

McGraw-Hill Series in Water Resources and Environmental Engineering

Hazardous Waste Management

2nd edition

Michael D. LaGrega • Phillip L. Buckingham • Jeffrey C. Evans
and Environmental Resources Management



McGRAW-HILL INTERNATIONAL EDITION
Biological Sciences Series

Foreword	xvii
Preface	xix
Acronyms	xxiii

PART I Fundamentals

1	Hazardous Waste	1
1-1	Working Definition	1
1-2	Historical Roots	3
1-3	Landmark Episodes	4
1-4	Regulatory Initiatives	8
1-5	Classification	13
1-6	Generation	20
1-7	Contaminated Sites	28
1-8	Future Endeavors	30
1-9	Toward an Environmental Ethic	32
	Discussion Topics and Problems	36
	References	37
	Additional Reading	39
2	The Legal Framework	41
2-1	Environmental Law	42
2-2	Resource Conservation and Recovery Act	47
2-3	Federal Hazardous Waste Regulations under RCRA	53

2-4	Superfund	58
2-5	Other Federal Statutes	64
2-6	International Perspectives	73
	Discussion Topics and Problems	88
	References	91
	Additional Reading	93
3	Process Fundamentals	95
3-1	A Little Chemistry	95
3-2	Physical-Chemical Properties	105
3-3	Energy and Mass Balances	119
3-4	Reactions and Reactors	137
3-5	Geochemical Modeling and Analysis Programs	141
	Discussion Topics and Problems	142
	References	145
	Additional Reading	147
4	Fate and Transport of Contaminants	149
4-1	Contaminant Release	151
4-2	Transport of Contaminants in the Subsurface	162
4-3	Fate of Contaminants in the Subsurface	193
4-4	Atmospheric Transport and Dispersion of Contaminants	213
	Discussion Topics and Problems	230
	References	234
	Additional Reading	239
5	Toxicology	242
5-1	Exposure	243
5-2	Toxic Effects	255
5-3	Dose-Response Relationships	263
5-4	Noncarcinogens	274
5-5	Carcinogens	280
5-6	Ecotoxicology	301
	Discussion Topics and Problems	321
	References	323
	Additional Reading	330

PART II Current Management Practices

6	Environmental Audits	332
6-1	Introduction	332
6-2	Program Planning	336
6-3	Preaudit Preparation	341
6-4	On-Site Audit	346
6-5	Evaluation and Presentation	356
6-6	Other Types of Audits	361

	Discussion Topics and Problems	368
	References	370
	Additional Reading	370
7	Pollution Prevention	372
	7-1 General Considerations	372
	7-2 Management Strategies	377
	7-3 Life Cycle Analysis	391
	7-4 Volume Reduction	400
	7-5 Toxicity Reduction	404
	7-6 Recycling	409
	Discussion Topics and Problems	413
	References	416
	Additional Reading	418
8	Facility Development and Operations	420
	8-1 Facility Types	420
	8-2 Facility Operations	429
	8-3 Needs Assessment	440
	8-4 Site Selection	441
	8-5 Public Participation	448
	8-6 Permitting	455
	Discussion Topics and Problems	458
	References	459
	Additional Reading	461

PART III Treatment and Disposal Methods

9	Physicochemical Processes	463
	9-1 Air Stripping	463
	9-2 Carbon Adsorption	476
	9-3 Steam Stripping	488
	9-4 Chemical Oxidation	505
	9-5 Supercritical Fluids	519
	9-6 Membrane Processes	527
	Discussion Topics and Problems	544
	References	546
	Additional Reading	551
10	Biological Methods	553
	10-1 Basics of Microbial Metabolism	554
	10-2 Biodegradation of Xenobiotics	561
	10-3 Growth Kinetics	571
	10-4 <i>Ex Situ</i> Systems—Treatment of Liquids	579
	10-5 <i>Ex Situ</i> Systems—Slurry-Phase Treatment	590
	10-6 <i>Ex Situ</i> Systems—Solid-Phase and Vapor-Phase Treatment	596

