

# Index

## A

- A<sup>2</sup>/O process, 14-102
- Absorption systems, 18-4
- Acceptance, septage, 11-68
- Access roads, 4-24, 4-28
- Accidental release prevention program, 7-27
- Acid-cleaning, 24-64
- Acidogenesis, anaerobic digestion, 25-18
- Activated alumina, odor control, 7-152
- Activated biofilter, process, 15-7
- Activated carbon, odor control, 7-145
- Activated primary clarifiers, 12-57
- Activated Sludge Models, IAWPRC, 20-21
- Activated sludge treatment (also, refer to suspended-growth biological treatment), 14-9
  - odor control, 7-130
  - upgrading, 15-51
- Activation, organic polymers, 22-51
- Administration offices, 4-34
- Adsorption, materials of construction, 10-47
- Advanced alkaline stabilization, 25-239
  - accelerated drying (AASAD), 25-243
  - biosolids product, 27-43
- Advanced integrated, pond systems, 18-25
- Advanced oxidation, 16-137
- Advanced treatment, 1-3
  - equalization, 11-79
  - materials of construction, 10-45
    - adsorption, 10-47
    - air stripping, 10-47
    - coagulation, 10-45
    - filtration, 10-46
    - sedimentation, 10-46
- Advantages, FBBRs, 13-112
- Advisory Council on Historical Preservation, 4-19
- Aerated channels, 6-27
- Aerated grit basins, 11-51
- Aerated grit chamber, 6-34
- Aerated static-pile composting, 25-204
- Aeration and mixing requirements, integrated biological treatment, 15-25
- Aeration basin volume design example, 14-297
- Aeration basins, 6-35
- Aeration
  - composting, 25-218
  - diffused aeration, 14-172
  - equalization, 11-85
  - equipment, aerobic digestion, 25-164
  - FBBRs, 13-125
  - MBBRs, 13-43

## Design of Municipal Wastewater Treatment Plants

- mechanical surface aerators, 14-180
- submerged turbine aerators, 14-185
- Aerobic conditions, composting, 25-199
- Aerobic digesters, 10-53, 25-151
  - Class A biosolids, 20-8
  - Class B biosolids, 20-9
- Aerobic granule-based reactors, 13-210
- Aerobic pretreatment, anaerobic digestion, 25-56
- Aerobic–anoxic operation, aerobic digestion, 25-184
- Aftergrowths, disinfection, 19-65
- Agitated-bed reactors, composting, 25-206
- Air drying, Class A biosolids, 20-8
- Air emissions, 4-42
  - combustions sources, 7-48
  - digester gas, 25-148
- Air flowrate, air emissions, 7-6
- Air pollution control, thermal processing, 26-77
  - acid gases, including sulfur oxides, 26-84
  - combustion modifications, 26-83
  - electrostatic precipitators, 26-82
  - fabric filters, 26-82
  - flue gas treatment, 26-83
  - mechanical collectors, 26-80
  - mercury, 26-84
  - nitrogen oxides, 26-82
  - particulate and metals, 26-77
  - stack-gas reheat, 26-85
  - wet scrubbers, 26-81
- Air quality, 4-19
- Air sampling plans, 7-38
- Air stripping, 16-7, 16-150, 16-152
- Air stripping, materials of construction, 10-47
- Air/oxygen injection, odor control, 7-100
- Air-lift pump, 21-37
- Air-permit-review process, 7-23
- Albertson and Okey model, 13-184
- Alkaline stabilization, 25-231
- Alkaline stabilization, Class B biosolids, 20-10
- Alkalinity, anaerobic digesters, 25-26, 25-118
- Aluminum salts, conditioning, 22-20
- Ambient-odor limits, 7-16
- Amendments, composting, 25-210
- American Concrete Institute, 4-24
- Americans with Disabilities Act, 4-33
- Amines, digester gas, 25-137
- Ammonia recovery, sidestream treatment, 17-26
- Ammonia stripping, sidestream treatment, 17-26
- Ammonia, odor emissions, 7-43
- Ammonia-nitrogen flux, 13-55
- Anaerobic digestion, 10-54, 25-15
  - Class A biosolids, 20-8
  - Class B biosolids, 20-9
- Anaerobic treatment (see also suspended-growth biological treatment), 14-125
- Analysis
  - digester gas, 25-131
  - odorant, 7-38
- Anionic polymers, 12-34
- Annamox
  - biofilm reactors, 13-211
  - sidestream treatment, 17-16
- Application rates
  - biosolids land application, 27-12
  - dedicated land disposal, 27-35, 27-37
- Application, organic polymers, 22-29
- Applying site evaluation criteria, 4-12
- Arc screens, 11-15
- Arc-flash studies, 9-15
- Architecture, 4-39
- Area sources, odors/air emissions, 7-61
- Arrangement of treatment processes, 4-29
- Arrhenius function, 13-21
- Ash, 27-37
- Ash-derived biosolids product, 27-44
- Asset management, 2-5
- ASTM sustainability standards, 5-8
- Asymmetrical flow distribution layout, 6-21
- Attached-growth biological treatment,
  - materials of construction, 10-41
  - rotating biological contactors, 10-42
  - trickling filters, 10-41
- Attainment status, air emissions, 7-19
- Audits, energy, 5-37
- Automation controls, temperature and building, 9-68
- Automation
  - equalization, 11-87
  - grit removal, 11-66
  - screening, 11-38
  - septage, 11-76

- Autothermal thermophilic aerobic digestion, 25-171
- Auxiliary equipment, thermal oxidation, 26-56
- Availability of funding, 4-29
- Available carbon, 12-58
  
- B**
- Backwash filters, moving bed, 13-82
- Backwash handling, BAFs, 13-105
- Bacteria, disinfection, 19-12, 19-15, 19-16
- Baffles, 6-26
  - nutrient control, 14-120
  - secondary clarification, 14-269
- Ballasted flocculation, 12-37, 12-39
- Band screens, 11-18
- Bar rack headloss, 6-32
- Bar screens, odor containment, 7-79
- Bardenpho™ process, 14-92, 14-93, 14-101
- Barrel-arch covers, odor containment, 7-71
- Bars, screening media, 11-8
- Basin cleaning, 11-86
- Basin configuration, aerobic digestion, 25-184
- Batch operation, aerobic digestion, 25-184
- Batch reactors, 6-37
- Batch reactors, anaerobic digestion, 25-67
- Bearings, belt presses, 24-35
- Belt conveyor, 21-57, 21-58, 21-59, 21-60, 21-61, 21-62, 21-63, 21-65, 21-67, 21-68, 21-69, 21-70
- Belt dryers, 26-17
- Belt filter presses, 10-52
  - conditioning, 22-23
  - dewatering, conditioning, 22-39
  - odor containment, 7-81
- Belt thickeners, odor containment, 7-81
- Belt presses, 24-29, 24-35
- Belts
  - cleaning system, 24-39
  - tracking, 24-39
  - wash system, 24-39
- Benchmarking, energy requirements, 5-39
- Beneficial use, incinerator ash, 27-38
- Bernoulli equation, 6-11
- Best-available control technology, odor treatment, 7-14
- Beta ray irradiation, Class A biosolids, 20-8
- Bioaugmentation, sidestream treatment, 17-16
- Biochemical oxygen demand and total suspended solids removal, integrated biological treatment, 15-28
- Biochemical oxygen demand removal efficiency, 12-12
- Biochemistry
  - anaerobic digestion, 25-16
  - biological odor treatment, 7-113
- Biocolloids, 22-6
- Biofilm airlift reactors, 13-212
- Biofilm carriers, trickling filters, 13-143
- Biofilm models, 13-31
- Biofilm reactors, 13-5
- Biofilm thickness
  - FBBRs, 13-124
  - RBCs, 13-140
- Biofilms, 13-5
- Biofilter activated sludge process, 15-9
- Biofilters, odor control, 7-114
- Biogas, 25-123
  - anaerobic digestion, 25-28
  - landfills, 27-29
- Biogasification, 26-67
- Biological fouling, 16-135, 16-136
- Biological treatment (see also suspended-growth biological treatment), 14-1
  - integrated (see integrated biological treatment), 15-1
  - odor control, 7-112
- Biologically active filters (BAFs), 13-73
- Biomass concentration, FBBRs, 13-113
- Biophosphorus, aerobic digestion, 25-188
- Biopolymers, 22-6
- Bioreactor classification, trickling filters, 13-153
- Bioreactor configuration, trickling filters, 13-151
- Bioscrubbers, odor control, 7-127
- Bioset process, 25-243
- Biosolids characteristics, land application, 27-6
- Biosolids, 1-4
- Biotowers, 6-36
- Biotrickling filters, odor control, 7-127
- Blowers and fans, thermal oxidation, 26-55
- Blowers, oxygen transfer, 14-190

