

Contents

Preface xxv
List of Figures xxvii
List of Tables xxx

SECTION 1: Planning and Managing Industrial Wastewater Pretreatment Processes

Chapter 1 Introduction

Introduction 1
New in This Edition 1
Layout of the Book 2
 Section 1: Planning and Managing Industrial Wastewater Pretreatment Processes 2
 Section 2: Design, Operation, and Procurement of Industrial Pretreatment Facilities 3
Purpose and Scope of the Book 4
The Need for Pretreatment 5

Chapter 2 Discharge and Disposal Regulations

Pretreatment Regulations 9
 Federal Pretreatment Regulations 9
 Prohibitions 12
 Categorical Pretreatment Standards 13
 Industrial User Definitions 15
 Requirements for All Industrial Users 16
 Reporting Requirements for Categorical Industrial Users 17
 Reporting Requirements for Significant Noncategorical Industrial Users 18
 Other Provisions 18
 Removal Credits 18
 Pretreatment Program Requirements 18
 Variances 21
 Other 21
Regulatory Outlook 21

Local Pretreatment Limits	21
<i>Limits</i>	21
<i>Fees or Surcharges</i>	25
<i>Permitting</i>	25
Direct-Discharge Regulations	27
Prohibitions and Definitions	27
Categorical Requirements	28
<i>Types of Technology-Based Limitations</i>	28
<i>Numerical Limits</i>	30
<i>Compliance Schedule</i>	31
<i>Other Potential Requirements</i>	31
<i>Need to Determine Applicable Requirements</i>	31
NPDES Permits	32
<i>General Requirements</i>	33
<i>Types of NPDES Permits</i>	33
<i>Comment Periods</i>	33
<i>Permit Contents</i>	38
<i>Best Management Practices</i>	38
<i>Variances and Waivers</i>	39
<i>Reporting Requirements</i>	40
<i>Numerical Limits</i>	41
Regulatory Outlook	42
Other Disposal Regulations for Wastewater and Its Treatment Residuals ..	44
Definitions and Applicable Regulations	44
Subsurface Injection Regulations	45
<i>General Requirements</i>	46
<i>Class I Wells</i>	46
<i>Class V Wells</i>	47
<i>Reporting Requirements</i>	47
<i>Permitting</i>	48
Land-Application Regulations for Sites Controlled by the Waste Producers	48
Regulations for Disposal at Third-Party Facilities	50
<i>Municipal Solid Waste Landfills</i>	50
<i>Municipal Solid Waste Incinerators</i>	50
<i>Hazardous Waste Disposal Facilities</i>	50
References	51
Suggested Readings	56

Chapter 3 Wastewater Sampling and Analysis

General Requirements	59
Flow Measurement	61
Estimation Options	62
<i>Bucket and Stop Watch</i>	62
<i>Float or Dye Method</i>	63
<i>Pump Cycles</i>	63
<i>Time to Fill or Empty a Tank</i>	64
<i>Estimating Stormwater Flows</i>	64
Measurement Options	65
Sampling	66
Types of Sampling	67
Sampling Methods	68
<i>Manual Sampling Methods</i>	69
<i>Automatic Sampling Methods</i>	70
Sampling Procedures and Techniques	71
Relevant Analysis Methods and Procedures	72
Quality Assurance and Quality Control	73
References	74
Suggested Readings	75

Chapter 4 Industrial Wastewater Survey and Characterization

Definitions	78
Industrial Wastewater Survey	83
Objective	83
Identifying Categorical Wastestreams	84
Identifying Wastewater Generators	84
Identifying Water Users	85
Preparing Flow and Mass Balances	86
In-Plant Control and Pollution Prevention	88
Characterizing Industrial Wastewater	89
Objective	89
Flow Measurement Plan	89