10-7	<i>In Situ</i> Biological Treatment Systems—Monitored Natural Attenuation	611
10-8	<i>In Situ</i> Biological Treatment Systems—Enhanced Degradation	625
10-9	Major Classes of Xenobiotic Compounds Amenable to Biological Treatment	643
10-10	Biological Treatment—Treatability Studies and Other Considerations	654
	Discussion Topics and Problems	659
	References	661
	Additional Reading	672
11	Stabilization and Solidification	677
11-1	Introduction	677
11-2	Mechanisms	684
11-3	Technology	687
11-4	Testing	701
11-5	Field Implementation	722
11-6	Design	726
11-7	Case Studies	728
	Discussion Topics and Problems	730
	References	732
	Additional Reading	739
12	Thermal Methods	741
12-1	Introduction	741
12-2	Regulations	745
12-3	Combustion	747
12-4	Gases and Vapors	759
12-5	Liquid Injection Incinerators	769
12-6	Solid Waste Incineration	776
12-7	Storage and Feed Systems	785
12-8	Flue Gas Temperature Reduction	788
12-9	Air Pollution Control	790
12-10	Instrumentation	799
12-11	Continuous Emission Monitors	802
12-12	Trial Burns	806
12-13	Mobile Systems	807
	Discussion Topics and Problems	808
	References	809
	Additional Reading	810
13	Land Disposal	812
13-1	Introduction	812
13-2	Landfill Operations	815
13-3	Site Selection	817
13-4	Liner and Leachate Collection Systems	818

13-5	Cover Systems	824
13-6	Materials	830
13-7	Contaminant Transport through Landfill Barriers	840
13-8	Landfill Stability	849
13-9	Surface Impoundments and Deep Well Injection	853
13-10	Closure and Postclosure Care	854
	Discussion Topics and Problems	857
	References	858
	Additional Reading	864

PART IV Site Remediation

14	Quantitative Risk Assessment	865
14-1	Risk	865
14-2	Hazard Identification	869
14-3	Exposure Assessment	872
14-4	Toxicity Assessment	884
14-5	Risk Characterization	887
14-6	Risk Communication	892
14-7	Ecological Risk Assessment	895
14-8	Monte Carlo Methods	898
14-9	Case Study	903
	Discussion Topics and Problems	906
	References	908
	Additional Reading	910
15	Site and Subsurface Characterization	912
15-1	Introduction	912
15-2	Methodology	914
15-3	Planning	916
15-4	Methods of Site Characterization	929
15-5	Geophysical Methods	930
15-6	Boring and Sampling	939
15-7	Monitoring Wells	954
15-8	Geographic Information System	966
15-9	Case Study	970
	Discussion Topics and Problems	976
	References	978
	Additional Reading	980
16	Remedial Technologies	982
16-1	Introduction	982
16-2	Remedial Objectives	984
16-3	Passive Contaminant Control Systems	986
16-4	Surface Water Control Technologies	987

16-5	Groundwater Control: Vertical Barriers	988
16-6	Groundwater Control: Horizontal Barriers	1010
16-7	Active Remediation Systems	1012
16-8	Soil Vapor Extraction	1021
16-9	Permeable Reactive Treatment Walls	1037
16-10	Other Remedial Technologies	1044
	Discussion Topics and Problems	1050
	References	1052
	Additional Reading	1060
17	Evaluation and Selection of Remedial Actions and Corrective Measures	1061
17-1	Overview of Remedy Selection Process	1061
17-2	Case Study 1—Evaluation and Selection of a Remedial Action for a “Model” Superfund Site	1064
17-3	Site Conceptual Model	1067
17-4	Remediation Objectives	1068
17-5	Development of Alternatives	1075
17-6	Analysis of Alternatives	1082
17-7	Regulatory Guidance	1093
17-8	Case Study 2—Focused Evaluation and Selection of an Interim Corrective Measure at an Operating Chemical Plant	1094
	Discussion Topics and Problems	1100
	References	1100
	Additional Reading	1101
	Appendices	1103
A	Basel Convention	1103
B	Contaminant Properties	1114
C	Thermodynamic Properties	1129
D	Conversion Factors	1147
	Index	1157