- BOD loadings
  - overland flow systems, 18-33
  - rapid-infiltration systems, 18-35
- Boilers, digester gas use, 25-137
- Brake power, 6-43
- Breakpoint chlorination, 19-53
- Brick manufacturing, 27-44
- Brine
  - disposal, 4-28, 16-148, 16-149, 16-150
  - recovery, 16-150
- Broad-crested weir, 6-14
- Bromine disinfection, 19-178
- Brownfields, 4-17
- Bucket elevator, 21-77, 21-78
- Buckingham equation, 21-23, 21-27
- Buffer zones, 4-19
- Building and grounds, safety, 8-10
- Building
  - classifications, fire protection, 9-82
  - enclosures, odor containment, 7-74
  - requirements, recessed-plate filter presses, 24-47
  - fire, and mechanical codes, thermal oxidation, 26-61
- Bulk density
  - compost, 27-47
  - heat-dried biosolids, 27-51
  - solids cake, 24-7
- Bulk liquid volume displacement, 13-38
- Bulk specific surface area, 13-38
- Bulking agent, composting, 25-216
- Bulking agents, 25-210
- Bus technology
  - DeviceNet, 9-40
  - fieldbus, 9-39
  - instrumentation and control systems, 9-39
  - profibus, 9-39
- Bypass screens, 11-10
  
- C**
- Cake
  - discharge, 24-28
  - removal, 24-62
  - solids content, 24-5
- Calcium
  - carbonate equivalency, biosolids land application, 27-14
  - loading rates, biosolids land application, 27-14
  - phosphate precipitation, 17-29
- Calculation procedure, 6-2
- Campus layout, 4-30
- Canada, disinfection regulations, 19-20
- Cap system, landfills, 27-30
- Capacity
  - landfills, 27-25
  - plant, 3-5
- Capital costs
  - heating, ventilating, and air conditioning, 9-61
  - site selection, 4-27
- Capture efficiency, 24-92
  - belt presses, 24-36
  - centrifuges, 24-24
  - recessed-plate filter presses, 24-47
- Carbon addition for nutrient removal, 14-111
- Carbon adsorption, 16-66, 16-67, 16-69, 16-70, 16-71, 16-72
- Carbon adsorption, odor control, 7-145
- Carbon dioxide
  - digester gas, 25-136
  - materials of construction, 10-16
- Carbon footprinting, 5-8
- Carbon monoxide
  - emissions control, 7-161
  - thermal processing, 26-69
- Carbon oxidation, 14-36, 14-37
  - MBBRs, 13-45
  - RBCs, 13-137
- Carbon-to-nitrogen (C:N) ratio, composting, 25-199
- Catalytic oxidation, odor control, 7-143
- Catalytic oxidizers, 7-157
- Catenary screens, 11-14
- Cathodic protection, 10-36, 10-94
  - galvanic anodes, 10-95
  - impressed-current systems, 10-97
- Ceiling concentration, biosolids, 27-8
- Centrifugal pumps, 6-40, 10-50, 21-28, 21-29, 21-30
- Centrifuges, 10-53, 24-17
  - dewatering, conditioning, 22-39
  - odor containment, 7-82
  - thickening, 23-41

- abrasion areas, 23-55
- back-drive, 23-55
- base, 23-54
- bearings, 23-54
- bowl geometry, 23-43
- bowl, 23-54
- case, 23-54
- chemical conditioning, 23-57
- conditioning, 22-37
- conveyor, 23-54
- design example, 23-58
- differential speed adjustment, 23-47
- electrical controls, 23-55
- evaluation and scale-up, 23-47
- feed pipe, 23-54
- motor type and size, 23-53
- operating principle, 23-42
- performance-control systems, 23-56
- pond-depth adjustments, 23-57
- process design, 23-50
- pumps, 23-55
- scroll configuration, 23-46
- scroll drive features, 23-47
- scroll geometry, 23-46
- solids transportation, 23-56
- variable-speed bowl and scroll, 23-57
- vibration, 23-55
- Certified tests, pumps, 6-52
- Chain and flights, 12-43
- Chain-driven screens, 11-12
- Channel design, 11-44
- Characteristics
  - design flow, 3-5
  - primary sludge, 12-46
  - sidestreams, 17-10
  - wastewater, 2-37
- Characterization, septage, 11-68
- Charge, organic polymers, 22-25
- Chemical coagulants, 12-34
- Chemical conditioning
  - dewatering, 24-11
  - rotary presses, 24-92
  - screw presses, 24-109
- Chemical feed systems, 6-39
- Chemical flocculants, 12-34
- Chemical handling, safety, 8-18
- Chemical oxidation, odor control, 7-102
- Chemical oxygen demand
  - anaerobic digestion, 25-28
  - removal efficiency, 12-12
- Chemical requirements, sidestream treatment, 17-13
- Chemical selection, 9-72, 9-74
- Chemical solids, 22-5
- Chemical solids, production, 20-24
- Chemical solution diffuser, 12-36
- Chemical spills, 4-20
- Chemical stabilization/fixation process, 25-241
- Chemical storage
  - conditioning, 22-41
  - feeding equipment, alkaline stabilization, 25-260
- Chemical systems, 9-71
  - application points, 9-75
  - bulk delivery and containers, 9-77
  - codes, 9-75
  - construction materials, 9-80
  - containment and diking, 9-77
  - costs, 9-72
  - dry chemical feed, 9-78, 9-79
  - equipment selection, 9-76
  - gas-chemical-feed, 9-78
  - liquid-chemical-feed, 9-78
  - mixing, 9-80
  - retrofitting and upgrading, 9-80
  - security, 9-80
  - solids management, 9-81
  - storage, handling, feed systems, and mixing, 9-77
  - odor control, 7-100, 7-131
- Chemical-feed and chemical-distribution facilities, material selection, 10-73
- Chemically enhanced primary treatment, 12-31, 12-46
- Chemicals/dose, alkaline stabilization, 25-248
- China, disinfection regulations, 19-21
- Chloramination, 16-136, 19-23
- Chloramines, disinfection, 19-52
- Chlorination and dechlorination chemicals, 19-56
  - chlorine dioxide, 19-59
  - elemental chlorine, 19-56
  - hypochlorites, 19-56
  - sulfite salts, 19-58
  - sulfur dioxide, 19-57

## Design of Municipal Wastewater Treatment Plants

- Chlorination, 6-36, 16-16, 16-38, 16-131, 16-135, 16-136, 16-138, 16-155, 16-156, 16-157, 16-158, 19-50
  - breakpoint, 19-53
  - chloramines, 19-52
  - chlorine/nitrogen reactions, 19-54
  - inorganic reactions, 19-52
  - organic reactions, 19-54
  - secondary effluent, 19-90
- Chlorinators, 19-75, 19-77
- Chlorine compounds, odor control, 7-102
- Chlorine dioxide
  - chlorination and dechlorination, 19-59
  - disinfection, 19-23
- Chlorine
  - byproduct toxicity, 19-64
  - disinfection, 19-26
  - disinfection and dechlorination, 10-43
  - efficacy, disinfection, 19-90
  - gas, disinfection, 19-22, 19-65
  - residual, disinfection, 19-71
- Cipoletti weirs, 6-13
- Circular clarifiers, 12-5, 14-249
- Clarifier depth, 12-14
- Clarifiers, 12-5, 14-205
  - secondary, integrated biological treatment, 15-14
  - suspended-growth biological treatment, 14-35
  - wet-weather considerations, 14-169
- Class A biosolids, 20-6
- Class B biosolids, 20-9
- Clean filter headloss, 6-38
- Clean Water Act, 2-8
- Cleaning system, screw presses, 24-103
- Cleaning
  - anaerobic digester equipment, 25-122
  - screening, 11-28
- Climate change, infrastructure design, 5-22
- Climate, 4-38
- Climate, heating, ventilating and air conditioning, 9-55
- Closure, landfills, 27-29
- Coagulant addition, 12-35
- Coagulant dosage, 12-32
- Coagulation, materials of construction, 10-45
- Coarse screens headloss, 11-34
- Coarse screens, 11-6, 11-11
- Coarse solids reduction, 11-49
- Codes
  - chemical systems, 9-75
  - fire suppression, 9-82
  - heating, ventilating, and air conditioning, 9-53, 9-69
  - thermal oxidation, 26-61
- Co-digestion, 25-76
- Co-disposal landfills, 27-23
- Cogeneration, digester gas use, 25-138
- Colloidal fouling, 16-133, 16-134
- Color coding
  - paints used to identify type of service, 10-93
  - piping, 8-13
- Combined aerobic-anaerobic digestion, 25-177
- Combined carbon oxidation and Nitrification, trickling filters, 13-173
- Combined sewer overflow screen, 11-23
- Combined solids, production, 20-23
- Combustion emissions, 26-69
- Combustion, 26-25
  - odor control, 7-152
  - waste gas, 25-132
- Commercial computation software, 6-54
- Commercial modeling software, 6-54
- Communication, 9-93
- Community effects, odor emissions, 7-55
- Compact layout, 4-30
- Compartments, biofilm reactors, 13-8
- Compensation options, 4-21
- Complete mix reactor, 14-13
- Complex siting study, 4-7
- Compliance assurance monitoring, air emissions, 7-28
- Composition of primary sludge, 12-48
- Composition of scum, 12-53
- Composition, screening, 11-8
- Compost, 25-198
  - biosolids product, 27-42
  - Class A biosolids, 20-8
  - Class B biosolids, 20-9
  - product quality, 27-46
- Comprehensive Environmental Response, Compensation, and Liability Act, 2-53
- Compressed-air systems, 9-92
- Compressible medium filtration, 16-51