Sampling and Analytical Plan	90
Representative Sampling	91
Analytical Services	92
Data Interpretation	93
Industrial Wastewater Toxicity Characterization	94
Regulatory Framework	94
Applicability	94
Common Toxics	94
Testing Approach	95
Test Methods	95
TRE Case Studies	96
<i>Case A</i>	96
<i>Case B</i>	97
<i>Case C</i>	97
References	97
Suggested Readings	98
Chapter 5 Wastewater Treatability Assessments	
Materials, Supplies, and Instrumentation	101
Wastewater Characterization	101
Aerobic Biological Treatability Testing	101
Batch Tests	101
Bench-Scale Reactor Tests	105
Anaerobic Bioassays and Treatability Testing	109
Batch Anaerobic Treatability Tests	109
Continuous Anaerobic Reactors	111
Physical and Chemical Tests	112
Membrane Filtration	115
Activated Carbon Absorption	115
Pilot Plant Operations	117
Sample Withdrawal, Processing, and Storage	118
Summary	119
References	120

Chapter 6 Industrial Wastewater Characteristics and Approach to Wastewater Management

Wastewater Characteristics	128
Wastewater Management Approach	143
Selection of a Wastewater Management Program	143
<i>Discharge Requirements</i>	143
<i>Facility's Site-Specific Conditions</i>	143
<i>Options for Wastewater Management</i>	144
Summary of Treatment Approaches per Point Source Category	144
Individual Point Source Categories	156
Aluminum Forming (40 CFR 467)	156
Asbestos Manufacturing (40 CFR 427)	156
Battery Manufacturing (40 CFR 461)	157
Canned and Preserved Fruits and Vegetables Processing (40 CFR 407)	157
Canned and Preserved Seafood Processing (40 CFR 408)	158
Carbon Black Manufacturing (40 CFR 458)	158
Cement Manufacturing (40 CFR 411)	164
Centralized Waste Treatment (40 CFR 437)	165
Coal Mining (40 CFR 434)	166
Coil Coating (40 CFR 465)	166
Concentrated Animal Feeding Operations (40 CFR 412)	167
Concentrated Aquatic Animal Production (40 CFR 451)	168
Copper Forming (40 CFR 468)	169
Dairy Products Processing (40 CFR 405)	169
Electrical and Electronic Components (40 CFR 469)	170
Electroplating (40 CFR 413)	170
Explosives Manufacturing (40 CFR 457)	171
Ferroalloy Manufacturing (40 CFR 424)	172
Fertilizer Manufacturing (40 CFR 418)	172
Glass Manufacturing (40 CFR 426)	173
Grain Mills (40 CFR 406)	174
Gum and Wood Chemicals Manufacturing (40 CFR 454)	174
Hospital (40 CFR 460)	175
Ink Formulating (40 CFR 447)	175

Inorganic Chemicals Manufacturing (40 CFR 415)	176
Iron and Steel Manufacturing (40 CFR 420)	176
Landfills (40 CFR 445)	178
Leather Tanning and Finishing (40 CFR 425)	178
Meat and Poultry Products (40 CFR 432)	179
Metal Finishing (40 CFR 433)	179
Metal Molding and Casting (40 CFR 464)	181
Metal Products and Machinery (40 CFR 438)	181
Mineral Mining and Processing (40 CFR 436)	182
Nonferrous Metals Forming and Metal Powders (40 CFR 471)	182
Nonferrous Metals Manufacturing (40 CFR 421)	183
Oil and Gas Extraction (40 CFR 435)	184
Ore Mining and Dressing (40 CFR 440)	185
Organic Chemicals, Plastics, and Synthetic Fibers (40 CFR 414)	186
Paint Formulating (40 CFR 446)	187
Paving and Roofing Materials (Tars and Asphalt) (40 CFR 443)	188
Pesticide Chemicals (40 CFR 455)	188
Petroleum Refining (40 CFR 419)	189
Pharmaceutical Manufacturing (40 CFR 439)	190
Phosphate Manufacturing (40 CFR 422)	191
Photographic (40 CFR 459)	192
Plastics Molding and Forming (40 CFR 463)	193
Porcelain Enameling (40 CFR 466)	193
Pulp, Paper, and Paperboard (40 CFR 430)	194
Rubber Manufacturing (40 CFR 428)	195
Soap and Detergent Manufacturing (40 CFR 417)	196
Steam Electric Power Generating (40 CFR 423)	196
Sugar Processing (40 CFR 409)	197
Textile Mills (40 CFR 410)	197
Timber Products Processing (40 CFR 429)	198
Transportation Equipment Cleaning (40 CFR 442)	200
Waste Combustors (40 CFR 444)	201
References	201
Suggested Readings	202

