

Table of Contents

Chapter 1

Introduction to Wastewater Treatment 1

1.1 Wastewater as a Resource 2

1.1.1 Urban Water Cycle 3

1.2 Wastewater Components 4

1.2.1 Types of Solids in Wastewater 8

1.3 Clean Water Act 10

1.3.1 NPDES Programs 10

1.4 Collection, Treatment, and Reuse Facilities 12

1.4.1 Wastewater Collection and Conveyance Systems 12

1.4.1.1 Types of Collection Systems 13

1.4.2 Wastewater Treatment 15

1.4.2.1 Preliminary Treatment 18

1.4.2.2 Primary Treatment 18

1.4.2.3 Secondary Treatment 18

1.4.2.4 Disinfection 19

1.4.2.5 Tertiary Treatment 19

1.4.2.6 Lagoon Systems 28

1.4.2.7 Membrane Bioreactor 30

1.4.3 Effluent Discharge, Reclamation, and Reuse 32

1.4.3.1 Solids Handling, Disposal, and Reuse 32

1.4.3.2 Odor Control 37

1.5 Sampling and Laboratory Analysis 38

1.6 Electrical Power and Instrumentation Control 38

1.7 Maintenance Program 38

1.7.1 Asset Management Program 39

1.8 Safety Program 40

1.8.1 Accident Prevention 41

1.8.2 Safety Hazards 42

1.9 Math Assignment 42

1.10 Additional Resources 43

Chapter Review 44

Chapter 2

Nutrient Removal (Tertiary Treatment) 47

2.1 Nutrient Removal 48

2.1.1 Rate Limiting Nutrient 49

2.2 Nitrogen Removal 50

2.2.1 Nitrification 51

2.2.1.1 Process Efficiency 53

2.2.1.2 Nitrification Using Suspended Growth Reactors 56

2.2.1.3 Operation 58

2.2.1.4 Nitrification Using Fixed Film Reactors 66

2.2.1.5 Operation 69

2.2.1.6 Laboratory Reporting and Regulatory Compliance 72

2.2.1.7 Troubleshooting 73

2.2.2 Denitrification 75

2.2.2.1 Fixed Film Reactor 76

2.2.2.2 Suspended Growth Reactor 77

2.2.2.3 Troubleshooting 79

2.2.3 Ammonia Stripping 80

2.2.3.1 Troubleshooting 83

2.2.4 Breakpoint Chlorination 83

2.2.4.1 Equipment 85

2.2.4.2 Operation 85

2.2.5 Ion Exchange 86

2.2.6 Anammox Treatment Process 86

2.2.7 Overland Flow 88

2.3 Phosphorus Removal 89

2.3.1 Biological Phosphorus Removal 91

2.3.1.1 Process Layouts 92

2.3.2 Luxury Uptake of Phosphorus 94	2.3.2.1 Safety 97	2.3.2.2 Equipment 98	2.3.2.3 Startup 99	2.3.2.4 Operation 100	2.3.2.5 Shutdown 103	2.3.2.6 Abnormal and Emergency Operating Conditions 103	2.3.2.7 Maintenance 103	2.3.2.8 Calculating Process Efficiency 104	2.3.2.9 Reviewing Plans and Specifications 105
2.3.3 Chemical Phosphorous Removal 107	2.3.3.1 Aluminum Sulfate 108	2.3.3.2 Ferric Chloride 110	2.3.3.3 Chemical Injection Locations 111	2.3.3.4 Sludge Production 114	2.3.3.5 Maintenance 115	2.3.3.6 Reviewing Plans and Specifications 115			
2.3.4 Lime Precipitation 116	2.3.4.1 Equipment 116	2.3.4.2 Operation 118	2.3.4.3 Sampling and Analysis 118	2.3.4.4 Recarbonation and Calcium Carbonate Recapture 119	2.3.4.5 Abnormal and Emergency Conditions 120	2.3.4.6 Maintenance 122	2.3.4.7 Loading Guidelines 124	2.3.4.8 Reviewing Plans and Specifications 126	
2.4 Enhanced Biological Control 126									
2.4.1 Multiple Processing Objectives 127	2.4.1.1 Process Control 128	2.4.1.2 System Flexibility 129	2.4.1.3 Operating Strategy 129						
2.4.2 Bardenpho Process 130	2.4.2.1 Operating Procedures 132								
2.4.3 Sequencing Batch Reactor 133									
2.4.4 Optimizing Nitrogen and Phosphorus Removal 134									
2.4.5 Enhanced SVI Control 137	2.4.5.1 Operations and Troubleshooting 138								
2.4.6 Reviewing Plans and Specifications 139	2.4.6.1 Overall Facility 140	2.4.6.2 Enhanced Phosphorus Control 144	2.4.6.3 Enhanced Nitrogen Oxidation 145						

2.4.6.4 Enhanced Nitrogen Removal 146	2.4.6.5 Enhanced SVI Control 147
---------------------------------------	----------------------------------

2.5 Math Assignment 148

Chapter Review 149

Chapter 3

Solids Removal from Effluent (Tertiary Treatment) 153

3.1 Removing Solids From Secondary Effluents 154
--

3.2 Physical-Chemical Treatment 157

3.2.1 Particle Surface Charge 157	
3.2.2 Coagulation 159	3.2.2.1 Coagulating Agents 161
	3.2.2.2 Jar Testing and Coagulant Selection 166
	3.2.2.3 Coagulant Performance Optimization 172
	3.2.2.4 Coagulant Injection 172
3.2.3 Flocculation 183	3.2.3.1 Flocculators 183
3.2.4 Sedimentation 186	3.2.4.1 Sedimentation Basins 186
	3.2.4.2 Performance Metrics 192
	3.2.4.3 Other Performance Considerations 199
3.2.5 Troubleshooting 200	
3.2.6 Safety 202	

3.3 Conditioning 204

3.3.1 Thermal Conditioning 204	
3.3.1.1 Normal Operating Procedures 205	
3.3.1.2 Troubleshooting 207	
3.3.2 Wet Oxidation 208	3.3.2.1 Typical Performance 211
3.3.3 Elutriation 211	3.3.3.1 Operating Guidelines 212

3.4 Gravity Filtration 212

3.4.1 Filtering Process 213	
3.4.2 Backwashing Process 214	
3.4.3 Filtration Methods 214	3.4.3.1 Surface Straining 216
	3.4.3.2 Depth Filtration 216

3.4.4 Filtering System Components 217	3.7.1 Pressure Vessels or Submerged Flow 271
3.4.5 Filter System Instrumentation 222	3.7.2 Membrane Flow Systems 273
3.4.6 Normal Operation 223	3.7.3 Membrane Materials and Lifespan 274
3.4.6.1 Operational Strategy 225	3.7.4 Membrane Configurations 276
3.4.6.2 Shutdown 230	3.7.4.1 Tubular Membranes 276
3.4.7 Safety 230	3.7.4.2 Hollow Fiber Membranes 277
3.4.8 Reviewing Plans and Specifications 231	3.7.4.3 Spiral Membranes 279
3.5 Inert-Media Pressure Filters 232	3.7.4.4 Plate and Frame Membranes 279
3.5.1 Holding Tank 234	3.7.4.5 Submerged Membrane Systems 280
3.5.2 Filter Feed Pumps 234	3.7.5 Evaluating Membrane Performance 283
3.5.3 Chemical Feed Systems 234	3.7.5.1 Membrane Flux 283
3.5.3.1 Alum 235	3.7.5.2 Rejection 284
3.5.3.2 Polymers 235	3.7.5.3 Log Removal 286
3.5.3.3 Adding and Mixing Chemicals 237	3.7.5.4 Waste Components Concentrations 286
3.5.4 Filters 240	3.7.5.5 Transmembrane Pressure 288
3.5.4.1 Vessels 240	3.7.5.6 Recirculation Flow 289
3.5.4.2 Interior Piping 243	3.7.5.7 Temperature 290
3.5.4.3 Underdrain System 243	3.7.5.8 Concentration-Dependent Flux 290
3.5.4.4 Inert Media 243	3.7.5.9 Membrane Fouling 290
3.5.4.5 Flow Control Method 244	3.7.6 Operation 291
3.5.5 Backwash System 245	3.7.6.1 Operating Modes 291
3.5.5.1 Wet Well 245	3.7.6.2 Feed Pretreatment 293
3.5.5.2 Pumps 245	3.7.6.3 System Automation 295
3.5.5.3 Backwash Cycle 246	3.7.6.4 Cleaning Procedures 296
3.5.6 Decant Tank 247	3.7.6.5 Water Flux Measurements 297
3.5.6.1 Operational Strategy 248	3.7.6.6 Sampling 299
3.5.7 Maintenance 250	3.7.7 Recordkeeping 300
3.5.8 Safety 251	3.7.8 Safety Precautions 301
3.5.9 Reviewing Plans and Specifications 252	3.8 Biological Aerated Filters 301
3.6 Continuous Backwash, Upflow, Deep-Bed Silica Sand Media Filters 253	3.9 Math Assignment 305
3.6.1 Auxiliary Equipment 257	3.10 Additional Resources 305
3.6.1.1 Channel or Piping 257	Chapter Review 306
3.6.1.2 Turbidity Monitoring 257	
3.6.2 Operation 259	
3.6.2.1 Operating Strategy 261	Chapter 4
3.6.2.2 Abnormal Operation 262	Residual Solids Management 311
3.6.3 Maintenance 262	
3.6.4 Safety 267	4.1 Solids Handling and Disposal 312
3.6.5 Reviewing Plans and Specifications 268	4.1.1 Solids Types and Characteristics 314
3.7 Membrane Filtration 269	4.1.2 Preparing Solids for Disposal and Reuse 315