- Compressors
  - digester gas, 25-129
  - dissolved air flotation, 23-37
- Computational fluid dynamics, 6-22, 6-55
  - disinfection, 19-49
  - UV disinfection, 19-107, 19-142
- Computer modeling, 6-53
- Concentration, scum, 12-55
- Concrete
  - properties and applications, 10-75
  - structural systems, 10-65
- Condensate traps, 25-127
- Conditioning agents, 22-4
- Conditioning, 22-3
  - screening, 11-24, 11-37
  - slurry carbonization, 26-6, 26-7
  - thermal, 26-6
- Conduction drying systems, 26-15
- Conduit losses, 6-16
- Conduit sizing, 6-10
- Configuration
  - BAFs, 13-74
  - equalization, 11-84
  - MBBRs, 13-44
- Confined spaces, odor containment, 7-94
- Confluence analysis, 6-27
- Conical grit washers, 11-62
- Consent decree, 4-4
- Conservation planning, land application, 27-5
- Constant speed pumps, 6-45
- Constant velocity channels, 6-34
- Constructed wetlands, materials of construction, 10-43
- Constructed, wetlands, 18-42
- Construction
  - considerations, sustainability, 5-13
  - instrumentation and control systems, 9-29
  - materials (see Materials of construction), 10-1
  - materials, chemical systems, 9-80
  - safety, 8-21
- Contact time
  - alkaline stabilization, 25-248
  - disinfection, 19-39, 19-40, 19-45
- Containment and diking, chemicals, 9-77
- Containment structure, trickling filters, 13-148
- Continuous self-cleaning screens, 11-14
- Continuous-element screens, 11-16
- Contract, project, 2-33
- Contractor safety prequalification, 8-24
- Control panels, instrumentation and control systems, 9-40
- Control point, 6-6
- Control systems
  - data systems, 9-52
  - instrumentation, 9-52
  - monitoring versus control, 9-52
  - plant control systems, 9-44
    - building blocks, 9-45
  - distributed control systems, 9-44
  - process controllers, 9-44
  - programmable logic controller, 9-44
  - supervisory and data acquisition systems, 9-43
- Control valve equation, 6-25
- Controlled discharge, facultative ponds, 18-11
- Controls and drives, belt presses, 24-37
- Controls
  - aerobic digestion, 25-167
  - centrifuges, 24-25
  - screw presses, 24-108
- Convection dryers, 26-11, 26-17
- Conventional aerobic digestion, 25-169
- Conventional sedimentation, 12-4
- Conveyance, post-digestion solids, 25-72
- Conveyance, solids, 10-51
- Conveyors, screening, 11-28
- Corrosion, 10-18
  - anaerobic digesters, 25-117
  - carbonation of concrete, 10-21
  - cavitation, 10-20
  - control, 10-1
  - control, clarifiers, 12-29
  - cracking, 10-21
  - crevice corrosion, 10-20
  - dealloying corrosion, 10-21
  - digester equipment, 25-128
  - embrittlement, 10-21
  - erosion-corrosion, 10-20
  - flexure, 10-21
  - fretting, 10-20
  - galvanic corrosion, 10-20
  - heat, 10-22

- microbiologically influenced corrosion, 10-22
  - pitting corrosion, 10-20
  - plastic deformation, 10-22
  - resistance, heating, ventilating and air conditioning, 9-60
  - selective leaching, 10-20
  - uniform corrosion, 10-19
  - UV deterioration of plastics and coating, 10-22
  - Cost-effectiveness, conditioning, 22-54
  - Costs
    - chemical systems, 9-72
    - estimating, 2-57
    - heating, ventilating and air conditioning, 9-61
    - site selection, 4-27
    - siting criteria, 4-10
  - Cothickening of primary and secondary, 12-58
  - Countercurrent adsorption, 16-75
  - Covered beds, 24-80
  - Covers
    - anaerobic digesters, 25-97
    - RBCs, 13-140
  - Covers/enclosures, odor containment, 7-69
  - Criteria analysis, 2-67
  - Critical depth, 6-19
  - Crop selection, slow-rate systems, 18-24
  - Cross collectors, primary sludge, 12-43
  - Cross-linkage, organic polymers, 22-27
  - Cryogenic refrigeration, 25-137
  - Cultural significance, site selection, 4-19
  - Curing, composting, 25-223
  - Cut-throat flume, 6-24
  - Cyclone systems, 11-60
  - Cylindrical digesters, 25-95
- D**
- Darcy-Weisbach equation, 6-16, 21-16, 21-24, 21-25, 21-26
  - Debris management, anaerobic digesters, 25-65, 25-114
  - Decanters, drying beds, 24-78
  - Dechlorination and chlorination chemicals, 19-56
    - chlorine dioxide, 19-59
    - elemental chlorine, 19-56
    - hypochlorites, 19-56
    - sulfite salts, 19-58
    - sulfur dioxide, 19-57
  - materials of construction, 10-43
    - chlorine, 10-43
    - miscellaneous electrotechnology processes, 10-45
    - ozone, 10-44
    - sodium metabisulfite, 10-44
    - sulfur dioxide, 10-44
  - Dechlorination, 16-136, 16-138, 16-158, 19-93
    - reactions and kinetics, 19-94
    - shipment and handling safety, 19-95
    - sulfur dioxide, 19-94
  - Dedicated land disposal, 27-32
  - Defining site evaluation criteria, 4-14
  - Degritting
    - materials of construction, 10-49
    - solids pretreatment, 20-39
  - Demand reduction, energy, 5-35
  - Denitritation, sidestream treatment, 17-15
  - Denitrification
    - BAFs, 13-97
    - MBBRs, 13-58
  - Dense sludge process, 12-37, 12-41
  - Depth filtration, 16-16, 16-17, 16-57, 16-58
  - Depth of clarifier, 12-14
  - Descriptors, odor character, 7-8
  - Design considerations
    - anaerobic digestion, 25-80
    - BAFs, 13-88
    - chemically enhance primary treatment, 2-33
      - heating, ventilating and air conditioning, 9-60
        - corrosion resistance, 9-60
        - costs, 9-61
        - hazard assessment, 9-60
        - system redundancy, 9-61
    - MBBRs, 13-66
    - preaeration, 12-30
    - primary treatment, 12-9
    - sidestream treatment, 17-9
    - stacked clarifiers, 12-29
    - trickling filters, 13-188
  - Design example, 15-39
    - aerobic digester, 25-194
    - biosolids land application, 27-15

- centrifuge, 23-58
- Class B lime stabilization, 25-287
- composting, 25-227
- dissolved air flotation, 23-40
- gravity belt thickeners, 23-72
- gravity thickeners, 23-17
- hydraulic profile, 6-57, 6-63
- incineration, 26-92
- mass balance, 20-25
- odor emissions, 7-63
- overland flow systems, 18-34
- pond systems, 18-17
- primary clarifier, 12-59
- rapid-infiltration systems, 18-40
- rotary drum thickeners, 23-77
- slow-rate systems, 18-29
- suspended-growth biological treatment, 14-294
  - addressing nutrients, 14-309
  - aeration basin volume, 14-297
  - aeration requirements, 14-301
  - secondary clarification, 14-307
  - summary for the base case, 14-308
- thermal drying, 26-85
- thermal processing, 26-85, 26-92
- thermophilic digestion, 25-119
- trickling filters, 13-198
- upgrading a conventional activated sludge plant, 15-51
- UV disinfection, 19-131
- wetlands, 18-48
- “Design for Safety”, 8-22
- Design models
  - FBBRs, 13-128
  - trickling filters, 13-160
- Design of unit processes, materials of construction, 10-37
  - advanced treatment, 10-45
    - adsorption, 10-47
    - air stripping, 10-47
    - coagulation, 10-45
    - filtration, 10-46
    - sedimentation, 10-46
  - attached-growth biological treatment, 10-41
    - rotating biological contactors, 10-42
    - trickling filters, 10-41
  - disinfection and dechlorination, 10-43
    - chlorine, 10-43
    - miscellaneous electrotechnology processes, 10-45
    - ozone, 10-44
    - sodium metabisulfite, 10-44
    - sulfur dioxide, 10-44
  - effluent discharge, 10-60
    - building reuse systems, 10-64
    - freshwater outfalls, 10-62
    - land sprinkling systems, 10-64
    - marine outfalls, 10-62
    - pipng, 10-61
    - pumps, 10-60
    - storage tanks, 10-63
  - gas collection, storage, and distribution, 10-56
  - natural systems, 10-43
    - constructed wetlands, 10-43
    - wastewater ponds, 10-43
  - preliminary treatment, 10-37
    - flow equalization, 10-38
    - grit removal, 10-38
    - screens, 10-37
  - primary treatment, 10-39
    - dissolved air flotation, 10-40
    - settling tanks, 10-39
  - solids conveyance, 10-51
  - solids dewatering, 10-52
    - belt filter presses, 10-52
    - centrifuges, 10-53
    - plate and frame presses, 10-53
  - solids handling and treatment, 10-47
  - solids processing, 10-48
    - degritting, 10-49
    - grinders, 10-48
    - screening, 10-50
  - solids pumping, 10-50
    - centrifugal pumps, 10-50
    - piston pumps, 10-50
  - solids stabilization, 10-53
    - aerobic digesters, 10-53
    - anaerobic digesters, 10-54
    - digester tanks, 10-55
    - gas-mixing systems, 10-55
    - mesophilic digestion, 10-54
    - mixing systems, 10-55
    - thermophilic aerobic digesters, 10-54
    - thermophilic digestion, 10-55
  - solids thickening, 10-51
    - flotation thickeners, 10-51

