

Contents

1	Introduction to Mine Wastes	1
1.1	Scope of the Book	1
1.2	Definitions	3
1.2.1	Mining Activities	3
1.2.2	Metals, Ores and Industrial Minerals	3
1.2.3	Mine Wastes	4
1.3	Mine Waste Production	9
1.4	Mine Wastes: Unwanted By-Products or Valuable Resources?	11
1.5	Mining and Environmental Impacts	13
1.5.1	Contamination and Pollution	16
1.5.2	Historic Mining	18
1.5.3	Present-Day Unregulated Mining	20
1.5.4	Regulation of Modern Mining	23
1.6	Rehabilitation of Mine Wastes and Mine Sites	26
1.7	Sources of Information	29
1.8	Summary	29
2	Sulfidic Mine Wastes	33
2.1	Introduction	33
2.2	Weathering of Sulfidic Mine Wastes	33
2.3	Acid Producing Reactions	34
2.3.1	Pyrite	34
2.3.2	Other Sulfides	43
2.3.3	Other Minerals	45
2.4	Acid Buffering Reactions	45
2.4.1	Silicates	46
2.4.2	Carbonates	47
2.4.3	Exchangeable Cations	49
2.4.4	Reaction Rates	49
2.5	Coal Mine Wastes	51
2.5.1	Spontaneous Combustion of Pyritic Wastes	52
2.6	Formation and Dissolution of Secondary Minerals	54
2.6.1	Pre-Mining and Post-Mining Secondary Minerals	55
2.6.2	Solubility of Secondary Minerals	58
2.6.3	Acid Consumption and Production	60
2.6.4	Coatings and Hardpans	60

2.7	Acid Generation Prediction	62
2.7.1	Geological Modeling	63
2.7.2	Geological, Petrographic, Geochemical and Mineralogical Descriptions	63
2.7.3	Sampling	64
2.7.4	Geochemical Tests	65
2.7.5	Modeling the Oxidation of Sulfidic Waste Dumps	71
2.8	Monitoring Sulfidic Wastes	72
2.9	Environmental Impacts	73
2.10	Control of Sulfide Oxidation	74
2.10.1	Wet Covers	75
2.10.2	Dry Covers	79
2.10.3	Encapsulation, In-Pit Disposal and Mixing	83
2.10.4	Co-Disposal and Blending	85
2.10.5	Addition of Organic Wastes	86
2.10.6	Bactericides	87
2.11	Summary	87
3	Mine Water	91
3.1	Introduction	91
3.2	Sources of AMD	93
3.3	Characterization	95
3.3.1	Sampling and Analysis	95
3.4	Classification	97
3.4.1	Acid Waters	98
3.4.2	Extremely Acid Waters	99
3.4.3	Neutral to Alkaline Waters	100
3.4.4	Coal Mine Waters	100
3.5	Processes	101
3.5.1	Microbiological Activity	101
3.5.2	Precipitation and Dissolution of Secondary Minerals	103
3.5.3	Coprecipitation	107
3.5.4	Adsorption and Desorption	107
3.5.5	Eh-pH Conditions	108
3.5.6	Heavy Metals	109
3.5.7	The Iron System	110
3.5.8	The Aluminium System	112
3.5.9	The Arsenic System	113
3.5.10	The Mercury System	115
3.5.11	The Sulfate System	115
3.5.12	The Carbonate System	116
3.5.13	pH Buffering	118
3.5.14	Turbidity	119
3.6	Prediction of Mine Water Composition	120
3.6.1	Geological Modeling	120
3.6.2	Mathematical and Computational Modeling	120
3.7	Field Indicators of AMD	122