4.1.3 Sludge Treatment, Reuse, and Disposal Regulations 316	4.4.1.10 Digester Cleaning 446
4.1.4 Sludge Quantities 317	4.4.1.11 Safety 448
4.1.4.1 Primary Sludge 318	4.4.1.12 Operational Strategy 450
4.1.4.2 Secondary Sludge 319	4.4.1.13 Troubleshooting 456
4.1.4.3 Sludge Volumes 321	4.4.1.14 Example of Actual Operation 457
4.1.5 Sludge Handling Methods 322	4.4.2 Aerobic Digestion 459
4.2 Preliminary Sludge Processing 324	4.4.2.1 Process Description 461
4.3 Sludge Thickening 325	4.4.2.2 Performance 463
4.3.1 Gravity Thickeners 326	4.4.2.3 Normal Operating Procedures 469
4.3.1.1 Performance 328	4.4.2.4 Typical Performance 474
4.3.1.2 Normal Operating Procedures 332	4.4.2.5 Troubleshooting 476
4.3.1.3 Troubleshooting 335	4.4.3 Chemical Stabilization 480
4.3.2 Dissolved Air Flotation Thickeners 344	4.4.3.1 Normal Operating Procedures 481
4.3.2.1 Performance 347	4.4.3.2 Troubleshooting 482
4.3.2.2 Normal Operating Procedures 351	4.4.4 Composting 482
4.3.2.3 Troubleshooting 353	4.4.4.1 Performance 486
4.3.3 Centrifuge Thickeners 356	4.4.4.2 Normal Operating Procedure 489
4.3.3.1 Solid Bowl Centrifuge 357	4.4.4.3 Typical Performance 489
4.3.3.2 Basket Centrifuge 357	4.4.4.4 Troubleshooting 490
4.3.3.3 Disc-Nozzle Centrifuge 358	4.5 Dewatering and Volume Reduction 491
4.3.3.4 Performance 358	4.5.1 Filtration 492
4.3.3.5 Normal Operating Procedures 364	4.5.1.1 Filter Press 492
4.3.3.6 Troubleshooting 367	4.5.1.2 Belt Filter Press 499
4.3.4 Gravity Belt Thickeners 371	4.5.1.3 Screw Press 506
4.3.4.1 Performance 373	4.5.1.4 Rotary Press 509
4.3.4.2 Normal Operating Procedures 375	4.5.2 Centrifugation 512
4.3.4.3 Troubleshooting 375	4.5.2.1 Typical Performance 512
4.3.5 Rotary Drum Thickeners 377	4.5.3 Sludge Drying 513
4.3.5.1 Performance 378	4.5.3.1 Sand Drying Beds 513
4.3.5.2 Normal Operating Procedures 379	4.5.3.2 Surfaced Drying Beds 519
4.4 Sludge Stabilization 381	4.5.3.3 Heat Drying 522
4.4.1 Anaerobic Digestion 381	4.5.4 Sludge Incineration 526
4.4.1.1 Process Description 382	4.5.4.1 Multiple Hearth Incinerator 526
4.4.1.2 System Components 387	4.5.4.2 Fluidized Bed Incinerator 530
4.4.1.3 Digester Mixing 395	4.5.4.3 Performance 531
4.4.1.4 Digester Heating 402	4.5.4.4 Normal Operating Procedure 532
4.4.1.5 Digester Gas Collection 404	4.5.4.5 Troubleshooting 536
4.4.1.6 Digester Gas Treatment 413	4.5.5 Facultative Sludge Storage Lagoons 536
4.4.1.7 Performance 418	4.6 Solids Disposal 537
4.4.1.8 Digester Operation 424	4.6.1 Disposal Options 540
4.4.1.9 Controls and Test Interpretation 434	4.6.1.1 Dewatered Biosolids 543

4.6.2 Monitoring Program 557**4.6.2.1 Odors 558****4.6.2.2 Sludge and Dedicated Land Disposal Sites 558****4.6.2.3 Groundwater 559****4.6.2.4 Surface Water Monitoring 559****4.6.2.5 Public Health Vectors 559****4.7 Math Assignment 561****Chapter Review 562****Chapter 5****Plant Maintenance 567****5.1 Wastewater Treatment System Maintenance 568****5.1.1 Maintenance Classifications 569****5.1.2 Collection System Maintenance 574****5.1.3 Computer Maintenance Management Systems 577****5.1.4 General Treatment Plant Maintenance 580****5.1.4.1 Headworks 580****5.1.4.2 Primary Treatment 581****5.1.4.3 Secondary Treatment Systems 582****5.1.4.4 Solids Handling 589****5.1.4.5 Disinfection Systems 591****5.1.4.6 Plant Tanks and Channels 593****5.1.4.7 Chain Drives 594****5.1.4.8 Building Maintenance 594****5.1.4.9 Plant Grounds 595****5.1.4.10 Repair Shop 595****5.1.4.11 Plant Safety Equipment 596****5.1.5 Lockout/Tagout Procedures 596****5.1.6 Emergencies 598****5.2 Electricity 600****5.2.1 Understanding Electricity 601****5.2.1.1 Volts 601****5.2.1.2 Amps 602****5.2.1.3 Current 602****5.2.1.4 Power 603****5.2.1.5 Energy Requirements 604****5.2.1.6 Conductors and Insulators 604****5.2.2 Meters and Testers 605****5.2.2.1 Voltage Testing 605****5.2.2.2 Ammeter 609****5.2.2.3 Megger 614****5.2.2.4 Ohmmeter 615****5.2.2.5 Motor Rotation Indicator 616****5.2.3 Flow Measurements 616****5.2.3.1 Flow Measurement Devices 617****5.2.3.2 Location and Integration 620****5.2.3.3 Sensor Maintenance 621****5.2.3.4 Calibration and Cross-Checking 621****5.2.4 Electrical System Equipment 622****5.2.4.1 Protective Devices 623****5.2.5 Motor and Supervisory Control Systems 632****5.2.5.1 Aluminum and Copper 635****5.2.6 Records 635****5.3 Motors 636****5.3.1 Nameplate Data 638****5.3.1.1 Power Supply 640****5.3.2 Causes of Failure 640****5.3.3 Insulation 641****5.3.3.1 Increasing Resistance Value 643****5.3.4 Starters 644****5.3.5 Variable Frequency Drives 647****5.3.6 Other Considerations 651****5.3.6.1 Alignment 651****5.3.6.2 Changing Rotation Direction 652****5.3.6.3 Allowable Deviations 653****5.3.6.4 Maximum Vibration Levels 653****5.3.6.5 Lubrication 653****5.3.7 Troubleshooting 654****5.4 Pumps 658****5.4.1 Types of Pumps 658****5.4.1.1 Centrifugal Pumps 659****5.4.1.2 Propeller Pumps 664****5.4.1.3 Reciprocating Pumps 664****5.4.1.4 Progressive Cavity Pumps 669****5.4.1.5 Rotary Lobe Pumps 669****5.4.1.6 Incline Screw Pumps 670****5.4.1.7 Pneumatic Ejectors 673****5.4.2 Pump Seals 673****5.4.2.1 Packing 673****5.4.2.2 Mechanical Seals 680**

5.4.3 Pump Lubrication 682	
5.4.3.1 Lubrication Schedule and Storage 683	
5.4.4 Other Pump Components 684	
5.4.4.1 Bearings 685	
5.4.4.2 Belt Drives 689	
5.4.4.3 Couplings 690	
5.4.4.4 Shear Pins 691	
5.4.4.5 Variable-Speed Belt Drives 691	
5.4.4.6 Dehumidifiers 692	
5.4.4.7 Air Gap Separation Systems 692	
5.4.4.8 Pump Controls 693	
5.4.5 Valves 693	
5.4.5.1 Check Valves 693	
5.4.5.2 Gate Valves 693	
5.4.5.3 Plug Valves 697	
5.4.5.4 Sluice Gates 697	
5.4.6 Pump Startup, Performance, and Shutdown 698	
5.4.6.1 Startup 698	
5.4.6.2 Verifying Pump Performance 701	
5.4.6.3 Shutdown 703	
5.4.7 Pump Drivers 703	
5.5 Pneumatic System Maintenance 706	
5.6 Unplugging Pipes, Pumps, and Valves 709	
5.6.1 Unplugging Pipelines 709	
5.6.1.1 Pressure Methods 709	
5.6.1.2 Cutting Tools 709	
5.6.1.3 High-Velocity Pressure Units 710	
5.6.2 Scum Lines 710	
5.6.3 Sludge Lines 711	
5.6.3.1 Digested Sludge Lines 711	
5.6.4 Plugged Pumps and Valves 712	
5.7 Math Assignment 713	
5.8 Additional Resources 714	
Chapter Review 715	

Appendix A

Introduction to Basic Math for Operators 719

Introduction 720

Basic Concepts (Sections A.1–A.4) 721

A.1 Numbers and Operations 721

 A.1.1 Addition 721

 A.1.2 Subtraction 722

 A.1.3 Multiplication 722

 A.1.4 Division 722

A.2 Order of Operations 723

 A.2.1 Addition and Subtraction 723

 A.2.2 Multiplication and Division 723

 A.2.3 Mixed Calculations 724

 A.2.4 Parentheses 726

A.3 Basic Algebra (Solving Equations) 728

A.4 Percentages 730

Intermediate Concepts (Sections A.5–A.7) 734

A.5 Units 734

 A.5.1 Distance or Length 734

 A.5.2 Area 735

 A.5.2.1 Rectangle 736

 A.5.2.2 Triangle 737

 A.5.2.3 Trapezoid 738

 A.5.2.4 Circle 739

 A.5.2.5 Cylinder 740

 A.5.2.6 Cone 741

 A.5.2.7 Sphere 743

 A.5.3 Volume 744

 A.5.3.1 Cube 744

 A.5.3.2 Rectangular Prism 744

A.5.3.3 Triangular Prism 746	A.8.7 Evaluating Pump Performance 798
A.5.3.4 Cylinder 747	A.8.7.1 Capacity 798
A.5.3.5 Cone 747	A.8.7.2 Efficiency (US Customary Units) 800
A.5.3.6 Sphere 748	A.8.7.3 Efficiency (Metric) 803
A.5.4 Mass and Weight 748	A.8.8 Pump Speed–Performance Relationships 807
A.5.5 Density, Specific Weight, and Specific Gravity 749	A.8.9 Friction or Energy Losses 809
A.5.6 Concentration 750	A.9 Data Analysis and Presentation 813
A.5.6.1 Dilution Ratio and Factor 752	A.9.1 Causes of Variations in Results 814
A.5.6.2 Mixtures 753	A.9.1.1 Water or Material Being Examined 814
A.5.7 Velocity and Flow Rate 757	A.9.1.2 Sampling 814
A.5.8 Force and Pressure 762	A.9.1.3 Testing 814
A.5.9 Work, Head, and Power 771	A.9.2 Controlling Systematic Variation 815
A.6 Significant Figures 776	A.9.2.1 Reading Charts 815
A.7 Metric System 778	A.9.3 Describing Data or Results 816
A.7.1 SI Base Units 778	A.9.3.1 Graphs and Charts 817
A.7.2 Length 779	A.9.3.2 Numerical Representation of Data 822
A.7.3 Capacity or Volume 780	A.9.3.3 Moving Averages 831
A.7.4 Weight (Mass) 780	A.9.4 Using Charts and Graphs 833
A.7.5 Temperature 781	A.9.4.1 Volume of Sludge in a Digester 833
Advanced Concepts (Sections A.8–A.9) 782	A.9.4.2 Tracking BOD Loading 835
A.8 Pumps 782	A.9.5 Regression Analysis (Prediction Equations, Trends, and Correlations) 838
A.8.1 Pressure (US Customary Units) 782	A.9.5.1 Correlations 843
A.8.2 Pressure (Metric) 783	Math Review 844
A.8.3 Work 785	Answer Key 849
A.8.4 Power 785	Glossary 853
A.8.4.1 Horsepower (US Customary Units) 786	Index 883
A.8.4.2 Watts (Metric) 790	
A.8.5 Head 790	
A.8.6 Pump Characteristics 795	

Index

Note: Page numbers followed by "f" refer to figures; those followed by "t" refer to tables.