## Design of Municipal Wastewater Treatment Plants

- gravity belt thickeners, 10-51
- gravity thickeners, 10-51
- storage, 10-48
- suspended-growth biological treatment, 10-40
- thermal destruction, 10-58
  - multiple-hearth furnace, 10-59
  - fluid-bed furnace, 10-60
  - rabble arms and teeth, 10-59
  - refractory and insulation, 10-60
- thermal processing, 10-56
  - thermal conditioning and wet-air oxidation, 10-56
  - thermal drying, 10-57
- Design
  - biofilm reactors, 13-15
  - electrical systems, 9-27
  - equalization, 11-79
  - facultative ponds, 18-10
  - fine screens, 11-36
  - grit removal, 11-63
  - guidelines, thermal drying, 26-18
  - heating, ventilating, and air conditioning, 9-53, 9-57
    - energy and sustainable initiatives, 9-62
    - energy and sustainable opportunities, 9-69
  - LEED, 9-69
  - materials of construction, 10-23
  - plumbing, 9-88, 9-89
  - projections, 2-37
  - rapid-infiltration systems, 18-38
  - requirements, 3-6
  - screening, 11-30
  - screw presses, 24-101
  - soil absorption, 18-5
  - standards, 2-20
  - standards, instrumentation and control systems, 9-29
  - standards and review, materials of construction, 10-98
  - thermal drying, 26-22
  - trends, 1-7
  - trickling filters, 13-180
- Destabilization, post-digestion solids, 25-68
- Detection threshold
  - odor concentration, 7-7
  - odorant, 7-11
- Detention time, 12-14
  - aerobic digestion, 25-159
  - composting, 25-214
- Determining site area requirements, 4-7
- Detritus tanks, 11-59
- Developing site evaluation criteria, 4-10
- Developing siting work plan, 4-3
- Development, biofilm, 13-12
- Dewatered cake/chemical mixing, alkaline stabilization, 25-264
- Dewatering, 24-4
  - alkaline stabilization, 25-274
  - materials of construction, 10-52
    - belt filter presses, 10-52
    - centrifuges, 10-53
    - plate and frame presses, 10-53
  - post-digestion solids, 25-73
  - sidestream treatment, 17-13
- Diaphragm filter press, 24-51
- Diaphragm pump, 21-34, 21-35
- Diaphragms, 24-57
- Digester gas, 25-123
- Digester gas, characteristics, 25-142
- Digester hydrogen sulfide control, 12-58
- Digestion
  - materials of construction, 10-53
    - aerobic digesters, 10-53
    - anaerobic digesters, 10-54
    - mesophilic, 10-54
    - mixing systems, 10-55
    - tanks, 10-55
    - thermophilic, 10-55
    - thermophilic aerobic digesters, 10-54
  - sand drying beds, 24-72
- Dilute residuals, 21-16
- Dilution-to-threshold (D/T) limits, 7-11
- Disadvantages, FBBRs, 13-112
- Disc filtration, 16-57
- Disc pump, 21-30
- Disease, disinfection, 19-8, 19-10, 19-13, 19-17
- Disinfection and dechlorination, materials of construction, 10-43
  - chlorine, 10-43
  - miscellaneous electrotechnology processes, 10-45
  - ozone, 10-44
  - sodium metabisulfite, 10-44
  - sulfur dioxide, 10-44

- Disinfection systems, 6-36
- Disinfection, 19-1
  - advanced oxidation, 19-182
  - aftergrowths, 19-65
  - alternatives to chlorination, 19-23
  - analytical determination of chlorine residuals, 19-71
  - breakpoint chlorination, 19-53
  - bromine, 19-178
  - byproduct formation, 19-48
  - byproduct toxicity, 19-64
  - chloramination, 19-23
  - chlorination, 19-50
    - chloramines, 19-52
    - chlorine/nitrogen reactions, 19-54
    - inorganic reactions, 19-52
    - organic reactions, 19-54
  - chlorination and dechlorination chemicals, 19-56
    - chlorine dioxide, 19-59
    - elemental chlorine, 19-56
    - hypochlorites, 19-56
    - sulfite salts, 19-58
    - sulfur dioxide, 19-57
  - chlorination of reclaimed water, 19-90
  - chlorination of secondary effluent, 19-90
  - chlorine dioxide, 19-23
  - chlorine efficacy, 19-90
  - combined processes, 19-182
  - computational fluid dynamics, 19-49
  - contact time, 19-39, 19-40, 19-45
  - dechlorination, 19-93
    - reactions and kinetics, 19-94
    - shipment and handling safety, 19-95
    - sulfur dioxide, 19-94
  - design example, 19-131
  - design for chemical disinfectants, 19-37
  - disease, 19-8, 19-10, 19-13, 19-17
  - effects of wastewater type and characteristics, 19-31
  - electrolyer systems, 19-61
  - electrolyer systems, separated (membrane systems), 19-62
  - electron-beam irradiation, 19-179
  - equipment, 19-75
    - chemical feed for hypochlorite solutions, 19-79
    - chlorinators, 19-75, 19-77
    - manifolds and vacuum-regulator location, 19-80
    - vaporizers, 19-81, 19-82
  - feed control strategies, 19-83
  - ferrate, 19-179
  - free versus combined chlorine residual, 19-71
  - kinetic equations, 19-36
  - kinetic models, 19-28
  - kinetics, 19-27
  - microbial inactivation, 19-26
    - chlorine, 19-26
    - UV radiation, 19-26
  - onsite generation of sodium hypochlorite, 19-61
  - ozone, 19-23, 19-166
    - analytical methods for ozone measurement, 19-169
    - environmental effects, 19-175
    - modeling, 19-171
    - process design, 19-172
      - ozone contactors, 19-173
      - ozone demand and absorption, 19-174
      - ozone exhaust destruction, 19-175
    - process design, ozone generators, 19-172
    - reaction kinetics, 19-169
    - safety and health, 19-175
    - shipment and handling safety, 19-176
  - pasteurization, 19-180
  - pathogens, 19-8, 19-9, 19-10, 19-12, 19-13, 19-15
    - bacteria, 19-12, 19-15, 19-16
    - fungi, 19-13
    - protozoa, 19-13
    - survival, 19-16, 19-17
    - viruses, 19-13
  - waterborne disease outbreaks, 19-17, 19-18
    - recreational water, 19-17
    - shellfish, 19-19
  - peracetic acid, 19-23, 19-177
  - pond treatment system die-off, 19-180
  - process design, 19-74
    - closed conduits, 19-74
    - contacting, 19-75
    - hydraulic devices, 19-74
    - mixing, 19-74
  - reactor design considerations, 19-34

