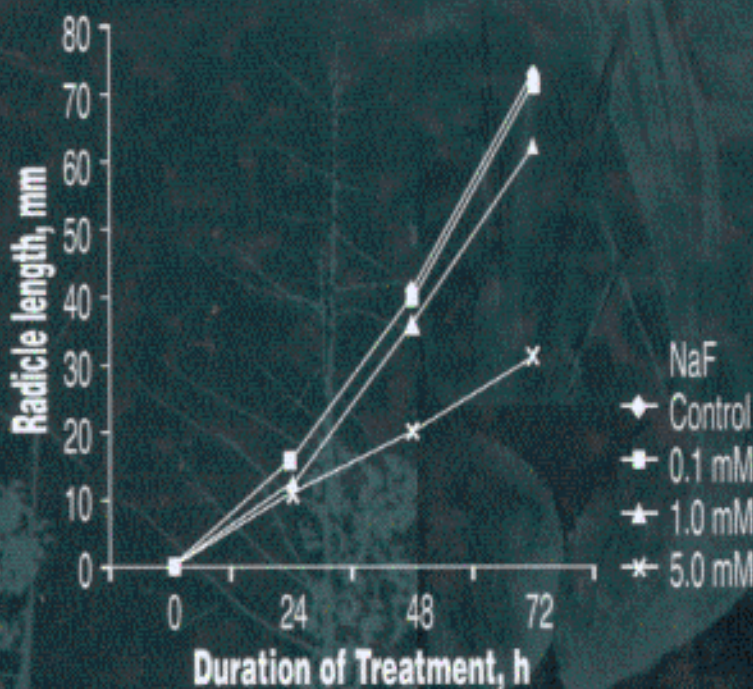


ENVIRONMENTAL TOXICOLOGY

*Impacts of
Environmental Toxicants
on Living Systems*



Ming-Ho Yu

Chapter 1 Introduction	1
1.1 Study of Environmental Toxicology	1
1.2 Postwar Development and the Environment	1
1.3 Environmental Pollution and Law	2
1.4 Importance of Environmental Toxicology	4
1.5 References and Suggested Readings	5
Chapter 2 Environmental Change and Health	7
2.1 Our Changing Environment	7
2.2 Our Changing Disease Pattern	9
2.3 Examples of Environmental Diseases	9
2.3.1 Cancer	11
2.3.2 Birth Defects	12
2.3.3 Reproductive Damage	13
2.3.4 Respiratory Diseases	13
2.3.5 Heavy Metal-Induced Diseases	14
2.4 References and Suggested Readings	16
2.5 Review Questions	17
Chapter 3 Occurrence of Toxicants	19
3.1 Introduction	19
3.2 Visible Smoke or Smog	19
3.3 Offensive Odors	20
3.4 Agricultural Damage	20
3.5 Intoxication of Animals	21
3.6 Injuries to Humans	21
3.7 Acute and Chronic Effects	22
3.7.1 Acute Effects	22
3.7.1.1 Meuse Valley, Belgium, 1930	23
3.7.1.2 Donora, Pennsylvania, USA, 1948	23
3.7.1.3 Poza Rica, Mexico, 1950	23
3.7.1.4 London, England, 1952	23
3.7.1.5 New York, USA, 1953	23
3.7.1.6 Los Angeles, California, USA, 1954	24
3.7.1.7 New Orleans, Louisiana, USA, 1955	24
3.7.1.8 Worldwide Episode, 1962	24
3.7.1.9 Tokyo, Japan, 1970	25
3.7.1.10 Bhopal, India, 1984	25
3.7.1.11 Chernobyl, USSR, 1986	26
3.7.1.12 Oil Spill in Alaska's Prince William Sound, 1989	27
3.7.2 Chronic Effects	27
3.8 References and Suggested Readings	28
3.9 Review Questions	28