A

- Accident prevention, 41
- Acid formers, 35
- Acidic waters, oSRT in, 60f
- Acid-phase digesters, 384
- Acid regression stage, 452
- AC powered electric motor, 636
- Activated carbon, 414
- Activated sludge process (ASP), 50, 57, 75, 157, 280, 314, 328, 329, 585, 586f
 - vs.* MBR system, 281f
 - with secondary effluent polishing process, 158f
- Addition, math operation, 721, 723, 723f
- Adsorption, 107, 414
- Advanced oxidation processes (AOP), 25–28, 26f–28f
- Aerated activated sludge systems, 61
- Aeration, 75, 278, 328, 329, 585, 586f, 587f
- Aerobic bacteria, 6
- Aerobic digestion, 36, 322, 459–461, 460f
 - air requirements, 468–469
 - dissolved oxygen, 463, 468–469
 - drawback to, 465
 - foaming, 478
 - operational and performance guidelines for, 476t
 - performance parameters, 474–476
 - pH and alkalinity, 469
 - pollutants, 464, 465t
 - process control and monitoring, 469–473
 - process description, 461–463
 - startup and shutdown, 473–474
 - temperature, 466, 477
 - time, 465–466
 - troubleshooting, 476–479, 479f–480f
 - volatile solids loading, 466–468
- Aerobic selector, 139
- Aerobic wastewater treatment, 48
- Agglomeration, 116, 156
- Aging tanks, 175
- Agronomic rates, 317
- Air binding, 247
- Air conditioning units (A/C), 591
- Air gap separation system, 692–693
- Air-liquid interface, 346
- Air to solids (A/S) ratio, 349
- Alarm systems, sludge incineration, 533–534

- Algae, 7, 48, 228
- Algebra, 728–730
- Alignment of motors, 651–652, 652f, 653f
- Alkaline waters, oSRT in, 60f
- Alkalinity, 51, 60–64, 62f, 395
 - aerobic digestion, 469
 - anaerobic digestion, 422
 - for AOBs, 61, 62
 - chemicals increase, 63t
 - composition, 62f
 - for enhanced biological and chemical control, 135–136, 135f
 - metal salts, 161
 - pH levels, 63
- Alternating current (AC), 602, 636
- Alum. *See* Aluminum sulfate
- Aluminum, 635
- Aluminum sulfate, 107, 108–110, 109f
 - inert-media pressure filters, 235, 236f
 - metal coagulants, 161
- Ammeter, 609–613
- Ammonia, 37
- Ammonia concentration, nitrification efficiency *vs.*, 53, 54f
- Ammonia-oxidizing bacteria (AOB), 51, 58
 - nitrification reaction for, 61, 62
- Ammonia stripping process, 80–83, 81f, 82f
 - Amperage, 601
 - Amperage draw, 573
 - Ampere (A), 602
 - Amplitude, 602
- Anaerobic ammonium oxidation (anammox), 86–88
- Anaerobic bacteria, 6
- Anaerobic digestion, 35, 98, 322, 381–382
 - actual digester operating data, 457–459, 458f
 - alkalinity, 422
 - calculation performance, 444–446
 - cleaning digester, 446–448, 449t
 - digester covers, 391–394, 391f, 392, 394f–396f
 - digester feeding, 425–426
 - digester tank, 388–389, 390f
 - enzymes, 429
 - feed sludge pretreatment, 385, 386t
 - foaming, 429–430
 - gas collection systems (*See* Gas collection systems)
 - gas mixing, 397, 399f
- Anamox. *See* Anaerobic ammonium oxidation
- Anhydrous ammonia, 427
- Anhydrous forms, 110, 162
- Anion, 159
- Anionic polymer, 235, 346
- Annular space, 393
- Anoxic, 461
- Anoxic denitrification, 127
- Anoxic environment, 57
- Anoxic selector, 139
- Anoxic zones, 131, 141, 142
 - with submerged baffles and turbine mixer, 142, 143f
- AOB. *See* Ammonia-oxidizing bacteria
- AOP. *See* Advanced oxidation processes
- Appurtenances, 568
- Arch, 105

- Area, units of measurement
 circle, 739–740, 739f
 cone, 741–743, 741f
 cylinder, 740–741, 740f
 rectangle, 736–737, 736f
 sphere, 743–744, 743f
 trapezoid, 738, 738f
 triangle, 737–738, 737f
- ASP. *See* Activated sludge process
- Aspirator-type air injection, 344
- Asset management program, 39
- ATAD process. *See* Autothermal thermophilic aerobic digestion process
- Attached growth processes, 52
- Auger-driven unit, 580
- Autothermal thermophilic aerobic digestion (ATAD) process, 462, 463
- Autotransformer reduced-voltage starters, 647
- Autotrophic bacteria, 51
- Auxiliary equipment, 257–259
- Axial to impeller, 664
- Axis of impeller, 664
- B**
- Backflow, 182, 693
- Backflushing process, 278
- Backwashing process/system, 213, 214, 214f, 220, 220f, 232, 245–247, 245f, 302, 304
- Bacteria, 48, 156
- Baffles, 73, 179, 326
- BAF systems. *See* Biological aerated filter systems
- Ball bearing failure, 685, 686f–689f
- Bardenpho process, 130–133, 130f–132f
- Basket centrifuge, 357–358, 358f, 364–365 troubleshooting, 368f, 369–370
- Batch operation mode, 206–207, 292, 292f, 293f
- Batch process, 357
- Belt drives, pumps, 689–690
- Belt filter presses, 499, 501f, 502f operating procedures, 503–504 performance, 501–503, 505 troubleshooting, 504–505
- Bimetallic strip, 646
- Biochemical oxygen demand (BOD), 9, 21, 22, 113, 154, 155, 314, 581, 817 loads, 835–838, 837f moving average, 831, 831t regression analysis, 838 test, 48, 65, 66, 73
- Biofouling on membrane surfaces, 281, 282f
- Biological aerated filter (BAF) systems, 157, 301–304, 302f, 303f, 587, 589f
- Biological control, 22
- Biological nutrient removal (BNR) process, 314 operating guidelines for, 133t
- Biological phosphorus removal, 89–91 accumulating organisms, 91f process layouts, 92–94, 93f
- Biological treatment processes, 48, 157, 314, 315, 568
- Biomass, 52
- Biosolids, 2, 11, 312, 315 composting process, 556 dewatered (*See* Dewatered biosolids) disposal, 541, 543 without dewatering, 550–556, 552f, 555f, 556f
- Blinding, 372
- Blowers, 585
- BNR process. *See* Biological nutrient removal process
- BOD. *See* Biochemical oxygen demand
- BOD₅. *See* Five-day biochemical oxygen demand
- Bound water, 204, 328
- Brake horsepower (BHP), 788, 801
- Brake power (BP), 805
- Breakpoint chlorination, 50, 83–85, 84f
- Breakthrough, 214
- Bridge clarifier, 188
- Buffer capacity, 61, 422
- Buffering, 61
- Building maintenance programs, 594–595
- Built-in thermal switches, 629
- Bulking process, 73, 157
- Burnout, sludge incineration, 534–535
- C**
- Calcium carbonate, 61, 98–99, 119–120, 123
- Calcium oxide, 119
- Calcium scaling, 262
- Calibration, of open-channel flow measurement systems, 621–622
- Capacity pumps, 798–799
- Capital improvement plan, 574
- Carbonaceous BOD₅ (CBOD₅), 73, 138
- Cartridge, 277, 277f
- Cation, 159
- Cationic polymer, 247, 346
- Caustic soda feed system, 175f
- Cavitation, 346, 662, 663f
- Cavities, 180
- Central tendency, 823
- Centrate, 102, 356
- Centrifugal pumps, 234, 245, 350, 616, 795 cavitation, 662, 663f concentric *vs.* eccentric fittings, 661f friction loss, 662f impeller, 659, 660f maintenance, 662–663 screen, 662, 664f for source water, 661f startup, 699–700
- suction piping, 659 wear rings, 660
- Centrifugation, dewatering process, 512–513, 512t
- Centrifuge thickeners, 326, 356–357 basket centrifuge, 357–358, 358f bowl speed, 362, 363 differential speed, 363 disc-nozzle centrifuge, 358, 359f feed time, 362–363 hydraulic and solids loading rate, 360–361 liquid depth, 363 nozzles, 364 operating procedures, 364–367, 365t performance of, 358–360, 366t polymer dose, 364 solid bowl centrifuges, 357, 357f troubleshooting, 367–371, 367f, 368f, 369f
- Chain drives, 594
- Channel filtration system, 257
- Charge neutralization, 160
- Check valves, 693, 694f
- Chemical coagulants, 158
- Chemical feed systems, 232, 234–235 adding and mixing chemicals, 237–240 aluminum sulfate, 235, 236f polymers, 235–236, 237f
- Chemical mixing equipment, coagulants, 173, 173f
- Chemical oxygen demand (COD), 9, 26, 63–64, 167, 437 regression analysis, 838
- Chemical phosphorous removal, 107–108 aluminum sulfate, 108–110 chemical injection point, 111–114, 112f, 112t ferric chloride, 110–111, 111f maintenance, 115 reviewing plans and specifications, 115 sludge production, 114
- Chemical piping, 144
- Chemical pumps, 180–182, 180f–182f
- Chemical sludge stabilization, 480–482
- Chloramines, 83
- Chlorinators, 591–593
- Chlorine, 17, 83–85
- Chlorine contact basin, 19, 20f
- Chlorine residual, 83
- CHP systems. *See* Combined heat and power systems
- CIP cycles. *See* Clean-in-place cycles
- Circuit breakers, 571, 627–630, 627f, 628f, 630f
- Circuits, 598
- Circuit testers. *See* Ohmmeters
- Circular clarifier, 187f, 188, 191f, 584f
- Clamp-on ammeter, 609
- Clamp-on multimeter, 607f
- Clarification process, 117
- Clarifiers, 18, 72, 186, 581 bridge, 188