- reactor maintenance, 19-47
- reactor modeling, 19-49
- reclaimed water, 19-33
- regrowth phenomena, 19-30
- regulations, 19-8, 19-20
  - Canada, 19-20
  - China, 19-21
  - European, 19-21
- residual toxicity, 19-31
- safety and health, 19-65
  - chlorine gas, 19-65
  - cylinders, 19-67
  - hypochlorites, 19-66
  - vaporizer facilities, 19-70
- solar, 19-179
- sustainability, 19-25
- technologies, 19-21
  - chlorine gas, 19-22
  - sodium hypochlorite, 19-22
- tertiary filtration and membrane treatment, 19-181
- UV, 19-23, 19-97
  - actinometers, 19-107
  - bench and pilot testing, 19-158, 19-159
  - bioassays, 19-108
  - computational fluid dynamic modeling, 19-107
  - computational fluid dynamics, 19-142
  - design, 19-146
    - bypass channels and flooding, 19-147
    - facility requirements, 19-147
    - module lifting, 19-148
    - power conditioning, 19-149
    - power supply and harmonic distortion, 19-148, 19-149
    - reactors, 19-147
    - spare parts, 19-148
    - system redundancy, 19-147
  - design example, 19-131
- dose (fluence), 19-106, 19-107, 19-110
- effects of water quality and design, 19-154
  - effects of upstream processes, 19-157
  - effects of chemicals, 19-157
- equipment, 19-149
  - horizontal systems, 19-151
  - low-pressure, high-intensity systems, 19-154
  - low-pressure, low-intensity systems, 19-150
  - medium-pressure, mercury-lamp systems, 19-153
  - vertical systems, 19-152
- fouling and sleeve-cleaning systems, 19-143
- inactivation kinetics, 19-110
- intensity, 19-101, 19-102
- mathematical models, 19-138
- photoreactivation and dark repair, 19-119
- point source-summation model, 19-107
- reactor design and testing, 19-120
  - headloss, 19-123, 19-125
  - hydraulics, 19-120
  - inlet structure, 19-121
  - lamp output, 19-124, 19-125
  - longitudinal dispersion, axial dispersion, and turbulence, 19-120
  - outlet structure, 19-122
  - reactor validation and scale-up, 19-127
  - validation concerns, 19-136
  - validation testing for reuse, 19-130
- safety and health, 19-145
  - electrical hazards, 19-146
  - exposure to UV light, 19-145
- system sizing and configuration, 19-159
  - design guidelines, 19-164
  - disinfection of secondary effluent, 19-163
  - disinfection of reclaimed water, 19-163
  - emerging methods, 19-166
  - final design, 19-160
  - flow and dose pacing, 19-166
  - intensity monitoring, 19-165
  - retrofitting, 19-163
  - transmittance monitoring, 19-164
- transmittance, 19-105
- wet weather, 19-33
- Dispersion modeling, odors/air emissions, 7-57, 7-64
- Disposal
  - incinerator ash, 27-38
  - scum, 12-55
- Dissolved air flotation, 23-18
  - ancillary equipment and controls, 23-36
  - pipes, valves, and instruments, 23-36
  - pumps and compressors, 23-37
  - cothickening primary and secondary solids, 23-38

- design example, 23-40
- evaluation and scale-up, 23-19
- flotation systems, 23-30
- location, 23-32
- materials of construction, 10-40, 23-30
- overflow weir, 23-33
- pressurization system, 23-33, 23-34
- pressurization tanks, 23-35
- process design, 23-21
  - air-to-solids ratio, 23-25
  - feed-solids concentration, 23-24
  - float-blanket depth, 23-26
  - floating solids concentration, 23-27, 23-28
  - hydraulic loading rate, 23-22
  - mixed-liquor sludge volume index, 23-23
  - polymer addition, 23-26
  - solids capture, 23-28
  - solids loading rate, 23-23
  - solubilization efficiency, 23-29
  - type of solids, 23-23
- skimmers and rakes, 23-32
- thickening, conditioning, 22-37
- Dissolved oxygen, suspended-growth
  - biological treatment, 14-45
- Distributed logic controller systems, 9-44
- Distribution channels, 6-22
- Distribution manifolds, 6-22
- Distribution of aeration, 5-25
- Distribution system, 9-15
- Distribution system, slow-rate systems, 18-25
- Distribution voltage, 9-13
- Distribution
  - biosolids products, 27-42, 27-57
  - overland flow systems, 18-34
  - reuse, 2-19
  - trickling filters, 13-142
- Doctor blade, 24-39
- Dome enclosures, odor containment, 7-76
- Dosage
  - organic polymers, 22-29
  - rates, alkaline stabilization, 25-275
- Dose optimization, conditioning, 22-54
- Downe's floating covers, 25-99
- Downflow, BAFs, 13-77
- Downstream process considerations, 12-57
- Downstream processes, septage, 11-75
- Drag conveyor, 21-74, 21-75, 21-76, 21-77
- Drawings, construction, 2-36
- Drip application, 18-5
- Drip traps, 25-127
- Drivers, sidestream treatment, 17-8
- Drum screens, 11-19
- Dry digestion, 25-77
- Dry lime stabilization, 25-239
- Dry polymer feeders, organic polymers, 22-46
- Dry polymers, organic polymers, 22-27
- Dry-adsorption systems, odor control, 7-145
- Dryers, digester gas, 25-128
- Drying beds, 24-66
- Drying beds, conditioning, 22-40
- Drying lagoons, 24-88
- Drying
  - alkaline stabilization, 25-273
  - composting, 25-203
  - thermal, 26-8
    - belt dryers, 26-17
    - conduction drying systems, 26-15
    - convection dryers, 26-11, 26-17
    - design guidelines, 26-18
      - selection, 26-20
        - labor requirements, 26-21
        - processing train unit capacity, 26-20
        - product quality and use, 26-20
      - sizing parameters, 26-18
        - evaporative capacity, 26-18
        - hours of operation, 26-19
        - operating temperatures, 26-19
        - solids retention time, 26-19
        - storage, 26-20
      - utility requirements, 26-21
        - electrical, 26-21
        - emissions and odor control, 26-22
        - sidestreams, 26-22
        - thermal, 26-21
        - water, 26-22
  - design practice, 26-22
    - materials of construction, 26-23
    - post-processing equipment, 26-23
    - pre-processing equipment, 26-22
    - safety, 26-23
      - dryer equipment, 26-24
      - dryer operations, 26-24
      - industry standards, 26-25
  - flash dryer, 26-12
  - fluidized bed dryer, 26-13
  - heat-transfer methods, 26-10

## Design of Municipal Wastewater Treatment Plants

- paddle and hollow-flight dryers, 26-15
  - pressure filter/vacuum dryer, 26-16
  - rotary drum dryer, 26-12
  - solar dryers, 26-18
  - tray dryers, 26-16
  - Dry-seal gas holders, 25-125
  - Dual digestion, 25-177
  - Duckweed systems, 18-41
  - Ductwork, odor-control system, 7-95
  - Durability, heat-dried biosolids, 27-50
  - Dust content, heat-dried biosolids, 27-50
  - Dust control, alkaline stabilization, 25-273
  - Dynamic loads, centrifuges, 24-27
- E**
- Eckenfelder formula, 13-168
  - Ecology, biofilm, 13-13
  - Economic considerations
    - alkaline stabilization, 25-268
    - sustainability, 5-15
  - Effects of viscosity, 6-44
  - Effluent discharge, materials of construction, 10-60
    - building reuse systems, 10-64
    - freshwater outfalls, 10-62
    - land sprinkling systems, 10-64
    - marine outfalls, 10-62
    - pipng, 10-61
    - pumps, 10-60
    - storage tank, 10-63
  - Effluent pumps, 6-6
  - Effluent quality, integrated biological treatment, 15-15
  - Egg-shaped digesters, 25-91
  - Electrical hazards, UV disinfection, 19-146
  - Electrical power consumption, 5-29
  - Electrical requirements, thermal drying, 26-21
  - Electrical systems, 9-7
    - "clean" power for computer systems, 9-27
    - energy savings and design features, 9-27
    - grounding systems, 9-25
    - harmonics, 9-23
    - hazardous areas, 9-26
    - lightning and surge protection, 9-27
    - load transfer and power failure, 9-25
    - material selection, 10-70
      - conduits and enclosures, 10-70
      - signal cables, 10-71
    - safety, 8-14
    - seismic protection, 9-26
  - Electrical-current-driven membrane, 16-124
  - Electricity requirements, thermal oxidation, 26-49
  - Electrolyer systems
    - disinfection, 19-61
    - disinfection, separated (membrane systems), 19-62
  - Electron-beam irradiation, 19-179
  - Electronic distributors, 13-190
  - Electrostatic precipitators, thermal processing, 26-82
  - Electrotechnology processes, disinfection and dechlorination, 10-45
  - Elevation, 4-21
  - Emergency access, 4-36
  - Emergency lighting systems, 9-21
  - Emergency Planning and Community Right-To-Know Act, 2-53
  - Emergency planning, 4-35
  - Emerging biofilm reactors, 13-205
  - Emerging methods, UV disinfection, 19-166
  - Emerging technologies, thermal oxidation, 26-35
  - Emission rates, odors, 7-62
  - Emission thresholds, air pollutant, 7-21
  - Emission control
    - objectives, odors, 7-7
    - odors, 7-56
    - thermal processing, 26-68
      - air pollution, 26-77
        - acid gases, including sulfur oxides, 26-84
        - combustion modifications, 26-83
        - electrostatic precipitators, 26-82
        - fabric filters, 26-82
        - flue gas treatment, 26-83
        - mechanical collectors, 26-80
        - mercury, 26-84
        - nitrogen oxides, 26-82
        - particulate and metals, 26-77
        - stack-gas reheat, 26-85
        - wet scrubbers, 26-81