Chapter 4 Damage Process and Action of Toxicants	31
4.1 Introduction.....	31
4.2 Plants	31
4.2.1 Sources of Pollution	31
4.2.2 Pollutant Uptake	31
4.2.3 Transport.....	33
4.2.4 Plant Injury	33
4.3 Mammalian Organism	34
4.3.1 Exposure	34
4.3.2 Uptake.....	35
4.3.3 Transport.....	36
4.3.4 Storage	36
4.3.5 Metabolism	36
4.3.6 Excretion.....	37
4.4 Mechanism of Action	37
4.4.1 Disruption or Destruction of Cellular Structure	37
4.4.2 Chemical Combination with a Cell Constituent.....	38
4.4.3 Effect on Enzymes	38
4.4.4 Secondary Action as a Result of the Presence of a Pollutant.....	41
4.4.5 Free Radical-Mediated Reactions	42
4.4.6 Endocrine Disruption.....	43
4.5 References and Suggested Readings	45
4.6 Review Questions	45
Chapter 5 Factors Affecting Xenobiotic Action	47
5.1 Introduction.....	47
5.2 Physicochemical Properties	47
5.3 Dose/Concentration.....	47
5.4 Duration and Mode of Exposure.....	49
5.5 Environmental Factors	49
5.5.1 Temperature	49
5.5.2 pH	49
5.5.3 Humidity	50
5.6 Interaction	50
5.6.1 Synergism, Additive, and Potentiation.....	50
5.6.2 Antagonism.....	51
5.7 Biological Factors.....	51
5.7.1 Plants.....	51
5.7.2 Animals and Humans	52
5.7.2.1 Genetic Factors	52
5.7.2.2 Developmental Factors	52
5.7.2.3 Diseases	53
5.7.2.4 Behavioral Factors	53
5.7.2.5 Gender.....	53
5.8 Nutritional Factors	53
5.8.1 Fasting/Starvation	54

5.8.2	Proteins	54
5.8.3	Carbohydrates	56
5.8.4	Lipids	56
5.8.5	Vitamin A.....	57
5.8.6	Vitamin D	58
5.8.7	Vitamin E (α -tocopherol).....	58
5.8.8	Vitamin C.....	59
5.8.9	Minerals	61
5.9	References and Suggested Readings.....	62
5.10	Review Questions	64
Chapter 6 Metabolism of Environmental Chemicals		
6.1	Introduction.....	67
6.2	Types of Biotransformation	67
6.3	Mechanism of Biotransformation.....	68
6.4	Consequence of Biotransformation.....	70
6.5	Factors Influencing Biotransformation.....	74
6.6	Characteristics of the Cytochrome P450s.....	75
6.6.1	Induction	75
6.6.2	Genetic Polymorphisms.....	76
6.7	References and Suggested Readings.....	76
6.8	Review Questions	77
Chapter 7 Defense Responses to Toxicants		
7.1	Introduction.....	79
7.2	Responses of Humans/Animals.....	79
7.2.1	The Respiratory Tract.....	79
7.2.1.1	Nasopharynx	80
7.2.1.2	Tracheobronchial Areas	80
7.2.1.3	Alveoli.....	80
7.2.2	Gastrointestinal Tract.....	82
7.2.3	Membranes	83
7.2.4	Liver.....	84
7.2.5	Kidneys	85
7.3	Responses of Plants	86
7.4	References and Suggested Readings.....	87
7.5	Review Questions	87
Chapter 8 Air Pollution — Inorganic Gases		
8.1	Introduction.....	89
8.2	Sulfur Dioxide	89
8.2.1	Sources of SO ₂	89
8.2.2	Characteristics of SO ₂	90
8.2.3	Effects on Plants.....	90
8.2.4	Effects on Animals	93
8.2.5	Effects on Humans	94

8.3	Nitrogen Dioxide	95
8.3.1	Forms and Formation of Nitrogen Oxides.....	95
8.3.2	Major Reactive N Species in the Troposphere	95
8.3.3	Effects on Plants.....	97
8.3.4	Effects on Animals and Humans.....	97
8.3.5	Biochemical Effect	98
8.4	Ozone	98
8.4.1	Sources.....	98
8.4.2	Photochemical Smog.....	99
8.4.3	Effects on Plants.....	100
8.4.4	Effects on Animals and Humans.....	100
8.4.5	Biochemical Effect	101
8.5	Carbon Monoxide.....	104
8.5.1	Introduction.....	104
8.5.2	Formation.....	104
8.5.3	Human Exposure	105
8.5.4	Physiological Effects	105
8.6	References and Suggested Readings	106
8.7	Review Questions	108
Chapter 9 Air Pollution — Particulate Matter		111
9.1	Introduction.....	111
9.2	Characteristics.....	111
9.3	Formation of Particulates	112
9.3.1	Physical Processes	112
9.3.2	Chemical Processes	112
9.4	Toxicity	113
9.5	Silica	114
9.5.1	Silicosis.....	114
9.5.2	Pathogenesis	114
9.6	Beryllium	115
9.6.1	Sources of Exposure.....	115
9.6.2	Health Effects	117
9.6.3	Biochemical Effect	117
9.6.4	Therapy	118
9.7	Asbestos	118
9.7.1	Chemical and Physical Properties.....	118
9.7.2	Uses.....	119
9.7.3	Exposure	119
9.7.4	Pathogenicity in Humans	120
9.8	References and Suggested Readings	120
9.9	Review Questions	121
Chapter 10 Environmental Fluoride.....		123
10.1	Introduction.....	123
10.2	Occurrence and Forms of Fluoride	123