- circular, 187f, 188, 191f, 584f
 efficiency, 199–200
 modified, plan view of, 192f
 primary, 581, 582
 rectangular, 186, 188f, 189f, 191f, 584f
 round, 188, 190
 secondary, 586
- Cleaned digester gas, 417
- Clean-in-place (CIP) cycles, 281, 282
- Clean Water Act (CWA), 10, 316
- Closed-circuit television (CCTV) camera, 575
- CMMS. *See* Computer maintenance management system
- C:N:P ratios, 48
- Coagulants, 156, 161–165
 chemical pumps, 180–182, 180f–182f
 dry chemical systems, 173f–178f, 174–179
 injection, 172–173
 liquid injection systems, 179
 maintenance requirements, 182–183
 performance optimization testing, 172
- Coagulation, 116, 155, 159–160, 160f
 jar testing and coagulant selection, 166–171, 166f
 metal salts, 161–162
 phase, 22
 polymers, 162–165, 164f
- COD. *See* Chemical oxygen demand
- Code of Federal Regulations (CFR), 316
- Cogeneration system, 402
- Coliforms, 154, 155
- Collection system, 568
 maintenance, 574–577
- Colloidal particles, 98, 157, 346
- Combined collection systems, 11
- Combined heat and power (CHP) systems, 417, 417f
- Combined sewer overflows (CSOs), 11
- Combustion zone furnace, 529
- Compartmentalization, 140
- Complete mix activated sludge process, 57
- Composite samples, 199, 351
- Composting, sludge stabilization
 definition of, 482
 guidelines, 482–483
 mechanical method, 484
 operating procedure, 489
 performance, 486–489, 489–490, 489t
 static pile, 483, 484f
 troubleshooting, 490, 491f–492f
 windrow method, 483, 485
- Compressed air systems, 706–707, 708f
- Compressed natural gas (CNG), 418
- Computer maintenance management system (CMMS), 39, 577–578, 579f, 605, 683
- Concentration, 750–752
 dilution ratio and factor, 752–753
 mixtures, 753–756
- Concentration factor (CF), 334, 335
- Concentration polarization, 290
- Conditioning, 204
 elutriation, 211–212
 thermal, 204–208
 wet oxidation, 208–211, 210f, 211t
- Conductivity, 182
- Conductors, 604
- Confined space, 251, 393, 596
- Coning, 336
- Constituents, 23
- Contactors, 622, 623
- Contact resistances, 629
- Contact stabilization, 57
- Continuous backwash sand filter, 253–255, 254f–256f
 auxiliary equipment, 257–259
 filter sand movement evaluation test, 262, 264–267, 265f, 266f
 operation, 259–262, 259f
 reviewing plans and specifications, 268
 safety precautions for, 267–268
 troubleshooting, 263f–265f
- Continuous feed system, 357
- Continuous operation, 206, 207
- Control circuit, 644
- Conventional aeration system, 57
- Conventional aerobic digester, 462–463
- Conventional anaerobic digesters, 384
- Conventional wastewater treatment plants, 7
- Cooling zone furnace, 529
- Copper, 635
- Co-precipitation, 113
- Corbels, 392
- Corrective maintenance, 569
- Corrosion, 162, 393, 571
- Cover indicator, 393
- Cross-flow media, in trickling filters, 68f
- Cross-flow membrane filtration, 23, 24f, 273, 274f, 289
- Cryptosporidium*, 27
- CSOs. *See* Combined sewer overflows
- Current, 601–603
- Current transducers, 573, 573f
- Current transformers (CT), 610
- Current unbalance, 610–613, 610f
- Cutting tools, pipelines, 709–710
- CWA. *See* Clean Water Act
- Cycle, 602
- Cylindrical digester tanks, 388, 389, 390f
- graphs and bar charts, 817–822
 moving averages, 831–832, 831t, 832f, 832t
 numerical representation of, 822–830
 regression analysis, 838–843
 systematic variations, 815–816
 in tabular form, 817
 variation, 814
- DBP. *See* Disinfection byproducts
- Dead-end membrane filtration, 273, 274f
- Decanting process, 431, 432f–433f
- Decant tanks, 205, 247–250
- Dedicated land disposal (DLD), 541, 559
 high-rate, 550–552
 onsite, 544, 546–548, 547f
 site layouts, 552–553
- Deep-bed silica sand filter, 253–255, 254f–256f
 auxiliary equipment, 257–259
 filter sand movement evaluation test, 262, 264–267, 265f, 266f
 operation, 259–262, 259f
 reviewing plans and specifications, 268
 safety precautions for, 267–268
 troubleshooting, 263f–265f
- Deep trenches, 546
- Dehumidifiers, 692
- Delamination, of membrane, 297
- Denitrification, 21–22, 50, 75–76, 328
 fixed film reactor, 76–77, 76f, 77f
 suspended growth reactor, 77–79, 78f, 79f
 troubleshooting, 79, 80f
- Density, 157, 314, 749
- Depth filtration, 216–217, 217f
- Detention time, 56, 156, 193–194, 319, 329, 331
- Dewatered biosolids, 543
 land applications, 548–549
 onsite dedicated land disposal, 544, 546–548, 547f
 sanitary landfill disposal, 543–544
- Dewatering process, 99, 183, 491–492, 580
 centrifugation, 512–513, 512t
 facultative lagoons, 536–537
 filtration-based (*See* Filtration-based dewatering process)
 heat drying process, 522–526, 523f, 527f
 sand drying beds, 513–518, 515f, 518t
 sludge incineration, 526–536
 surfaced drying beds, 519–522, 520f, 521f
- Dewatering units, 17
- Dew point, 416, 592
- Dial indicators, 690
- Diaphragm pumps, 180, 180f–182f, 182
- Diatomaceous earth, 497
- Diffused air systems, 141
- Digested sludge lines, 711
- Digesters, 324, 593
 tank, 388–390
 volume of sludge in, 833–835

D

- DAF. *See* Dissolved air flotation
- Daltons, 25
- Dangerous air conditions, 393
- Data analysis, 813, 813f
 in chart form, 816f
 charts and graphs, 833–838
 correlation coefficient, 843
 data sets, 827, 827t, 828f

Digital input signal, 633
 Digital multimeter, 606f
 Dilution, 752–753
 Direct current (DC), 602, 636
 Direct potable reuse (DPR), 3, 154, 155
 Discharge head, 699
 Disc-nozzle centrifuges, 358, 359f
 troubleshooting, 369f, 370–371
 Disc-type mixer, 397, 401f
 Disease transmission, 6–7
 Disinfection byproducts (DBP), 27
 Disinfection systems, 7, 19, 20f, 591–593
 Dispersion, 827–830
 Dissolved air flotation (DAF), 22, 157, 326,
 345f
 components, 344
 configurations, 344
 operating procedures, 351–353, 352t
 performance of, 347–351
 troubleshooting, 353–354, 355f
 Dissolved oxygen (DO), 18, 50, 64, 463,
 468–469, 471, 476–477
 nitrification efficiency *vs.*, 53, 54f
 oSRT on, 59, 59f, 60, 60f
 Dissolved solids, 8
 Distance, units of measurement, 734–735
 Distribution and marketing (D&M), 541
 Division, math operation, 722–724
 DLD. *See* Dedicated land disposal
 DO. *See* Dissolved oxygen
 Domestic contribution, 5
 Doppler flow meters, 618–619, 619f
 Dot diagrams, 819, 820f, 821
 Double disc pumps, 668–669, 668f
 DPR. *See* Direct potable reuse
 Dry alum, 110
 Dry chemical systems, 173f–178f, 174–179
 Drying zone furnace, 529
 Dry polymers, 163–164, 164f, 178–179, 178f

E

Edison Electric Institute (EEI), 637
 EDL. *See* Electrical double layer
 Eductors, 176
 Effluent, 3, 48, 312
 discharge, reclamation, and reuse, 32–37
 disinfection systems, 591
 from lagoons, 30
 rate-control valve, 221
 removing solids from, 154–156
 Egg-shaped digester (ESD), 388–389, 390f,
 396
 Elapsed time meters (ETMs), 577
 Electrical double layer (EDL), 158, 160
 Electrical energy, 40
 Electrical power, 38
 Electrical system equipment, 622–623
 circuit breakers, 627–630, 627f, 628f
 fused disconnect switches, 623, 624f
 fuses, 625–626, 625f
 ground, 630–632, 631f

motor and supervisory control systems,
 632–635
 motor circuit elements, 623, 624f, 625
 records, 635
 Electricity, 600–601
 ammeter, 609–613
 ampere, 602
 conductors, 604
 current, 602–603
 electrical system equipment, 622–632
 energy requirements, 604
 flow measurements, 616–622
 insulators, 604
 megger, 614–615, 614f
 motor rotation indicator, 616
 ohmmeters, 615–616
 power, 603–604
 voltage testing meters, 605–608,
 606f–609f
 volts, 601–602
 Electric motors
 alignment, 651–652, 652f, 653f
 causes of failure, 640–641
 changing rotation direction, 652
 classifications, 636, 636f
 deviations, 653
 insulation systems, 640–643, 642t, 643t
 lubrication, 653–654, 654f
 magnetic starters, 644–647, 644f–646f,
 648f–650f
 maximum vibration levels, 653
 nameplate data, 638–640, 639f
 squirrel cage induction motor, 636, 637f
 troubleshooting, 654–655, 656f–658f
 variable frequency drives, 647, 650–651,
 650f
 Electro-dewatering process, 492
 Electromagnetic flow meters, 618, 618f
 Electromotive force (EMF), 601
 Electron, 602
 Elutriation, 204, 211–212
 Endogenous respiration, 94, 461
 Energy-isolating device, 596
 Energy requirements, 604
 Enhanced biological control, 126–127
 Bardenpho process, 130–133, 130f–132f
 facilities, 140–144
 multiple processing objectives, 127–129,
 128f
 nitrogen oxidation, 145–146
 nitrogen removal, 146–147
 optimizing nitrogen and phosphorus
 removal, 134–136
 phosphorus control, 144–145
 sequencing batch reactors, 133, 134f
 sludge volume index, 137–139, 137f, 147
 Enteric viruses, 381
 Entrainment, 143
 Entrain water, 204
 Enzymes, anaerobic digestion, 429
 Epidemic, working in, 6
 Equalizing basin, 294
 ESD. *See* Egg-shaped digester