- combustion emissions, 26-69
  - carbon monoxide, 26-69
  - nitrogen oxides, 26-71
  - polycyclic organic matter, 26-71
  - volatile organic compounds, 26-70
- odors, 26-68
- regulations, 26-71
  - future, 26-74
  - local prohibitory rules, 26-74
  - National Emission Standard for Hazardous Air Pollutants, 26-72
  - new source performance standards, 26-72
  - new source review, 26-73
  - nonregulated emissions (greenhouse gases), 26-76
  - prevention of significant deterioration, 26-72
  - source-specific standards, 26-75
  - Standards for the Use and Disposal of Sewage Sludge, 26-73
- thermal drying, 26-22
- thermal oxidation, 26-47
- Empirical models
  - biofilms, 13-20
  - RBCs, 13-138
- Emulsion polymers, organic polymers, 22-28
- Endogenous decay, solids production, 20-19
- Energy and mass balance, thermal oxidation, 26-47, 26-48
- Energy and sustainability, heating, ventilating, and air conditioning, 9-62, 9-69
- Energy
  - balance, composting, 25-200
  - code compliance, heating, ventilating and air conditioning, 9-69
  - conservation, sidestream treatment, 17-8
  - costs, heating, ventilating and air conditioning, 9-61
  - efficiency, integrated fixed-film activated sludge systems, 15-49
  - integrated biological treatment, 15-15
  - management, 5-28
  - management, U.S. EPA guidance, 5-10
  - manager, 5-41
  - MBBRs, 13-72
  - modeling, heating, ventilating and air conditioning, 9-70
  - recovery, heating, ventilating and air conditioning, 9-71
  - requirements, alkaline stabilization, 25-256
    - centrifuges, 24-28
    - rotary presses, 24-92
    - screw presses, 24-110
    - sidestream treatment, 17-12
  - savings, electrical systems, 9-27
  - services contracting (ESC), 5-19
- Energy Star Program, 5-34
- Energy-impacting requirements, 5-31
- Energy-Water Nexus report, 5-28
- Enhanced biological phosphorous removal (see also suspended-growth biological treatment), 12-57, 14-55
- Enhanced sedimentation, 12-30
- Envessel pasteurization, 25-243
- Environmental considerations in site selection, 4-16
- Environmental constraints, 4-41
- Environmental effects, ozone disinfection, 19-176
- Environmental justice, 4-26
- Environmental management systems, 5-10
- Environmental management systems, biosolids, 20-13
- Environmental site assessment, 4-17
- Environmental site criteria, 4-10
- Environmental siting issues, 4-41
- Equalization, 11-76
  - requirements, sidestream treatment, 17-11
  - septage, 11-75
- Equipment
  - biosolids land application, 27-19
  - dissolved air flotation, 23-36
    - pipes, valves, and instruments, 23-36
    - pumps and compressors, 23-37
  - enclosures, odor containment, 7-78
  - gravity belt thickeners, 23-68
    - belt washwater supply, 23-71
    - feed pumps and feed flow control, 23-69
    - odor control, 23-72
    - polymer system and feed control, 23-70
    - thickened-solids pumps, 23-71
  - gravity thickening, 23-17

- identification, materials of construction, 10-101
  - membrane bioreactors, 14-147, 14-159
  - oxygen transfer, 14-198
  - rotary drum thickeners, 23-77
  - safety, thermal drying, 26-24
  - secondary clarification, 14-293
  - selection
    - aerobic digestion, 25-168
    - chemical systems, 9-76
  - selection/layout, anaerobic digestion, 25-120
  - thermal drying, 26-22, 26-23
  - thermal oxidation, 26-44, 26-50, 26-52, 26-55, 26-56
  - UV disinfection, 19-149
    - horizontal systems, 19-151
    - low-pressure, high-intensity systems, 19-154
    - low-pressure, low-intensity systems, 19-150
    - medium-pressure, mercury-lamp systems, 19-153
    - vertical systems, 19-152
  - Europe, disinfection regulations, 19-21
  - Evaluating sites, 4-15
  - Evolution of municipal wastewater treatment, 1-2
  - Exceptional quality (EQ) biosolids, 27-8
  - Excessive freefall, 6-9
  - Exclusionary areas, 4-12
  - Exhaust system, composting, 25-218
  - Expanded bed biofilm reactors (EBBRs), 13-109
  - Expansion, 4-31
  - Explosion and fire protection, thermal oxidation, 26-64
  - Extraneous flows, 2-47
  - Extreme flow conditions, 12-28
- F**
- Fabric filters, thermal processing, 26-82
  - Facility design, BAFs, 13-105
  - Factory inspections, pumps, 6-52
  - Factory witnessed tests, 6-52
  - Facultative ponds, 18-8
  - Fans and blowers, thermal oxidation, 26-55
  - Fans, odor-control system, 7-97
  - Fats, oil, and grease (FOG), anaerobic digestion, 25-78
  - Federal requirements, land application, 27-4
  - Feed cake–chemical mixture, alkaline stabilization, 25-254
  - Feed characteristics
    - aerobic digestion, 25-155
    - alkaline stabilization, 25-246
    - anaerobic digestion, 25-20
  - Feed equipment
    - alkaline stabilization, 25-260
    - conditioning, 22-41
    - thermal oxidation, 26-50
  - Feed piping, belt presses, 24-38
  - Feed pumps, belt presses, 24-38
  - Feed solids concentration, sidestream treatment, 17-12
  - Feed system
    - anaerobic digesters, 25-103
    - belt presses, 24-37
    - centrifuges, 24-25
    - chemical, 9-77
    - dry chemical, 9-78, 9-79
    - gas–chemical, 9-78
    - liquid–chemical, 9-78
    - recessed-plate filter presses, 24-46, 24-60
    - thermal oxidation, 26-50
  - Fermentation, 14-115
  - Ferrate disinfection, 19-179
  - Ferric chloride, inorganic chemicals, 22-42
  - Ferric salts, conditioning, 22-15
  - Field sampling, odors, 7-31
  - Field storage, biosolids land application, 27-19
  - Field testing, pumps, 6-53
  - Fill-and-draw mode, 11-83
  - Filter media, trickling filters, 13-194
  - Filter press plates, 24-55
  - Filter-cloths, 24-57
  - Filtration, 6-38
  - Filtration, materials of construction, 10-46
  - Fine screen headloss, 6-33, 11-35
  - Fine screens, 11-7, 11-16, 12-41
  - Fire protection, 8-20, 9-81
    - building classifications, 9-82
    - codes, thermal oxidation, 26-61
    - fire-suppression codes, 9-82
    - fire-suppression-systems overview, 9-83
    - gaseous, foam, and other systems, 9-84
    - jurisdiction and agency review, 9-83
    - practices, 8-7

- regulations/toxic and hazardous
  - chemicals, materials of construction, 10-28
- sprinkler systems, 9-84
- standpipe, fire-pump, and water-supply systems, 9-85
- thermal oxidation, 26-64
- First-regions, biofilm reactors, 13-25
- Fixed biofilm media, integrated biological treatment design, 15-12
- Fixed biofilm reactor stage, integrated biological treatment, 15-18
- Fixed-cover digesters, 25-97
- Fixed-film activated sludge systems, 15-40
  - biofilm flux rates, 15-40
  - biofilm rate model, 15-50
  - design example, 15-51
  - design tools/procedures, 15-48
  - disadvantages, 15-49
    - energy efficiency, 15-49
    - Nocardia foaming, 15-50
    - red worms, 15-50
    - storage of media, 15-50
  - empirical design methods, 15-48
  - heterotrophs and nitrifiers, 15-47
  - mixed liquor suspended solids and biofilm, 15-47
  - organics removal, 15-40
  - process kinetics design methods (process models), 15-50
    - flux rates based on location along aerobic zone, 15-51
    - quantify removal, 15-51
    - range of flux rates, 15-50
  - removals in biofilm per unit of tank volume, 15-44
  - removals in mixed liquor suspended solids, 15-46
  - upgrading a conventional activated sludge plant, 15-51
- Fixed-volume press, 24-51
- Flares, odor control, 7-155
- Flash dryer, 26-12
- Flat covers, odor containment, 7-70
- Flexible membrane covers, 25-125
- Floatable solids management, 12-49
- Floating aquatic plant systems, 18-40
- Floating digester covers, 25-126
- Floating-cover digesters, 25-98
- Flocculation system, screw presses, 24-104
- Flocculation, 6-38, 12-36
- Flood protection, 4-21, 6-7
- Floodplains, 4-23
- Flotation thickeners, 10-51
- Flow automatic control systems, 6-51
- Flow control valves, 6-25
- Flow distribution, 6-19
- Flow equalization, 6-34, 11-77
  - materials of construction, 10-38
  - sidestreams, 17-4
- Flow sheets, MBBRs, 13-44
- Flow spitting, 6-20
- Flow transients, 6-56
- Flowrates, 6-8
- Flue gas treatment, thermal processing, 26-83
- Fluid level automatic control systems, 6-51
- Fluid-bed furnace, materials of construction, 10-60
- Fluidized bed biofilm reactors (FBBRs), 13-109
- Fluidized bed incinerator, 26-30, 26-31
  - cold (warm) wind box, 26-33
  - hot wind box, 26-32
- Flumes, 6-28
- Foam control, anaerobic digesters, 25-114
- Food wastes, anaerobic digestion, 25-79
- Food-to-microorganism ratio, integrated biological treatment, 15-24
- Form cycle, 24-43
- Forward osmosis, 16-127, 16-128
- Frame, belt presses, 24-34
- Free flow conditions, 6-15
- Free water surface, wetlands, 18-43
- Freeboard, 6-9
- Freefall launders, 6-24
- Freeze-thaw, post-digestion solids, 25-69
- Froude number, 12-38
- Fuel cells, 25-143
- Fuel storage, safety, 8-18
- Fuel, 9-92
- Fully submerged disc filters, 16-57, 16-65, 16-66
- Function, biofilm, 13-8
- Funding, sustainability, 5-18
- Fungi, disinfection, 19-13