Chapter 7 Management Strategies for Pollution Prevention and Waste Minimization

Corporate Philosophy	204
Managing for Success	207
Define the Problem with Written Goals	208
Obtain Top Management Support	208
Inclusive Planning	209
Product Characterization for Waste Minimization	209
<i>Improving Plant Operations</i>	209
<i>Altering Process Technology</i>	209
<i>Material Substitution</i>	209
<i>Product Reformulation</i>	210
<i>Recycle/Recovery/Reuse</i>	210
<i>Pretreatment</i>	210
Waste Characterization and Waste Generation	210
<i>In-Plant Survey</i>	210
<i>Identifying Categorical Wastestreams</i>	210
<i>Identifying Wastewater-Generating Operations</i>	210
<i>Preparing Mass Balances</i>	210
Generate Options and Prioritize Solutions	211
<i>In-Plant Control</i>	211
<i>Water Conservation and Recycling</i>	217
<i>Pretreatment</i>	218
<i>Physical Separation</i>	219
<i>Chemical Pretreatment</i>	221
<i>Biological Pretreatment</i>	222
<i>Cross-Media Pollutants</i>	224
<i>Safety Considerations</i>	225
<i>Offsite Pretreatment</i>	225
<i>Residue Management (Disposal)</i>	225
Periodic Waste Minimization Assessments	225
Assess Effect of Process Change on Product Quality and Quantity ...	227
Create a Cost-Allocation System	227
Encourage Technology Transfer Between Operating Divisions	229
Program Evaluation, Feedback, and Incentives for Improvement	229
References	231
Suggested Readings	234

SECTION 2: Design, Operation, and Procurement of Industrial Pretreatment Facilities

Chapter 8 Flow and Load Equalization

Capital Cost and Operations Benefits of Equalization	236
Types of Equalization Processes	238
Alternating Flow Diversion	238
Intermittent Flow Diversion	239
Completely Mixed Equalization	239
Design of Facilities	241
Data Collection	241
Alternating Flow Diversion	242
Intermittent Flow Diversion	242
Completely Mixed Combined Flow	245
Cumulative Flow Curve	247
Other Design Considerations	250
Mixing Requirements	250
Aeration	251
Baffling	251
Tank Configuration	251
<i>Freeboard</i>	251
<i>Tank Cover</i>	251
<i>Air Diffusers</i>	252
<i>Foam Spray</i>	252
<i>Freezing</i>	252
<i>Draining and Cleaning</i>	252
<i>Pumping Controls and Drives</i>	252
References	253
Suggested Readings	253

Chapter 9 Solids Separation and Handling

Background	256
Suspended Solids Classifications	258
Removal Methods	258
Straining	258
<i>Coarse Screens</i>	259
<i>Fine Screens</i>	259
<i>Static Screens</i>	259

<i>Rotary Drum Screens</i>	262
<i>Vibratory Screens</i>	263
Gravity Separation	264
<i>Grit Removal</i>	264
<i>Conventional Sedimentation</i>	266
<i>Inclined-Plate Clarifiers</i>	270
<i>Chemical Coagulation and Flocculation</i>	271
<i>Jar Testing</i>	272
<i>Chemical Feed Systems</i>	273
<i>Flotation</i>	276
Filtration	277
<i>Granular Media</i>	277
<i>Filter Types</i>	278
<i>Filter Backwash</i>	278
<i>Filter Operating Characteristics and Design Considerations</i>	279
<i>Conventional Downflow Gravity Filters</i>	279
<i>Downflow Pressure Filters</i>	280
<i>Upflow, Continuous Backwash Filtration</i>	280
<i>Automatic Backwash Filtration</i>	282
<i>Precoat Filtration</i>	284
<i>Cartridge Filtration</i>	284
<i>Bag Filtration</i>	285
<i>Indexing Media Filtration</i>	285
Solids Handling and Processing	286
Solids Conditioning	287
Solids Thickening and Dewatering	288
<i>Thickening</i>	289
<i>Gravity Thickening</i>	289
<i>Dissolved Air Flotation</i>	290
<i>Centrifuges</i>	291
<i>Gravity Belt Thickeners</i>	291
<i>Rotary Drum Thickeners</i>	292
<i>Dewatering</i>	292
<i>Centrifuges</i>	293
<i>Belt Filter Presses</i>	294
<i>Recessed-Plate Filter Presses</i>	295
<i>Screw Presses</i>	298
<i>Vacuum Filters</i>	299
<i>Container Filters</i>	299

