	Mixture Models	296
9.4	Factors Influencing Lethality	297
9.4.1	Biotic Qualities	297
9.4.2	Abiotic Qualities	298
9.5	Summary	304
	Suggested Readings	304
 Chapter 10		
	Effects on Populations	305
10.1	Overview	305
10.2	Epidemiology	306
10.3	Population Dynamics and Demography	310
10.3.1	Overview	310
10.3.2	General Population Response	311
10.3.3	Demographic Change	313
10.3.4	Energy Allocation by Individuals in Populations.....	318
10.4	Metapopulations.....	324
10.5	Population Genetics	333
10.5.1	Change in Genetic Qualities	336
10.5.2	Acquisition of Tolerance	337
10.5.3	Measuring and Interpreting Genetic Change	340
10.5	Summary	342
	Suggested Readings	342

Chapter 11	
Effects to Communities and Ecosystems.....	343
11.1 Overview	343
11.1.1 Definitions and Qualifications	343
11.1.2 Context	344
11.1.3 General Assessment of Effect.....	346
11.2 Interactions Involving Two or a Few Species	348
11.2.1 Predation and Grazing	348
11.2.2 Competition.....	351
11.3 Community Qualities.....	352
11.3.1 General.....	352
11.3.2 Structure.....	358
11.3.2.1 Community Indices	358
11.3.2.2 Approaches to Measuring Community Structure	366
11.3.3 Function	370
11.4 Ecosystem Qualities.....	371
11.5 Summary.....	374
Suggested Readings	375
Chapter 12	
Landscape to Global Effects.....	377
12.1 General.....	377
12.2 Landscapes and Regions	384
12.3 Continents and Hemispheres.....	386
12.4 Biosphere.....	393
12.4.1 General.....	393
12.4.2 Global Movement of Persistent Organic Pollutants	394
12.4.3 Global Warming.....	395
12.5 Summary.....	396
Suggested Readings	396
Chapter 13	
Risk Assessment of Contaminants	397
13.1 Overview	397
13.1.1 Real and Perceived Risk	397
13.1.2 Logic of Risk Assessment.....	397
13.1.3 Expressions of Risk.....	401
13.1.4 Risk Assessment	402
13.2 Human Risk Assessment.....	403
13.2.1 General.....	403
13.2.2 Hazard Identification (Data Collection and Data Evaluation)	404
13.2.3 Exposure Assessment.....	405
13.2.4 Dose–Response Assessment.....	405
13.2.5 Risk Characterization	407
13.2.6 Summary.....	408

13.3	Ecological Risk Assessment	409
13.3.1	General.....	409
13.3.2	Problem Formulation	410
13.3.3	Analysis.....	412
13.3.3.1	Exposure Characterization	413
13.3.3.2	Ecological Effects Characterization.....	413
13.3.4	Risk Characterization	413
13.3.5	Summary.....	414
13.4	Radiation Risk Assessment.....	414
13.4.1	Characteristics of Types of Radiations and Their Effects	414
13.4.2	Expressing Radiation Dose and Effect	414
13.4.3	Models of Radiation Effect.....	417
13.5	Conclusion.....	423
	Suggested Readings	423
Chapter 14		
	Conclusions	425
14.1	Overview	425
14.2	Practical Importance of Ecotoxicology	425
14.3	Scientific Importance of Ecotoxicology.....	426
Appendix 1: International System (SI) of Units Prefixes..... 429		
Appendix 2: Miscellaneous Conversion Factors		
Appendix 3: Summary of U.S. Laws and Regulations		
Appendix 4: Summary of European Union Laws and Regulations..... 441		
<i>Mark Crane and Albina Grosso</i>		
	Appendix 5: Summary of Modern Environmental Laws and Regulations of China	447
<i>Taiping Wang</i>		
	Appendix 6: Regulation and Management of Chemicals in Australia: A 2013 Update..... 451	
<i>Michael StJ. Warne</i>		
	Appendix 7: Summary of Indian Environmental Laws and Regulations..... 457	
<i>S. Bijoy Nandan</i>		
	Appendix 8: Regulation and Management of Hazardous Chemical Substances in South Africa..... 463	
<i>Theunis Meyer and Claudine Roos</i>		
	Appendix 9: Derivation of Units for Simple Bioaccumulation Models..... 471	
	Appendix 10: Equations for the Estimation of Exposure	473
	Study Questions	475
	Glossary	501
	References	549
	Index	635