Eutrophication, 89
 Excavation, 41
 Existing drainage, 546
 Exponentiation, 723
 Extended aeration, 58

F

Facility electrical systems, 634
 Facultative bacteria, 381
 Facultative lagoons, 29, 536–537, 544
 Fats, oils, and greases (FOG), 17, 290, 314
 Feed sludge pretreatment, 385, 386t
 FEG 1-inch tube, 276f
 Ferric chloride, 107, 110–111, 111f, 161,
 162, 163f
 Filamentous foam, 139
 Filamentous organisms, 126, 328, 329
 Filter aid, 228
 Filter backwash pumps, 245–246, 245f
 Filter feed pumps, 234, 235f
 Filter press, 492, 493f
 belt, 499, 501–505, 501f, 502f, 505t
 operating procedures, 497–498
 performance, 494–497, 498t
 plate-and-frame presses, 492, 493f, 498t
 recessed-plate, 494
 troubleshooting, 498–499, 500f–501f
 Filters. *See* Pressure filters
 Filter sand movement evaluation test, 262,
 264–267, 265f, 266f
 Filtration-based dewatering process, 492
 belt filter presses, 499, 501–505, 501f,
 502f, 505t
 filter press, 492, 493f, 494–499,
 500f–501f
 rotary press, 509–511, 510f, 511t
 screw press, 506, 507f, 508–509, 508t
 Filtration systems, 22–23
 membrane, 23–25
 Fit-for-purpose treatment, 3, 155, 271
 Five-day biochemical oxygen demand
 (BOD₅), 51, 319
 Five-stage Bardenpho process, 131, 131f
 oxidation ditch, 132, 132f
 Fixed digester covers, 391–392, 391f, 394f
 Fixed film processes/reactors, 582,
 584–585
 denitrification, 76–77, 76f, 77f
 nitrification using, 66–69, 71t
 Flame arresters, 409–410, 409f
 Flame trap assembly, 410, 411f
 Flash mixer, 99
 Flights, 186, 346, 582
 Floatable solids, 9
 Floating digester covers, 392–393, 392f, 395f
 Float switches, 633
 Floc. *See* Flocculation
 Flocculation, 22, 91, 99, 116, 156, 160f
 aluminum sulfate, 109f
 flocculators, 183, 185f, 186
 by polymer addition, 183, 184f

Flooding, 551
 Flood protection, 546
 Flotation chamber, 393
 Flow control method, 244–245
 Flow measurement, 18, 616
 calibration and cross-checking, 621–622
 devices, 617–620
 location and integration, 620–621
 sensor maintenance, 621
 Flow rate, 757–762
 Fluidized beds, 76, 246
 incinerator, 530–531
 Flux, 278, 283–284, 297–299, 298t
 Foam control, 139
 FOG. *See* Fats, oils, and greases
 Food/microorganism (F/M), 58
 Force, 762–771
 Forced-air system, 483
 Four-stage Bardenpho process, 130, 130f
 oxidation ditch, 132, 132f
 Free oxygen, 52
 Free water, 371
 Full-flow pressure flotation, 344
 Full-scale filter press, 498
 Furnace shell, 529
 Fused disconnect switches, 623, 624f
 Fuses, 571, 625–626, 625f

G

Garnet, 217
 Gas collection systems, 404–405
 components, 406f
 gas dome, 405–406, 408
 meters, 412, 412f
 moisture traps, 410, 411f, 412
 pressure- and vacuum-relief valves, 408–409
 pressure regulators, 412–413, 412f
 thermal protection devices, 409–410, 409f, 411f
 troubleshooting, 407f–408f
 waste gas burners, 413, 413f
 Gas dome, 405–406, 408
 Gas formers, 35
 Gas-holder covers, 394, 396f
 Gasification, 328
 Gas manometer, 412, 412f
 Gas mixing system, 397, 399f
 Gate valve, 693–697, 695f, 696f
 Gauges, 595
 Geographic information system (GIS), 574
 map, 575f, 577f
Giardia, 27
 Global navigation satellite system (GNSS), 574
 Gravity belt thickeners, 371–373, 371f, 372f
 operating procedures, 375
 performance of, 373–375, 375t
 troubleshooting, 375–377, 376f
 Gravity filtration systems, 212–213

backwashing process, 214, 214f, 220, 220f
 components, 217–221
 depth filtration, 216–217, 217f
 downflow filters, 214–215
 filter configurations, 215f
 filtering process, 213
 instrumentation, 222–223
 operational strategy, 225, 228–230
 operation mode, 223–225
 reviewing plans and specifications, 231
 safety, 230–231
 shutdown, 230
 surface straining, 216
 troubleshooting, 225, 226f–228f
 Gravity thickeners, 326–328, 327f
 operating procedures, 332–335, 333t
 performance, 328–332
 troubleshooting, 335–342, 343f
 Grease fittings, 654
 Grit, 312, 324
 removal systems, 5, 17
 tanks, 593
 Ground, 601, 630–632, 631f
 Ground alum, 161
 Growth rate (Y), 319

H

Hand-off-automation (HOA) switch, 234
 Harvested biosolids piping, 553
 Hazardous waste, 537
 Head
 on backwash water, 221
 loss, 214, 222, 618
 pumps, 790–795, 791f
 Headworks, 35, 136, 220, 334, 580–581
 Heat drying process, 522–526, 523f, 527f
 Hertz (Hz), 602
 Heterotrophic bacteria, 51
 High-pressure hydraulic cleaning unit, 712f
 High-pressure wet oxidation (HPO), 209, 211
 High-purity oxygen aerobic digester, 463
 High-rate digesters, 384
 High-velocity cleaner (HVC), 665
 High-velocity pressure units, 710
 Histograms, 817–819, 818f
 Holding tank, 232, 234
 Hollow fiber membranes, 277–279, 277f, 278f
 Horsepower, 785–790
 HPO. *See* High-pressure wet oxidation
 HRT. *See* Hydraulic retention time
 Human machine interface (HMI), 632, 633f
 Humus sludge, 425
 Hybrid systems, 586, 587f
 Hydrated lime, 165
 Hydraulic loading, 70, 101–102, 329, 503
 Hydraulic retention time (HRT), 418–421

Hydrazine, 87
 Hydrogen sulfide, 6, 13, 37, 328, 414, 415f
 Hydrolysis, 93, 382
 Hydrophobic, 414
 Hypotenuse, 741

I

Imhoff tanks, 389
 Impeller, 234, 616
 Incinerator ash, onsite landfilling of, 557
 Incline screw pumps, 670–671, 672f, 673
 Indirect potable reuse (IPR), 3, 154, 155
 Indole, 37, 430
 Indoor ferric chloride day tank, 163f
 Induction draft (ID), 529, 532
 Induction motors, 637
 Inert-media gravity filters, 23
 Inert-media pressure filters. *See* Pressure filters
 Infiltration, 14
 Influent wastewater, 12, 56, 172, 318
 Inoculation, 395
 Inorganic solids, 9
 Inorganic waste, 5
 Insertion-style paddlewheel flow meters, 620f

Instrumentation, gravity filtration systems, 222–223

Instrumentation control, 38
 Insulation resistance test, 628–629
 Insulation systems, 604, 640–643
 of motor, 640–643, 642t, 643t
 Insulators, 604
 Interior piping, 243
 Intermediate-pressure wet oxidation (IPO), 209
 Internal combustion engines, 417
 Internal thermal protection devices, 629
 International System of Units (SI), 734
 Interparticle bridging, 160
 Ion exchange, 86
 IPO. *See* Intermediate-pressure wet oxidation
 IPR. *See* Indirect potable reuse

J

Jar testing, 107, 166–167
 apparatus with mechanical stirrers, 166f
 calculations, 167–171

L

Laboratory analysis, in wastewater treatment, 38
 Lagoon digesters, 389
 Lagoon systems, 28–30, 29f
 Laminar flow path, 617

Land application, 540–541, 553–554, 555f, 556f
 Land discharge, 32
 Lantern ring, 660
 Lateral surface area
 of cone, 741
 of cylinder, 740, 740f
 of sphere, 743
 Launders, 260
 Leads, 602
 LEL. *See* Lower explosive limit
 Length, units of measurement, 734–735
 in metric system, 779–780, 780t
 Lime
 clarification process, 100, 103, 104
 coagulants, 165
 feed system, 174f
 slaking mechanism, 123
 Lime–phosphorus sludge, 99, 101, 102, 122
 Lime precipitation process, 117f
 abnormal and emergency conditions, 120–122
 calcium carbonate recapture, 119–120
 equipment, 116–118
 loading guidelines, 124–126
 maintenance, 122–124
 operation, 118
 physical/chemical treatment processes, 116
 recarbonation process, 119–120, 120f
 reviewing plans and specifications, 126
 sampling and analysis, 118–119
 Limestone, 99, 123
 Lineal feet, of weir, 195
 Liquid alum, 110, 161–162
 Liquid coagulants, 172–173
 Liquid ferric chloride, 162
 Liquid injection systems, 179
 Liquid polymers, 164, 164f, 165
 Liquid surface, gravity thickeners, 335–336
 Lockout/tagout procedures, 203, 596–598, 597f
 Lower explosive limit (LEL), 448
 Low-pressure wet oxidation (LPO), 204, 209–211
 Low-rate digesters, 384
 LPO. *See* Low-pressure wet oxidation
 Lubrication
 of motors, 653–654, 654f
 pumps, 682–684, 684t
 Lump alum, 161
 Luxury uptake of phosphorus, 96f, 97f
 abnormal and emergency operating conditions, 103
 equipment, 98–99
 lime, chemical reaction of, 96
 maintenance, 103–104
 microorganism cell reactions during, 94–95, 95f
 operation of, 100–102
 Phostrip system, 96

process efficiency calculation, 104–105
 reviewing plans and specifications, 105–106
 safety, 97–98
 shutdown, 103
 startup, 99