<i>Geotextiles</i>	300
<i>Sand Drying Beds</i>	300
<i>Lagoons</i>	301
Drying	302
Composting	303
Disposal Practices and Technologies	304
Grit and Screenings	304
Chemical Fixation	304
Oily Sludge and Residues	305
Toxic or Hazardous Waste	306
Nonhazardous Wastewater Solids	306
Landfilling	306
Land Application	307
Incineration	307
References	308

Chapter 10 Removal of Fats, Oil, and Grease

FOG Characteristics	312
The Need for FOG Pretreatment	312
FOG Characteristics	313
Analytical Procedures for FOG	314
Total FOG	314
Floatable FOG	314
Sampling	315
Sources of FOG	315
Food-Processing Industry	315
Metalworking Industry	316
Petroleum Industry	317
Other Industries	317
Pretreatment Techniques	317
Gravity Separation	318
<i>Coalescing Gravity Separators</i>	320
<i>Chemically Enhanced Separation</i>	322
Dissolved Air Flotation	323
Centrifuges	327

Hydrocyclones	327
Conventional Filtration	328
Ultrafiltration	328
Organoclays	330
Options for Using Recovered FOG	331
Reuse	331
Recycle	332
References	332

Chapter 11 pH Control

Terms and Definitions	337
pH and pOH	337
Acidity and Alkalinity	338
<i>Acidity</i>	339
<i>Alkalinity</i>	340
Buffering Capacity	341
pH Measurement Principles	342
Wastewater Characteristics	343
Titration Curves and Analysis	343
Wastewater Variability	344
Solids Production Potential	346
Selection of Neutralizing Agents	347
Type of Neutralizing Agent Required	347
Operating Costs	348
Capital Cost	348
Reaction Time	348
Dissolved Solids Production	348
Solids Production	348
Safety	349
Maximum/Minimum pH in Overtreatment	349
Ease of Chemical Handling	349
Availability and Other Issues	349
Basic Agents	350
<i>Lime</i>	350
<i>Caustic Soda</i>	353
<i>Sodium Bicarbonate</i>	353

<i>Sodium Carbonate</i>	353
<i>Magnesium Hydroxide</i>	354
Acidic Agents	354
<i>Sulfuric Acid</i>	354
<i>Carbon Dioxide and Flue Gas</i>	354
<i>Other Acids</i>	355
Bulk Storage and Handling Requirements	355
Design of pH Control Systems	357
General Design Considerations	358
Batch and Continuous Flow Systems	359
<i>Batch pH Control</i>	359
<i>Continuous-Flow pH Control</i>	360
Hydraulic Detention Time	361
System Geometry	363
Mixing Requirements	363
Operational Considerations	363
Process Control	363
<i>Batch Systems</i>	364
<i>Continuous-Flow Systems</i>	365
Corrosion	365
Scale	366
Solids Handling	366
Operating Costs	366
References	367
 Chapter 12 Removal of Inorganic Constituents	
Effects on Municipal Wastewater Treatment Plants	371
Metals and Cyanide	371
Sulfides	372
Phosphorus Compounds	372
Nitrogen Compounds	373
<i>Ammonia</i>	373
<i>Nitrite</i>	374
<i>Nitrate</i>	374
Typical Industries with Inorganic Compounds	374