10.3	Sources of Environmental Fluoride.....	124
10.4	Industrial Sources of Fluoride in the Environment	125
10.4.1	Manufacture of Phosphate Fertilizers	125
10.4.2	Manufacture of Aluminum.....	127
10.4.3	Manufacture of Steel.....	127
10.5	Effects on Plants.....	127
10.5.1	Toxicological Effects.....	127
10.5.2	Biochemical Effect.....	128
10.6	Effects on Animals	130
10.6.1	Acute Effects	130
10.6.2	Chronic Effects.....	131
10.7	Effects on Humans	133
10.7.1	Daily Intake	133
10.7.2	Absorption	133
10.7.3	Acute Effects	133
10.7.4	Chronic Effects.....	134
10.7.5	Biochemical Effect.....	135
10.8	References and Suggested Readings.....	135
10.9	Review Questions	137
Chapter 11	Volatile Organic Compounds.....	139
11.1	Introduction.....	139
11.2	Sources.....	139
11.3	Petroleum Hydrocarbons	140
11.3.1	Alkanes	140
11.3.1.1	Properties and Use.....	140
11.3.1.2	Health Effects	141
11.3.2	Alkenes	142
11.3.2.1	Properties and Use.....	142
11.3.2.2	Health Effects	142
11.3.3	The Aromatic Hydrocarbons	142
11.3.3.1	Benzene	143
11.3.3.2	Toluene	144
11.3.3.3	The Xylenes.....	144
11.4	Polycyclic Aromatic Hydrocarbons.....	145
11.4.1	Introduction.....	145
11.4.2	Sources.....	146
11.4.3	Physical and Chemical Properties.....	146
11.4.4	Transport.....	146
11.4.5	Exposure	146
11.4.6	Metabolism	148
11.5	References and Suggested Readings.....	149
11.6	Review Questions	150
Chapter 12	Environmental Metals.....	151
12.1	Introduction.....	151

12.2	Lead.....	152
12.2.1	Characteristics and Uses	152
12.2.2	Sources of Exposure.....	152
12.2.2.1	Airborne Lead.....	152
12.2.2.2	Waterborne Lead.....	153
12.2.2.3	Lead in Food.....	153
12.2.2.4	Lead in Soils.....	154
12.2.3	Metabolism	154
12.2.4	Toxicity	154
12.2.4.1	Effects on Plants.....	154
12.2.4.2	Lead Poisoning in Animals/Fish	155
12.2.4.3	Lead Toxicity in Humans	156
12.2.5	Biochemical Effect	157
12.2.6	Lead and Nutrition	158
12.3	Cadmium.....	159
12.3.1	Characteristics and Uses	159
12.3.2	Exposure	160
12.3.2.1	Airborne Cadmium	160
12.3.2.2	Waterborne Cadmium.....	160
12.3.2.3	Cadmium Pollution of Soils.....	160
12.3.2.4	Cadmium in Food.....	161
12.3.3	Metabolism	161
12.3.4	Toxicity	162
12.3.4.1	Effects on Plants.....	162
12.3.4.2	Effects on Animals	163
12.3.4.3	Effects on Humans	164
12.3.5	Biochemical Effect	165
12.3.6	Cadmium and Nutrition.....	166
12.4	Mercury.....	167
12.4.1	Introduction.....	167
12.4.2	Extraction and Uses.....	167
12.4.3	Sources of Mercury Pollution	168
12.4.4	Biotransformation	169
12.4.4.1	Biomethylation of Mercury	169
12.4.4.2	Demethylation of Methylmercury	169
12.4.4.3	Methylmercury Biosynthesis and Diffusion into Cells	170
12.4.5	Toxicity	170
12.4.5.1	Effects on Algae	170
12.4.5.2	Effects on Plants.....	170
12.4.5.3	Effects on Animals	171
12.4.5.4	Effects on Human Health	171
12.4.6	Biochemical Effect	173
12.4.7	Mercury and Nutrition.....	173
12.5	Nickel	174
12.5.1	Introduction.....	174