M

Magnetic starters, 644, 644f
 maintenance, 647
 operation, 645, 646f
 overload protection devices, 646
 three-phase, 645f, 646–647
 troubleshooting, 648f–650f
 Maintenance program, 38–39
 Manometer readings, 815f
 Mass, units of measurement, 748–749
 Math assignment, 42–43
 Math operations
 addition, 721, 723, 723f
 division, 722–724
 mixed calculations, 724–726
 multiplication, 722–724
 parentheses, 726–727
 subtraction, 722, 723, 723f
 MBR systems. *See* Membrane bioreactor systems
 MCRT, 91, 92, 128, 129, 139, 145. *See* Mean cell residence time
 Mean, 720
 Mean cell residence time (MCRT), 56
 Mechanical composting method, 484
 Mechanical dewatering, 492, 514
 Mechanical flocculators, 183, 185f
 Mechanical heat drying. *See* Heat drying process
 Mechanical maintenance, 39
 Mechanical mixing system, 178, 179f, 397, 398f, 399–402, 400f, 401f
 Mechanical seals, pumps, 680–682, 681f
 Mechanical surface aerators, 141
 Media, 18
 Median, 720
 Megger, 614–615, 614f
 Megohm, 615
 Membrane bioreactor (MBR) systems, 30–32, 30f, 31f, 157, 280–282, 280f–282f, 587, 588f
 Membrane filtration, 23–25, 156, 269, 270f, 271
 cleaning procedures, 296–297
 concentration-dependent flux, 290
 feed pretreatment, 293–295, 294f
 flow systems, 273, 274f
 flux, 283–284
 fouling, 290–291
 hollow fiber membranes, 277–279, 277f, 278f
 log removal, 286
 materials and lifespan, 274
 operating modes, 291–293, 292f, 293f
 plate and frame configurations, 279–280
 pressure vessels/submerged flow, 271–273, 271f–275f
 recirculation flow, 289–290
 recordkeeping, 300–301
 rejection, 284–285
 safety precautions, 301
 sampling, 299–300
 spiral membranes, 279, 279f
 system automation, 295–296
 temperature, 290
 transmembrane pressure, 288–289
 tube arrangement, 291f
 tubular membranes, 276, 276f, 277f
 waste components concentrations, 286–288
 water flux measurements, 297–299, 298t
 Membrane fouling, 274
 Membrane gas storage, 416, 416f
 Meniscus, 815
 Mercaptans, 37, 430
 Mesophilic bacteria, 381
 Metabolism, 75
 Metal hydroxyl floc, 107
 Metal salts, 161–162
 Methane-phase digesters, 384
 Methanol, 76, 146
 Metric system, 778
 capacity/volume, 780, 780t
 length, 779–780, 780t
 SI unit system, 778–779, 778t, 779t
 temperature, 781, 781f
 watts, 790
 weight, 780, 780t
 Microfiltration (MF), 24, 269
 Microns, 159
 Milligrams per liter (mg/L), 5
 Mils, 278, 690
 Mineralization, of contaminants, 27
 Mixed-bed bioreactor (MBBR), 586
 Mixed liquor, 56
 Mixed liquor suspended solids (MLSS), 280, 471
 Mixed liquor volatile suspended solids (MLVSS), 65
 Mixing chamber, 117
 MLSS. *See* Mixed liquor suspended solids
 MLVSS. *See* Mixed liquor volatile suspended solids
 Mobile inspection vehicle, 575, 576f
 Mode, 720
 Modified activated sludge systems, 126–127
 Moisture traps, 410, 411f, 412
 Molded-case circuit breaker, 627, 628f
 Mole, 163
 Molecular weight, 162, 382
 Molecular weight cutoff (MWCO), 25
 Monitoring program, solids disposal, 557–558, 557t
 groundwater, 559

land disposal sites, 558
 odors, 558
 public health vectors, 559–560
 surface water runoff, 559
Monofilling, 541
Monomer, 163
Most probable number (MPN), 11
Motor and supervisory control systems, 632–635
Motor circuit elements, 623, 624f
Motor control center (MCC), 591
Motor rotation indicator, 616
Motors. *See* Electric motors
MPN. *See* Most probable number
MS4s. *See* Municipal separate storm sewer systems
Mudballs, 218
Multiple hearth furnace (MHF). *See* Multiple hearth incinerator
Multiple hearth incinerator, 526, 528f, 529–530
Multiplication, math operation, 722–724
Multistage anaerobic digestion, 385
Municipal separate storm sewer systems (MS4s), 11
Municipal solid waste (MSW), 538
MWCO. *See* Molecular weight cutoff

N

Nameplates, 601
 data, of motor, 638–640, 639f
Nanofiltration (NF), 25, 269
National Electrical Manufacturers Association (NEMA), 637
National Institute of Standards and Technology (NIST), 778
National Pollutant Discharge Elimination System permit (NPDES permit), 10–12, 90, 133, 155t, 232, 317, 616
National Pretreatment Program, 11
Nephelometric turbidity units (NTUs), 253
NF. *See* Nanofiltration
Nitrification, 21, 50–53
 alkalinity, 61–64, 62f, 63t
 dissolved oxygen, 64
 efficiency, 53–56, 54f, 55f
 hydraulic loading, 70–71
 laboratory reporting and regulatory compliance, 72–73
 nitrogen compounds, 65
 nitrogenous food, 65
 organic loading, 71
 oxygen and flow variations, 72
 oxygen transfer, 71
 sloughing off organisms, 72
 temperature, 65
 temperature variations, 71
 time under aeration, 58–60
 troubleshooting, 73, 74f–75f
 using fixed film reactors, 66–69

using suspended growth reactors, 56–58, 57f, 79f
Nitrite-oxidizing bacteria (NOB), 51, 52, 53, 58
Nitrogen compounds, 65
Nitrogenous food, 65
Nitrogen oxidation, 145–146
Nitrogen oxygen demand (NOD), 51
Nitrogen removal systems, 50–51, 50t, 51f
 ammonia stripping, 80–83, 81f, 82f
 anammox treatment process, 86–88
 breakpoint chlorination, 83–85, 84f
 denitrification, 75–80
 enhanced, 146–147
 ion exchange, 86
nitrification (*See* Nitrification)
 optimizing, 134–136
 overland flow systems, 88
NOB. *See* Nitrite-oxidizing bacteria
Nocardia foam, 139
Nonvolatile matter, 314
Normal distribution, 819, 820f
NPDES permit. *See* National Pollutant Discharge Elimination System permit
Nutrients, 2, 48–49

O

Obligate aerobes, 52
Occupational Safety and Health Administration (OSHA), 41, 596
Odor control, 37
Ohm, 602
Ohmmeters, 615–616
Oil analysis, 571, 572
Online turbidity meters, 222–223
Onsite dedicated land disposal, 544, 546–548, 547f
Open-channel flow systems, 617
Operations and maintenance (O&M), 183, 578
Organic carbon, 9
Organic loading, 71
Organic solids, 9
Organic waste, 5
Orifices, 173
O-ring, 680, 695, 696
Ortho phosphorus, 48, 49
OUR test. *See* Oxygen uptake rate test
Out-of-service pumps, 698
Overland flow systems, 88
Overload trip test, 629
Oxic solids retention time (oSRT), 58
 in acidic waters, 60f
 in alkaline waters, 60f
 on dissolved oxygen concentration, 59, 59f, 60, 60f
 on water temperature, 59, 59f, 60, 60f
Oxidation lagoons, 29
Oxidation-reduction potential (ORP), 134

Oxidized nitrogen return (ONR), 145–147
Oxygen depletion, 5–6
Oxygen transfer, 71
Oxygen uptake rate (OUR) test, 470–471, 476

P

Packed towers, 66
Packing rings, 660
Paddlewheel flow meters, 619–620, 620f
PAOs. *See* Phosphate accumulating organisms
Parentheses, math operation, 726–727
Parshall flume, 617, 617f
Partial-flow pressure flotation, 344
Particulates, 154, 155
Part 503 Rule, 538, 539t, 540, 541
Parts per million (ppm), 414
Part-winding starters, 647
Pathogens, 7, 19, 253, 314, 315, 591
Percentages, 730–733, 731t
Peristaltic pumps, 182
Permeates, 23, 24, 269
Personal flotation device (PFD), 40
Personal protective equipment (PPE), 110, 162
PFAS. *See* Polyfluoroalkyl substances (PFAS)

PFD. *See* Personal flotation device
pH, 7, 52, 61–64, 159, 161
 adjustment, phosphorus removal by, 118
 aerobic digestion, 469, 477
 anaerobic digestion, 422, 435
 for enhanced biological and chemical control, 135–136, 135f
 nitrification efficiency *vs.* 53, 55f
Phosphate accumulating organisms (PAOs), 89, 91
Phosphorus, 48, 49, 65
Phosphorus removal, 22
 biological, 89–94, 91f, 93f
 chemical (*See* Chemical phosphorous removal)
 depends pH, 90f
 enhanced, 144–145
 lime precipitation (*See* Lime precipitation process)
 luxury uptake (*See* Luxury uptake of phosphorus)
 optimizing, 134–136
Phostrip system, 96
Photosynthesis, 28
Physical–chemical treatment systems, 22, 157
 coagulation (*See* Coagulation)
 flocculation, 183–186
 particle surface charge, 157–158
 safety, 202–203
 sedimentation, 186–200
 troubleshooting, 200, 201f–202f

Pigs, 711, 713f
 Pilot-/full-scale testing, 494
 Pilot-scale study, 252, 423
 Pipelines, 709–710
 Piping filtration system, 257
 Piston pumps, 665, 665f, 666f
Planctomyces, 86
 Plant maintenance, 38
 building maintenance, 594–595
 chain drives, 594
 disinfection systems, 591–593
 headworks, 580–581
 plant grounds, 595
 plant tanks and channels, 593–594
 primary treatment, 581–582
 repair shop, 595–596
 safety equipment, 596
 secondary treatment systems, 582, 584–589
 solids handling, 589, 590f, 591
 Plant tanks and channels, 593–594
 Plastic media trickling filters, 68f
 Plate-and-frame filter presses, 492, 493f, 498t
 Plate and frame membranes, 279–280
 PLCs. *See* Programmable logic controllers
 Plug flow aeration system, 57
 Plugged pump/valve, 712–713
 Plug sample, 229, 229f
 Plug valves, 697
 Plunger pump, 665, 666f, 667f, 668
 Pneumatic ejectors system, 659, 673, 674f–676f
 Pneumatic feeding mechanisms, 106
 Pneumatic leaks, 571–573
 Polyelectrolytes, 119, 156, 162
 Polyfluoroalkyl substances (PFAS), 513, 525
 Polymers, 156, 162–165, 164f, 346, 370
 inert-media pressure filters, 235–236, 237f
 mixing and aging system, 184f
 of phosphorus, 94
 Polysaccharide material, 204
 Porosity, 372
 Positive displacement pumps, 180, 180f–182f, 658, 700–701
 Post-secondary chemical treatment, 113–114, 114f
 Potable water quality, 25
 POTWs. *See* Publicly owned treatment works
 Power, 603–604, 775–776
 generation systems, 417
 pumps, 785–790, 789f
 supply, 640
 Power factor (PF), 603
 PPE. *See* Personal protective equipment
 Precipitation, 48, 107, 159, 315
 Precoats, 494, 499
 Predictive maintenance programs, 570
 Preliminary screening tests, 166–167
 Preliminary sludge processing, 324–325