Typical Treatment Strategies and Processes	374
Neutralization–Precipitation	376
<i>Predicting Inorganic Compound Solubilities</i>	376
<i>Hydroxide Precipitation–Coagulation</i>	378
<i>Iron and Aluminum Salt Precipitation–Coagulation</i>	380
<i>Sulfide Precipitation–Coagulation</i>	380
<i>Carbonate Precipitation–Coagulation</i>	383
<i>Chelating Agents and Metals</i>	384
Chemical Conversion	384
<i>Cyanide Destruction</i>	384
<i>Destruction of Cyanide Not Amenable to Chlorination</i>	385
<i>Hexavalent Chromium Reduction</i>	386
<i>Iron Coprecipitation</i>	388
<i>Sodium Borohydride Reduction</i>	388
<i>Sodium Dimethyldithiocarbamate</i>	389
<i>Arsenic, Selenium, and Mercury Removal</i>	389
<i>Arsenic</i>	389
<i>Selenium</i>	390
<i>Mercury</i>	392
<i>Summary of Chemical Treatment Methods</i>	393
Solids Separation Processes	393
<i>Sedimentation Pond</i>	393
<i>Conventional Clarifier</i>	395
<i>Solids Contact Clarifier</i>	395
<i>Inclined-Plate Clarifier</i>	396
<i>Dissolved Air Flotation</i>	396
<i>Filtration Systems</i>	396
Pretreatment Processes for Nutrients	397
<i>Phosphorus Removal</i>	397
<i>Iron and Aluminum Salts</i>	397
<i>Lime</i>	398
<i>Nitrogen Removal</i>	399
<i>Air/Steam Stripping of Ammonia</i>	400
<i>Ion Exchange</i>	400
<i>Breakpoint Chlorination of Ammonia</i>	401
<i>Biological Nitrification of Ammonia</i>	402
<i>Biological Denitrification</i>	403
Other Technologies	403

Ion Exchange	404
<i>Pretreatment</i>	405
<i>General Design Approach</i>	405
<i>Metals</i>	405
<i>Arsenic</i>	406
<i>Selenium</i>	406
<i>Ammonia</i>	407
<i>Nitrate</i>	407
<i>Radioactive Materials</i>	407
<i>Column Regeneration</i>	407
Adsorption	408
<i>Activated Carbon</i>	408
<i>Activated Alumina</i>	408
<i>Fluoride</i>	408
<i>Arsenic</i>	409
Membrane Filtration	409
<i>Reverse Osmosis</i>	410
<i>Nanofiltration</i>	410
Electrodialysis	411
Evaporation	411
<i>Evaporation Ponds</i>	412
<i>Mechanical Evaporators</i>	412
<i>Vertical-Tube Falling Film</i>	414
<i>Horizontal-Tube Spray Film</i>	416
<i>Forced Circulation</i>	416
<i>Combined Systems</i>	417
References	418

Chapter 13 Removal of Organic Constituents

Biological Treatment Processes	424
Energy-Synthesis Relationships	425
Treatment Organisms	425
Microbial Growth Kinetics	428
Factors Affecting Biological Treatment Processes	429
<i>Carbon Source</i>	429
<i>Nutrients and Growth Factors</i>	430
<i>Energy Source or Electron Donor</i>	431
<i>Electron Acceptor</i>	431

<i>Temperature</i>	431
<i>pH</i>	432
<i>Toxic Substances</i>	432
<i>Shock Loading</i>	432
<i>Salinity</i>	432
<i>Solids Retention Time</i>	432
<i>Mixing (Reactor Design)</i>	433
Design Approaches	433
Treatment Technologies	434
<i>Activated Sludge Process</i>	434
<i>Microbiology</i>	436
<i>Problems in Solids-Liquid Separation</i>	437
<i>Process Design</i>	438
<i>Sequencing Batch Reactors</i>	440
<i>Lagoons</i>	444
<i>Facultative Ponds</i>	444
<i>Aerobic Ponds</i>	446
<i>Combined Aerobic-Anaerobic Ponds</i>	446
<i>Anaerobic Lagoons</i>	446
<i>Fixed-Film Technologies</i>	446
<i>Trickling Filters</i>	448
<i>Rotating Biological Contactors</i>	448
<i>Submerged Media Attached-Growth Reactors</i>	452
<i>Upflow Anaerobic Sludge Blanket Reactors</i>	455
<i>Anaerobic Treatment</i>	455
Nutrient Removal	460
<i>Nitrogen Removal</i>	460
<i>Phosphorus Removal</i>	461
Secondary Emissions	462
Chemical Oxidation Processes	462
Applicability to Organic Contaminants	463
Design Considerations	464
Oxidizing Agents	465
<i>Hydrogen Peroxide/Fenton's Reagent</i>	465
<i>Chlorine</i>	468
<i>Chlorine Dioxide</i>	468
<i>Ozone</i>	468
<i>Permanganate</i>	469