3.8	Monitoring AMD	122
3.9	AMD from Sulfidic Waste Rock Dumps	126
3.9.1	Hydrology of Waste Rock Dumps	127
3.9.2	Weathering of Waste Rock Dumps	129
3.9.3	Temporal Changes to Dump Seepages	130
3.10	Environmental Impacts of AMD	132
3.11	AMD Management Strategies	135
3.12	Treatment of AMD	136
3.12.1	Neutralization	138
3.12.2	Other Chemical Treatments	141
3.12.3	Anoxic Limestone Drains	142
3.12.4	Wetlands	143
3.12.5	Adit Plugging	148
3.12.6	Ground Water Treatment	148
3.13	Summary	150
4	Tailings	153
4.1	Introduction	153
4.2	Tailings Characteristics	154
4.2.1	Process Chemicals	154
4.2.2	Tailings Liquids	155
4.2.3	Tailings Solids	156
4.3	Tailings Dams	157
4.3.1	Tailings Hydrogeology	159
4.3.2	AMD Generation	160
4.3.3	Tailings Dam Failures	163
4.3.4	Monitoring	164
4.3.5	Wet and Dry Covers	170
4.4	Thickened Discharge and Paste Technologies	171
4.5	Backfilling	172
4.6	Riverine and Lacustrine Disposal	173
4.7	Marine Disposal	175
4.8	Recycling	178
4.9	Summary	178
5	Cyanidation Wastes of Gold-Silver Ores	183
5.1	Introduction	183
5.2	Occurrences and Uses of Cyanide	183
5.3	Cyanide Chemistry	184
5.3.1	Free Cyanide	184
5.3.2	Simple Cyanide Compounds	186
5.3.3	Complexed Cyanide	186
5.4	Gold Extraction	187
5.4.1	Heap Leach Process	187
5.4.2	Vat/Tank Leach Process	188
5.5	Hydrometallurgical Wastes	189
5.6	Cyanide Analysis and Monitoring	190

5.7	Environmental Impacts	191
5.8	Cyanide Destruction	193
5.8.1	Natural Attenuation	194
5.8.2	Enhanced Natural Attenuation	196
5.8.3	Engineered Attenuation	197
5.9	Summary	198
6	Radioactive Wastes of Uranium Ores	201
6.1	Introduction	201
6.2	Mineralogy and Geochemistry of Uranium	201
6.2.1	Uranium Ores	201
6.2.2	Placer and Beach Sands	202
6.3	Aqueous Chemistry of Uranium	203
6.3.1	Oxidative Dissolution of Uranium Minerals	203
6.3.2	Uranium Solubility	204
6.3.3	Uranium Precipitation	205
6.4	Radioactivity	206
6.4.1	Principles of Radioactivity	206
6.4.2	Radioactive Decay of Uranium and Thorium	208
6.4.3	Units and Measurements of Radioactivity and Radiation Dose	210
6.4.4	Radioactive Equilibrium and Disequilibrium	212
6.5	Uranium Mining and Extraction	213
6.5.1	Conventional Mining and Extraction	213
6.5.2	In Situ Leach (ISL) Operations	215
6.6	Mining, Processing and Hydrometallurgical Wastes	217
6.7	Tailings	219
6.7.1	Tailings Radioactivity	220
6.7.2	Tailings Solids	221
6.7.3	Tailings Liquids	222
6.7.4	Tailings Disposal	223
6.7.5	Long-term Stability of Tailings Dams	225
6.8	Mine Water	227
6.8.1	Constituents	227
6.8.2	Treatment	228
6.9	Monitoring	230
6.10	Radiation Hazards	231
6.10.1	Radiation Dose and Human Health	232
6.10.2	Occupational Radiation Exposure	232
6.11	Environmental Impacts	235
6.12	Summary	241
7	Wastes of Phosphate and Potash Ores	245
7.1	Introduction	245
7.2	Potash Mine Wastes	245
7.2.1	Potash Ores	246
7.2.2	Mining and Processing Wastes	246

7.3	Phosphate Mine Wastes	247
7.3.1	Phosphate Rock	247
7.3.2	Mining, Processing and Hydrometallurgical Wastes	249
7.3.3	Phosphogypsum	252
7.3.4	Disposal of Phosphogypsum	255
7.3.5	Potential Hazards and Environmental Impacts	260
7.4	Summary	263
	References	265
	Subject Index	297