Preliminary treatment, 17, 18
 Pressure, 762–771, 763f, 766f
 pumps, 782–783, 782f, 783–785, 784f
 Pressure filters, 23, 232, 233f, 243–244
 backwash system, 245–247, 245f
 chemical feed systems, 234–240
 decant tanks, 247–250
 filter feed pumps, 234, 235f
 flow control method, 244–245
 holding tank, 234
 interior piping, 243
 maintenance, 250–251
 performance test chart, 251f
 reviewing plans and specifications, 252–253
 safety precautions, 251–252
 underdrain system, 243
 vessels, 240, 241f, 242f, 243
 Pressure methods, pipelines, 709
 Pressure regulators, 412–413, 412f
 Pressure-relief valve, 408–409
 Pressure swing adsorption (PSA), 418
 Pressure vessels, membrane filtration, 271, 271f–274f
 Preventive maintenance program, 39, 570
 Primary clarifier, 315, 581–582
 Primary digestion, 385
 Primary scum, 314
 Primary sludge, 314, 315, 318–319
 chemical composition of, 316t
 Primary treatment, 18
 Prime, 663
 Proactive maintenance, 569
 Process variables, 570
 Programmable logic controllers (PLCs), 38, 134, 632–634, 634f
 Progressive cavity pumps, 669, 670f
 Propeller pumps, 664
 Proper grounding, 631, 632
 Proteinaceous material, 204
 Psychrophilic anaerobic digestion, 384
 Public health vectors, 559–560
 Publicly owned treatment works (POTWs), 10, 11
 Pug mill, 483
 Pumps, 658
 air gap separation system, 692–693
 bearings, 685, 686f–689f, 689
 belt drives, 689–690
 capacity, 798–799
 centrifugal, 659–664, 660f, 661f, 699
 characteristics, 795–797, 795f–797f
 controls, 693
 couplings, 690–691
 dehumidifiers, 692
 double disc, 668–669, 668f
 drivers, 703
 efficiency of, 800–807
 friction/energy losses, 809–813, 810f, 811f
 head, 790–795, 791f
 incline screw, 670–671, 672f, 673
 lubrication, 682–684, 684t
 maintenance, 685, 685f
 mechanical seals, 680–682, 681f
 packing, 673–674, 676–677, 677f–679f
 performance verification, 701–702
 piston, 665, 665f, 666f
 plugged, 712–713
 plunger, 665, 666f, 667f, 668
 pneumatic ejectors, 673, 674f–676f
 power, 785–790
 pressure, 782–783, 782f, 783–785, 784f
 progressive cavity, 669, 670f
 propeller, 664
 reciprocating, 664–669
 rotary lobe, 669–670, 671f
 shear pins, 691
 shutdown, 703
 speed–performance relationships, 807–809
 startup, 698–701
 troubleshooting, 704f–706f
 valves (*See* Valves)
 variable-speed belt drives, 691–692, 692f
 work, 785
 Putrefaction, 314, 315
 Pythagoras' Theorem, 741

Q

Quicklime, 105, 165
 Quick response (QR) code, 577, 578f

R

Radial to impeller, 664
 Range, 818
 Raw wastewater lagoons, 29
 RBCs. *See* Rotating biological contactors
 RDTs. *See* Rotary drum thickeners
 Reactive maintenance, 569
 Reaeration tank, 75
 Recalcination, 102
 Recarbonation, 103
 Receiving waters, 2
 Recessed-plate filter press, 494
 Reciprocating pumps, 664
 double disc pumps, 668–669, 668f
 plunger pump, 665, 666f, 667f, 668
 Recirculation pumps, for trickling filters, 69f
 Reclaimed wastewater, 154, 155
 Records, electrical maintenance, 635
 Rectangular clarifier, 186, 188f, 189f, 191f, 584f
 Rectangular sedimentation basin, 187f
 Recycle-flow pressure flotation, 344
 Reject water, 253
 Representative sample, 752
 Resilience, 574
 Resistance, 602
 Retentate, 23, 284

Return activated sludge (RAS), 57, 616
 Reverse osmosis (RO), 25, 269
 Right-angle triangle, 741, 741f
 Rising sludge, 328
 Rodding tools, 711f
 Rotameter, 236
 Rotary drum thickeners (RDTs), 377–380, 377f, 378f, 379t, 380f
 Rotary dryers, 522–523, 523f, 527f
 Rotary lobe pumps, 669–670, 671f
 Rotary press, 509–511, 510f, 511t
 Rotating biological contactors (RBCs), 52, 69, 70f, 75, 157, 570, 584
 Rotor, 180, 619
 Round clarifier, 188, 190
 Runoff basin, 546
 Run-to-failure (RTF) approach, 569

S

Safety data sheet (SDS), 165
 Safety program, in wastewater treatment plants, 40–41
 accident prevention, 41
 safety hazards, 42
Salmonella bacteria, 560
 Sampling analysis, in wastewater treatment, 38
 Sand drying beds, 513–518, 515f, 518t
 Sand filter, 218f
 differential pressure through, 217f
 Sanitary landfill disposal, 543–544
 Sanitary sewer overflows (SSOs), 11, 568
 SCADA system. *See* Supervisory control and data acquisition systems
 Scale/scaling, 165, 591
 Scatter plots, 821–822, 821f, 822f
 SCFM (standard cubic feet per minute), 260, 349
 Screening, preliminary treatment, 17
 Screening unit, 580, 581f
 depositing sludges, 583f
 differential level of, 582f
 Screw press dewatering process, 506, 507f, 508–509, 508t
 Scum, 312, 676
 Scum blanket, 35–36, 389f, 399
 Scum lines, 710
 Secondary clarifier, 57, 157, 314, 315, 586
 Secondary digestion, 385
 Secondary sludge, 314, 315, 319–321
 chemical composition of, 316t
 Secondary treatment, 18
 Sectional filter, 220, 221f
 Sedimentation, 116, 156, 318, 325
 clarifier efficiency, 199–200
 detention time, 193–194
 performance metrics, 192–193
 solids loading rate, 197–198
 surface loading rate, 196–197
 weir overflow rate, 195–196

Sedimentation basins, 63, 186–192, 187f, 318
 Seed sludge, 388
 Selector, 73
 recycle, 127
 Sensitivity, 616
 Sensor maintenance, 621
 Septic conditions, 199, 314, 315
 Septicity, 325
 Septic wastewater, 132
 Sequencing batch reactors (SBRs), 133, 134f
 Set points, 222, 633
 Settleometer, 9, 9f
 Shallow trenches, 546
 Shear pins, 597, 691
 Sheaves, 689
 Shock load, 423
 Short-circuiting, 118, 195, 199, 200f, 327
 Shredding, preliminary treatment, 17
 Significant figures, 776–778, 777t
 Siloxanes, 414–415
 Single-phase circuit, 607f, 608f
 Single-phase power, 603
 Single-stage lime recarbonation process, 119, 120f
 SI unit system, 778–779, 778t, 779t
 Skatole, 37, 430
 Skewed distribution, 819, 820f
 Slake, 165
 Slaked lime, 97
 Sleeves, 659
 Slough, 281
 Sloughing off organisms, 72
 Sludge, 5, 156, 312, 582
 age, 58, 328
 blanket, 338–340
 bulking, 328
 digestion, 32–36, 33f–36f
 dewatering, 32–36, 33f–36f, 312
 handling facilities/methods, 106, 322, 323f, 323t
 lime-phosphorus, 99, 101, 102, 122
 lines, 711
 preliminary processing, 324–325
 primary, 318–319
 production, 114
 secondary, 319–321
 treatment, reuse, and disposal
 regulations, 316–317
 wet oxidation, 208–209
 Sludge incineration, 526
 air supply, 531
 burner location and firing rate, 531–532
 feed rate and quality, 531
 fluidized bed incinerator, 530–531
 multiple hearth incinerator, 526, 528f, 529–530
 operating procedure, 532–536, 534t
 shaft speed, 532
 troubleshooting, 536
 Sludge stabilization, 312, 381
 aerobic digestion (*See* Aerobic digestion)
 anaerobic digestion, 381–386 (*See* Anaerobic digestion)
 chemical stabilization, 480–482
 composting, 482–491
 Sludge thickening, 312, 325–326
 centrifuge thickeners (*See* Centrifuge thickeners)
 dissolved air flotation thickeners, 344–355
 gravity belt thickeners, 371–377, 371f, 372
 gravity thickeners (*See* Gravity thickeners)
 rotary drum thickeners, 377–380, 377f, 378f, 379t, 380f
 Sludge volume index (SVI), 134, 137–139, 137f, 147
 Sludge/volume (S/V) ratio, 332
 Sludge volumes, 321–322
 Slug, 193
 Sluice gates, 697
 Slurry, 96, 165
 Sodium bisulfite, 17, 19
 Solar drying beds, 514–515
 Solenoid valves, 236
 Solid alum, 110, 161
 Solid bowl centrifuges, 357, 357f, 364
 troubleshooting, 367f, 368–369
 Solids. *See also* Sludge
 accumulation, 5
 anaerobic digestion, 430, 435, 440–444
 handling, 32–36, 33f, 34f, 106, 312–314, 313f, 589, 590f, 591
 loading rate, 197–198, 330, 495–496
 management, 102
 preparation for disposal and reuse, 315–316
 removing from effluent, 154–156
 types and characteristics, 314–315
 in wastewater treatment plants, 8–10, 8f
 Solids disposal, 312–314, 313f, 537–540
 biosolids without dewatering, 550–556, 552f, 555f, 556f
 dewatered biosolids, 543–549
 disposal options, 540–543, 542f
 monitoring program, 557–560, 557t
 Solids retention time (SRT), 56, 58–59, 92, 329, 331–332, 340, 384, 418–421, 466, 474
 Solid-state reduced-voltage starters, 647
 Sonic industrial imager, 572, 572f, 707
 SOUR. *See* Specific oxygen uptake rate
 Sour digester, 426–429
 SPC chart. *See* Statistical process control chart
 Specific gravity (SG), 224, 314, 749–750
 Specific oxygen uptake rate (SOUR), 469–473
 Specific weight, 749
 Spiral membranes, 279, 279f
 Squirrel-cage induction motor, 703