**G**

- Galler and Gotaas formula, 13-163
  - Gamma ray irradiation, Class A biosolids, 20-8
  - Gas
    - collection, storage, and distribution, materials of construction, 10-56
    - handling, anaerobic digestion, 25-123
    - management, landfills, 27-29
    - monitoring, safety, 8-18
    - processing, anaerobic digestion, 25-127
    - production, anaerobic digesters, 25-87
  - Gas-absorption scrubbers, odor control, 7-131
  - Gas-holder covers, 25-100
  - Gasification, 26-67
  - General fate models, air emissions, 7-50
  - Generation of volatile fatty acids, 12-57
  - Generators, digester gas use, 25-139
  - Geographic information systems, 4-12, 4-14
  - Geology, 4-23
  - Geosynthetics, properties and applications, 10-87
  - Germain formula, 13-167
  - Glass
    - aggregate, 27-44
    - properties and applications, 10-87
  - Goals, energy, 5-40
  - Granular media filtration, 16-17, 16-22, 16-71, 16-77, 16-90
  - Graphical procedure, 13-17
  - Gravel layers, drying beds, 24-76
  - Gravity belt thickeners, 10-51, 23-60, 23-61
    - ancillary equipment/controls, 23-68
    - belt washwater supply, 23-71
    - feed pumps and feed flow control, 23-69
    - odor control, 23-72
    - polymer system and feed control, 23-70
    - thickened-solids pumps, 23-71
  - belt washing, 23-68
  - conditioning, 22-38
  - design example, 23-72
  - discharge area, 23-67
  - drive, tracking, and tensioning, 23-68
  - evaluation and scale-up, 23-60
  - filtrate and wash Water Environment Federation 23-68
  - flocculation tank and feed distribution, 23-67
  - frame, 23-67
  - gravity drainage area, 23-67
  - process design, 23-62
  - process design, belt speed, 23-65
    - discharge, 23-66
    - flocculation, 23-64
    - mixing, 23-64
    - plow, 23-65
    - unit sizing, 23-63
  - solids polymer injection and mixer, 23-66
- Gravity drainage zone, belt presses, 24-33
  - Gravity thickeners, 10-51, 23-4
    - ancillary equipment/controls, 23-17
    - conditioning, 22-21
    - design example, 23-17
    - evaluation and scale-up procedures, 23-5
    - operational considerations, 23-16
      - feed solids source and characteristics, 23-16
      - polymer, 23-17
      - underflow withdrawal, 23-17
  - process design, 23-12
    - drive mechanisms, 23-14
    - inlet, 23-13
    - loading rate, 23-12
    - overflow rate, 23-12
    - pickets, 23-13
    - rectangular thickeners, 23-16
    - skimmers and scrapers, 23-14
    - underflow piping, 23-15
- Grease removal, 11-66
  - Green Globes, 5-8
  - Greenfields, 4-17
  - Greenhouse gases (GHGs)
    - adaptation, 5-23
    - digester gas, 25-148
    - estimating, 5-9
    - mitigation, 5-23
    - regulations, 5-25
    - thermal processing emissions, 26-76
  - Grinder pump, 21-30, 21-31
  - Grinding
    - anaerobic digestion, 25-66
    - materials of construction, 10-48
    - solids pretreatment, 20-39

- Grit
    - handling, 11-65
    - removal, 6-33, 11-50
      - anaerobic digestion, 25-65
      - materials of construction, 10-37
      - septage, 11-73
    - slurry, 11-50
    - solids, 11-51
  - Ground conditions, 4-32
  - Groundwater, 4-23
    - monitoring, monofills, 27-28
    - protection, dedicated land disposal, 27-34, 27-37
  - Grout, structural systems, 10-66
  - Growth screening test, compost, 27-48
  - Guidelines, life-cycle cost evaluations, 2-63
  - Gujer and Boller model, 13-182
- H**
- Handling of primary sludge, 12-49
  - Handling of scum, 12-54
  - Harmonics, 9-23
  - Hazard and operability design,
    - instrumentation and control systems, 9-49
  - Hazard and operability reviews, thermal oxidation, 26-65
  - Hazard assessment, heating, ventilating and air conditioning, 9-60
  - Hazard communication, 8-21
  - Hazard index, biosolids, 27-8
  - Hazardous air pollutants (HAPs), 7-25
  - Hazardous and toxic chemicals/fire-protection regulations, materials of construction, 10-28
  - Hazardous chemicals, 4-20
  - Hazardous materials, safety, 8-17
  - Hazardous substances, 2-48
  - Hazen-Williams equation, 6-16, 21-24, 21-27
  - Header pipe, 6-22
  - Headloss, 6-10, 6-16, 6-22, 6-27, 6-31
  - Headloss, UV disinfection, 19-123, 19-125
  - Health considerations
    - alkaline stabilization, 25-270
    - composting, 25-230
  - Health effects, air emissions, 7-30
  - Heat drying, 20-9
    - Heat drying, Class A biosolids, 20-8
    - Heat exchangers, anaerobic digesters, 25-110
    - Heat generation, alkaline stabilization, 25-238
    - Heat recovery and reuse, thermal oxidation, 26-66
    - Heat recovery, digester gas, 25-146
    - Heat treatment, Class A biosolids, 20-8
    - Heat-dried biosolids, 27-43, 27-49
  - Heating
    - equipment, anaerobic digestion, 25-122
    - systems, anaerobic digesters, 25-108
    - value, heat-dried biosolids, 27-53
  - Heating, ventilating, and air conditioning, 9-53
    - acoustics, 9-63
    - air distribution, 9-65
    - central, 9-66
    - climate, 9-55
    - climatic data sources, 9-55
    - codes, standards, and regulations, 9-53
    - cooling loads, 9-59
    - design constraints and selection criteria, 9-60
      - corrosion resistance, 9-60
      - costs, 9-61
      - hazard assessment, 9-60
      - system redundancy, 9-61
    - design criteria, 9-53
    - design parameters, 9-57
    - design-temperature frequency levels, 9-56
    - energy and sustainable-design initiatives, 9-62
    - energy and sustainable-design opportunities, 9-69
    - energy modeling, 9-70
    - evaporative, 9-67
    - heating loads, 9-59
    - hydronic, 9-64
    - indoor air quality, 9-69
    - LEED, 9-69
    - material selection, 10-68
      - air-handling units, 10-68
      - boilers, 10-69
      - duct work, 10-69
      - fans and blowers, 10-69
      - pipng, 10-69
      - terminal heating equipment, 10-69

## Design of Municipal Wastewater Treatment Plants

- renewable energy and energy-recovery systems, 9-71
- space environmental requirements, 9-56
- space requirements, 9-62
- temperature and building automation controls, 9-68
- testing, balancing, and commissioning, 9-69
- unitary, 9-66
- utilities, 9-58
- Heat-recovery systems, anaerobic digesters, 25-113
- Heat-transfer equipment, anaerobic digestion, 25-122
- High-performance, aerated ponds, 18-14
- High-pressure gas storage, 25-127
- High-pressure homogenization, anaerobic digestion, 25-62
- High-pressure membrane, 16-119, 16-121, 16-128
- High-purity oxygen aeration, aerobic digestion, 25-177
- High-rate anaerobic digestion, 25-31
- High-rate clarification, 12-37
- High-strength wastes, anaerobic digestion, 25-79
- Historical significance, site selection, 4-19
- Hollow-flight dryers, 26-15
- Human-machine interface systems, 9-43
- Hydration, conditioning, 22-7
- Hydraulic application, NTFs, 13-187
- Hydraulic considerations, 6-2
- Hydraulic considerations, screening, 11-31
- Hydraulic controls, 6-7
- Hydraulic detention time, 12-14
- Hydraulic effect of out-of-service processes, 6-8
- Hydraulic elements, 6-11, 6-19
- Hydraulic equations, 6-11
- Hydraulic loading rate
  - belt presses, 24-31
  - dissolved air flotation, 23-23
  - rapid-infiltration systems, 18-38
  - rotary presses, 24-91
  - screw presses, 24-106
  - slow-rate systems, 18-26
- Hydraulic loading, trickling filters, 13-150
- Hydraulic losses, 6-12
- Hydraulic modeling, 6-53
- Hydraulic profile design example, 6-57, 6-63
- Hydraulic profile, 6-2
- Hydraulic propelled distributors, 13-189
- Hydraulic residence time
  - anaerobic digestion, 25-20
  - integrated biological treatment, 15-24
- Hydraulic retention time, 16-111, 16-112
- Hydraulic washout, 6-8
- Hydraulics, trickling filters, 13-155
- Hydrodynamics, 13-10
- Hydrogen base, MBFRs, 13-207
- Hydrogen peroxide, odor control, 7-103
- Hydrogen sulfide, 12-58
  - digester gas, 25-133
  - materials of construction, 10-15
  - odor emissions, 7-41
- Hydrogeology, 4-23
- Hydrograph controlled release, facultative ponds, 18-11
- Hydrolysis, anaerobic digestion, 25-18
- Hygiene facilities, 8-19
- Hypochlorite solutions, disinfection, 19-79
- Hypochlorites
  - chlorination and dechlorination, 19-57
  - disinfection, 19-66