12.5.2 Sources of Environmental Pollution	174
12.5.3 Health Effects	175
12.6 Arsenic	176
12.6.1 Occurrence and Properties	176
12.6.2 Uses.....	177
12.6.3 Sources of Exposure.....	177
12.6.3.1 Natural Sources.....	177
12.6.3.2 Anthropogenic Sources.....	177
12.6.4 Exposure	178
12.6.4.1 Human Exposure	178
12.6.4.2 Animal Exposure	178
12.6.5 Distribution in the Body.....	178
12.6.6 Toxicity	179
12.6.6.1 Toxicity to Plants.....	179
12.6.6.2 Toxicity to Animals/Humans.....	179
12.6.7 Biochemical Effect	180
12.7 References and Suggested Readings.....	182
12.8 Review Questions	185
Chapter 13 Pesticides and Related Materials.....	187
13.1 Introduction.....	187
13.2 Insecticides.....	187
13.2.1 Chlorinated Hydrocarbons.....	188
13.2.1.1 DDT	188
13.2.2 Organophosphorus Compounds	191
13.2.3 Carbamates	193
13.3 Herbicides	194
13.4 Polychlorinated Biphenyls (PCBs).....	196
13.4.1 Introduction.....	196
13.4.2 Properties	196
13.4.3 Uses.....	197
13.4.4 Environmental Contamination.....	197
13.4.4.1 Wildlife Exposure	197
13.4.4.2 Human Exposure	198
13.4.5 PCB Degradation	199
13.4.6 Metabolism	199
13.4.7 Toxicity	200
13.4.8 Biochemical Effect	201
13.5 Polybrominated Biphenyls.....	201
13.5.1 Introduction.....	201
13.5.2 Chemistry.....	202
13.5.3 Toxicity	202
13.5.4 Biochemical Effect	202
13.6 Dioxin	203
13.6.1 Exposure	203
13.6.2 Environmental Degradation of TCDD	204

13.6.3 Toxicity	204
13.6.3.1 Effects on Animals	204
13.6.3.2 Effects on Humans	205
13.6.4 Mechanism of Dioxin's Gene Regulation.....	205
13.7 References and Suggested Readings.....	206
13.8 Review Questions	208
Chapter 14 Mutagenic Pollutants	209
14.1 Introduction.....	209
14.2 Types of Mutation.....	210
14.2.1 Chromosomal Aberrations.....	210
14.2.2 Gene Mutations	211
14.3 Effect of Mutations.....	211
14.4 Induction of Mutation.....	212
14.4.1 UV Light.....	212
14.4.2 Ionizing Radiations.....	213
14.4.3 Chemical Mutagens.....	214
14.4.3.1 Alkylating Agents	214
14.4.3.2 Intercalating Agents.....	215
14.4.3.3 Metals.....	215
14.5 References and Suggested Readings.....	216
14.6 Review Questions	217
Chapter 15 Environmental Cancer	219
15.1 Introduction.....	219
15.2 Causes of Cancer	220
15.3 Stages in the Development of Cancer.....	220
15.4 Metastasis.....	222
15.5 Classification of Carcinogens.....	222
15.5.1 Radiation.....	223
15.5.2 Chemical Carcinogens.....	223
15.6 Metabolism of Chemical Carcinogens.....	225
15.6.1 Free Radicals	225
15.6.2 DDT	225
15.6.3 Vinyl Chloride	226
15.6.4 Alkylating Agents.....	226
15.6.5 Polycyclic Aromatic Hydrocarbons	228
15.6.5.1 Benzo[a]pyrene	228
15.6.6 Halogenated Aromatic Hydrocarbons.....	229
15.7 DNA Repair	230
15.8 References and Suggested Readings.....	230
15.9 Review Questions	231
Glossary	233
Index.....	241