SRT. *See* Solids retention time
 SSOs. *See* Sanitary sewer overflows
 Stabilization, 6
 Standard deviations, 830, 830t
 Static compost pile, 483, 484f
 Static head, 699, 772, 790
 Static mixers, 178, 179f
 Statistical process control (SPC) chart, 300
 Stator, 180
 windings, 636
 Stem-and-leaf plot, 821, 821f
 Step-feed aeration, 58
 Sterilization, 19
 Stern layer, 157
 Storage buffer, 536
 Stormwater collection system, 13
 Stratification, 358
 Struvite control, 431, 433t
 Submerged membrane filtration system, 273, 275f
 Submerged turbine aerators, 141
 Submersible propeller mixers, 141–142, 142f
 Substrate, 63
 Subtraction, math operation, 722, 723, 723f
 Suction head, 699
 Suction lift, 659
 Suction piping, 659
 Sulfonators, 593
 Sulfur dioxide, 17, 19, 593
 Supernatants, 96, 166, 334, 381, 430, 584
 Supervisory control and data acquisition (SCADA) systems, 38, 115, 222, 223, 230, 231, 246, 280, 281, 434, 450, 570, 586, 605, 621, 633, at membrane rack, 296f in plant control room, 295f Surcharged tank, 247 Surface-active agents, 290 Surface disposal, 541 Surfaced sludge drying beds, 519–522, 520f, 521f Surface loading rate, 192, 196–197, 329 Surface-straining systems, 216 Surface wash system, 213 Surface water monitoring, 559 Suspended growth reactor/system, 52, 585–586 denitrification, 77–79, 78f, 79f nitrification using, 56–58, 57f, 79f Suspended solids, 5, 8, 56, 154, 155, 318 Sweep-floc, 160 Switchgear, 622

T

Tagout, 203
 Tangential flow membrane filtration, 23
 Temperature, 65
 aerobic digestion, 466, 477
 anaerobic digestion, 383–384, 422, 434
 membrane filtration, 290

metric system, 781, 781f
 nitrification efficiency *vs.* 53, 55f variations, 71
 Temperature-phased anaerobic digestion (TPAD), 385
 Tertiary treatment, 19, 21–28, 21f, 154
 Thermal conditioning, 204–205
 operating guidelines, 205–207
 troubleshooting, 207–208, 209f
 Thermal imaging analysis, 570, 571f
 Thermal-magnetic trip circuit breakers, 628
 Thermal overload devices, 646
 Thermal valves, 410, 411f
 Thermophilic bacteria, 381
 Thermophilic digestion, 384, 422
 Three-phase circuit, 608f
 Three-phase induction motor, 703
 Three-phase magnetic motor starters, 645f, 646–647
 Three-phase motors, 629
 Three-phase power, 603
 Throughput, 360
 Time under aeration, 58–60
 TMP. *See* Transmembrane pressure
 Total dissolved solids (TDS), 25, 86
 Total dynamic head (TDH), 701, 796, 799
 Total Kjeldahl nitrogen (TKN), 48
 Total nitrogen (TN), 48, 49f
 Total organic carbon (TOC), 9, 26, 77
 Total solids (TS), 8, 366
 Total suspended solids (TSS), 22, 92, 113, 167, 366, 419, 616
 Toxicity, 5, 393, 419, 592
 Tramp oil, 294
 Transmembrane pressure (TMP), 281, 282, 288–289
 Trickling filters, 66, 157, 582, 584, 585f
 cross-flow media in, 68f
 humus, 425
 plastic media, 68f
 recirculation pumps for, 69f
 vertical-flow media in, 67f
 Trihalomethanes (THM), 27
 Troubleshooting
 aerobic digestion, 476–479, 479f–480f
 ammonia stripping process, 82f–83f, 83
 anaerobic digestion, 456–457
 ball bearing failure, 685, 686f–689f
 basket centrifuges, 368f
 continuous backwash, upflow, deep-bed silica sand media filter, 263f–265f
 decanting, 432f–433f
 denitrification, 79, 80f
 digested sludge, 388f
 digester gas system, 407f–408f
 disc-nozzle centrifuges, 369f
 dissolved air flotation thickeners, 353–354, 355f
 electric motors, 654–655, 656f–658f
 filter press, 498–499, 500f–501f
 fixed digester covers, 394f
 floating digester covers, 395f
 gas holder type digester covers, 396f
 gravity belt thickeners, 375–377, 376f
 gravity filtration systems, 225, 226f–228f
 gravity thickeners, 335–342, 343f
 magnetic starters, 648f–650f
 nitrification, 73, 74f–75f
 physical-chemical treatment systems, 200, 201f–202f
 pneumatic ejectors, 675f–676f
 pressure filter operation, 249f–250f
 pumps, 704f–706f
 rotary drum thickeners, 380f
 rotary dryers, 527f
 scum blanket, 389f
 solid bowl centrifuges, 367f
 solids mixing, 398f, 399f
 solids pumping and pipelines, 387f
 solids temperature control, 403f–404f
 thermal conditioning, 207–208, 209f
 TSS. *See* Total suspended solids
 Tube-in-tube heat exchanger, 406f
 Tubular membranes, 276, 276f, 277f
 Turbidity meters, 222–223, 257–259, 258f
 Turbidity units, 228
 Turbine flow meters, 619–620, 620f
 Two-phase digestion, 384–385
 Two-stage digestion, 385
 Two-stage lime recarbonation process, 119, 121f

U

ULTRA-COR® VII ½-inch tubules module, 277f
 Ultrafiltration (UF), 24, 269
 Underdrain system, 213, 218, 219f, 223, 243
 Uninterruptible power supply (UPS) systems, 602
 Units of measurement, 734
 area (*See* Area, units of measurement)
 concentration, 750–756
 density, 749
 distance, 734–735
 flow rate, 757–762
 force, 762–771
 head, 772–774
 length, 734–735
 mass, 748–749
 power, 775–776
 pressure, 762–771, 763f, 766f
 velocity and flow rate, 757–762
 volume (*See* Volume, units of measurement)
 weight, 748–749
 work, 771–772
 Upflow sand media filter, 253–255, 254f–256f
 auxiliary equipment, 257–259
 filter sand movement evaluation test, 262, 264–267, 265f, 266f
 operation, 259–262, 259f

reviewing plans and specifications, 268
safety precautions for, 267–268
troubleshooting, 263f–265f
Uplift force, 770
Upset digester, 424
Urban water cycle, 3–4, 4f
US Environmental Protection Agency (EPA), 10, 50, 316
UV disinfection systems, 591
UV disinfection unit, 19, 20f

V

Vacuum collection systems, 15
Vacuum-relief valve, 408–409
Valves, 693
 check, 693, 694f
 gate, 693–697, 695f, 696f
 plug, 697
 sluice gates, 697
Variable-area flowmeter, 236
Variable frequency drives (VFDs), 186, 603, 605, 647, 650–651, 650f
Variable-speed belt drives, 691–692, 692f
Variances, 830, 830t
VCF. *See* Volumetric concentration factors
Vector, 316
Vector attraction reduction (VAR), 382, 474, 539
Velocity, 757–762
Vertical-flow media, in trickling filters, 67f
Vessels, 240, 241f, 242f, 243
VFA. *See* Volatile fatty acids
VFDs. *See* Variable frequency drives
Vibration monitoring, 570, 571f
Viscosity, 106, 199, 571, 572
Volatile acids, 93, 422
Volatile fatty acids (VFA), 91
Volatile solids, 314, 466–468
Volatile solids reduction (VSR), 419, 436–440, 456, 466, 474
Volatile suspended solids (VSS), 418
Voltage, 601–602
Voltage tick, 608, 609f
Volume, units of measurement, 744

cone, 747–748, 747f
cube, 744, 744f, 745f
cylinder, 747, 747f
rectangular prism, 744–746, 745f
sphere, 748
triangular prism, 746, 746f
Volume reduction, 492, 536
Volumetric concentration factors (VCF), 286, 287
Volute, 659
VSR. *See* Volatile solids reduction

W

Waste activated sludge (WAS), 89, 114, 183, 325, 426, 616
Waste gas burners, 413, 413f
Waste stabilization lagoons, 29
Wastewater collection systems, 4, 12–15, 13f, 14f
Wastewater, defined, 2
Wastewater facility, 568
Wastewater treatment plants, 2–3, 15, 17, 568
 Clean Water Act, 10–12
 collection and conveyance systems, 12–15, 13f, 14f
 components, 4–7
 disinfection, 19, 20f
 electrical power, 38
 instrumentation control, 38
 lagoon systems, 28–30, 29f
 maintenance program, 38–39
 math assignment, 42–43
 membrane bioreactor, 30–32, 30f, 31f
 odor control, 37
 preliminary, 18
 primary, 18
 process flow diagram, 15, 16f
 safety program, 40–42
 sampling and laboratory analysis, 38
 secondary, 18
 solids handling systems, 32–36, 33f, 34f
 solids in, 8–10, 8f
 tertiary, 19, 21–28, 21f

treatment processes flow diagram of, 313f
urban water cycle, 3–4, 4f
Wastewater treatment system maintenance, 568–569, 569f
 classifications, 569–574
 collection system, 574–577
 computer maintenance management systems, 577–578, 579f
 emergency procedures, 598–600, 599t
 lockout/tagout procedures, 596–598, 597f
 plant maintenance (*See* Plant maintenance)

Water hammer, 225, 387, 651
Water horsepower (WHP), 787, 802
Water inflow, 14
Water power (WP), 804, 806
Water resource recovery facilities (WRRF), 2
Water temperature, effect on oSRT, 59, 59f, 60, 60f
Watts, 603
 in metric system, 790
Wear rings, 660
Weight, units of measurement, 748–749
 in metric system, 780, 780t
Weirs, 18, 186, 326
 loading rate, 329
 overflow rate, 195–196
Wet oxidation, 204, 208–211, 210f, 211t
Wet-oxidized sludges, 486
Wet wells, 232, 245, 593
Windrow composting method, 483, 485, 489t
Wire-to-water efficiency, 789
Wire-to-water power delivery system, 801, 802, 802f
Work, pumps, 785
WRRF. *See* Water resource recovery facilities
Wye-delta starters, 647

Z

Zeta potential, 158
Zinc-to-cadmium (Zn/Cd) ratio, 549