Advanced Oxidation Processes	469
<i>Ultraviolet Light-Enhanced Oxidation</i>	470
<i>Sonication</i>	470
Other Oxidation Processes	470
<i>Wet Air Oxidation</i>	471
<i>Supercritical Water Oxidation</i>	471
Physical Treatment Processes	471
Air-Water Distribution	472
Diffusion Coefficients	474
Liquid to Gas Systems	474
<i>Stripping Towers</i>	474
<i>Stripping with Conventional Aeration Equipment</i>	484
<i>Steam Stripping, Steam Distillation</i>	486
Liquid to Solid Systems	489
<i>Activated Carbon</i>	489
<i>Activated Alumina, Organoclays, and Synthetic Resins</i>	494
References	495

Chapter 14 Process Instrumentation and Control

Philosophy and Approach	506
Need for Instrumentation	506
Regulatory Requirements	506
Measurement	507
Flow	507
<i>Open Channel Flow</i>	507
<i>Weirs</i>	507
<i>Flumes</i>	509
<i>Velocity-Area Meters</i>	511
<i>Submerged Orifices</i>	511
<i>Closed Pipe Flow</i>	512
<i>Magnetic Flow Meters</i>	512
<i>Ultrasonic Flow Meters</i>	514
<i>Venturis</i>	515
<i>Orifice Plates</i>	516
<i>Mass Flow Meters</i>	516
Level	517
<i>Bubbler Systems</i>	517
<i>Pressure Transducers</i>	517

Impedance and Capacitance Probes 518

Ultrasonic 520

Pressure 521

Process Analyzers 521

pH 521

Dissolved Oxygen 521

Oxidation-Reduction Potential 522

Conductivity 522

Streaming Current Detector 522

Turbidity and Particle Counters 522

Respirometry 523

Total Organic Carbon 524

Chemical Oxygen Demand, Biochemical Oxygen Demand 524

Ammonia and Nitrates 525

Chlorine/Sulfite Residual 525

Samplers 525

Control 526

Control Concepts 526

Final Control Elements 526

Process Controllers 527

Design of pH Control Systems 530

Batch-Control Systems 531

Continuous-Flow Systems 532

On-Off Control 532

Multimode Control 534

Cascade Control 535

Two-Stage Neutralization 537

Design of ORP Control Systems 538

References 538

Suggested Readings 538

Chapter 15 Project Procurement

Regulatory Review 542

Project Life Cycle 542

Project Identification 543

Feasibility Study 543

Design 544

In-House Engineers vs. Outside Design Firms	544
Design Drawings	545
Design Specifications	545
Construction	547
Bonds	547
Construction Inspection	548
Shop Drawings	548
Progress Payments	548
Retainage	549
Change Orders	549
Liquidated Damages	549
Startup and Operation	550
Operations and Maintenance Manual	550
Warranty Period	551
Traditional versus Alternative Project Procurement Methods	551
Traditional Project Procurement (Design-Bid-Build)	554
Design-Build	554
Construction Manager-at-Risk	555
Engineer-Procure-Construct	555
Design-Build-Operate	555
Design-Build-Own-Operate-Transfer	556
Operations and Maintenance Service Contract	557
Predictive Maintenance Contracts	557
Suggested Readings	558
Appendix: Conversions from SI to U.S. Customary Units	559
Index	568