## I

- Impeller mixer, 16-105, 16-106, 16-109
- Implementation times, project, 2-32
- Incineration
  - 40 CFR requirements, 20-12
  - air emissions, 7-28
  - design example, 26-92
  - materials of construction, 10-58
    - fluid-bed furnace, 10-60
    - multiple-hearth furnace, 10-59
    - rabble arms and teeth, 10-59
    - refractory and insulation, 10-60
  - odor control, 7-153
  - safety, 8-16
- Inclined cylindrical screens, 11-21
- Induced vortex, 11-57
- Infiltration basins, 4-28
- Influent pumping, 6-5
- Influent wastewater characteristics, 12-10

- Inlet
  - baffling devices, 12-16
  - conditions, 12-15
  - pipe header, 6-22
- Inline flow equalization, 6-34
- Inorganic chemicals, 22-42
- Inorganic chemicals, conditioning, 22-13
- Input parameters, dewatering, 24-14
- Installations, FBBRs, 13-115
- Institution of Water and Environmental Management formula, 13-169
- Instrument Society of America, 9-34, 9-35
- Instrumentation and control systems, 9-29
  - bus technology, 9-39
    - DeviceNet, 9-40
    - fieldbus, 9-39
    - profibus, 9-39
  - construction, 9-29
  - control panels, 9-40
  - design standards, 9-29
  - diagrams, 9-30
    - process and instrumentation, 9-31
    - process-flow, 9-30, 9-32
    - three-dimensional/four-dimensional modeling, 9-31
  - field instruments, 9-31
    - instrumentation data sheets, 9-33, 9-34, 9-35
    - mounting detail, 9-37
    - networking considerations, 9-38
    - physical drawings, 9-36
  - hazard and operability design, 9-49
  - plant control systems, 9-44
  - precautions, 9-50
  - process control strategies, 9-50
  - process/plantwide-control systems, 9-45
  - project scope development, 9-30
  - redundancy, 9-51
  - retrofitting, 9-29
  - spare systems, 9-51
  - supervisory control and data acquisition systems, 9-43
    - control systems, 9-43
    - human-machine interface systems, 9-43
    - independent data-acquisition systems, 9-43
- Instrumentation
  - aerobic digestion, 25-167
  - dissolved air flotation, 23-36
  - equalization, 11-87
  - material selection, 10-71
    - field instruments, 10-72
    - panel-mounted devices, 10-72
    - panels/enclosures, 10-71
  - screening, 11-38
  - secondary clarification, 14-293
- Instruments, field, 9-31
  - instrumentation data sheets, 9-33, 9-34, 9-35
  - mounting detail, 9-37
  - networking considerations, 9-38
  - physical drawings, 9-36
- Insurance programs, safety, 8-28
- Insurance, thermal oxidation, 26-63
- Integrated biological treatment, 15-1
  - activated biofilter, 15-7
  - biofilter activated sludge, 15-9
  - design, 15-10
    - distribution, 15-11
    - energy, 15-15
    - existing treatment units, 15-16
    - final effluent quality, 15-15
    - fixed biofilm media, 15-12
    - odor, 15-12
    - primary treatment, 15-10
    - secondary clarification, 15-14
    - site considerations, 15-15
    - sloughing, 15-11
    - snails, 15-14
    - solids production, 15-10
    - solids recycle, 15-11
    - temperature, 15-14
  - integrated fixed-film activated sludge, 15-10
  - process design, 15-16
    - biochemical oxygen demand and total suspended solids removal, 15-28
    - criteria, 15-16
    - fixed biofilm reactor stage, 15-18
    - food-to-microorganism ratio, 15-24
    - hydraulic residence time, 15-24
    - mixing and aeration requirements, 15-25
    - nitrogen removal, 15-29
    - phosphorus removal, 15-33
    - solids production and settleability, 15-26
    - solids retention time, 15-21

- suspended growth biological reactor stage, 15-20
  - roughing filter activated sludge, 15-7
  - specific process design, 15-34
    - design example, 15-39
    - roughing-filter activated sludge, 15-37
    - trickling filter activated sludge, 15-38
    - trickling filter/solids contact, 15-34
    - trickling filter activated sludge, 15-9
    - trickling filter/solids contact, 15-5
  - Integrated fixed-film activated sludge process, 15-10, 15-40
    - biofilm flux rates, 15-40
    - biofilm rate model, 15-50
    - design example, 15-51
    - design tools/procedures, 15-48
    - disadvantages, 15-49
      - energy efficiency, 15-49
      - Nocardia foaming, 15-50
      - red worms, 15-50
      - storage of media, 15-50
    - empirical design methods, 15-48
    - heterotrophs and nitrifiers, 15-47
    - mixed liquor suspended solids and biofilm, 15-47
    - organics removal, 15-40
    - process kinetics design methods (process models), 15-50
      - flux rates based on location along aerobic zone, 15-51
      - quantify removal, 15-51
      - range of flux rates, 15-50
    - removals in mixed liquor suspended solids per unit of tank volume, 15-40
    - removals in mixed liquor suspended solids, 15-46
    - upgrading a conventional activated sludge plant, 15-51
  - Intensity, odor concentration, 7-8
  - Internal circulation reactor, 13-213
  - International regulations, reuse, 2-18
  - International wastewater discharge, standards, 2-11
  - Inversion, organic polymers, 22-51
  - In-vessel composting, 25-206
  - Investigative results, interpretation, 3-18
  - Iron salts, odor control, 7-108
  - Iron sponges, odor control, 7-151
- J**
- Johannesburg process, 14-109
  - Joint ownership approach, energy management, 5-21
  - Junctions, 6-27
- K**
- Kincannon and Stover model, 13-165
  - Kinetic pump, 21-7, 21-14, 21-15, 21-28
  - Kinetics
    - anaerobic digestion, 25-17
    - secondary solids production, 20-18
    - trickling filters, 13-180
  - Kirschmer's equation, 11-35
  - Kyoto Protocol, 5-9
- L**
- Labor requirements, thermal drying, 26-21
  - Laboratory safety, 8-16
  - Laboratory facilities, 4-34
  - Lagoon digestion, 25-60
  - Lagoons, 24-66, 24-86
  - Lamella velocity, 12-38
  - Laminar flow, 21-16, 21-21, 21-23, 21-24, 21-26
  - Land acquisition and ownership, 4-25
  - Land application, 27-4
  - Land area, biosolids land application, 27-19
  - Land disposal, 27-32
  - Land reclamation, biosolids, 27-21
  - Land requirements
    - overland flow systems, 18-33
    - slow-rate systems, 18-28
    - wetlands, 18-47
  - Land treatment, 18-19
  - Land use, 4-17
  - Landfill gas, 27-29
  - Landfilling, 27-22
  - Landscaping, 3-10, 4-39
  - Launder spacing, 12-24
  - Launders, 6-24
  - Layout considerations, 4-35
  - Layout, anaerobic digestion equipment, 25-120
  - Leachate
    - composting, 25-218
    - monofills, 27-26

- Leadership in Energy and Environmental Design (LEED), 2-4, 4-25, 4-40, 5-7, 9-69
  - Liability, hazardous substances, 2-55
  - Life-cycle product assessment, 5-9
  - Lighting systems, 9-19
    - emergency, 9-21
    - indoor, 9-19, 9-20
    - outdoor, 9-21
  - Lightning and surge protection, electrical systems, 9-27
  - Lime, 25-248
    - alkaline stabilization, 25-277
    - conditioning, 22-14
    - feed system, inorganic chemicals, 22-44
    - inorganic chemicals, 22-43
    - loading rates, biosolids land application, 27-14
    - silos, inorganic chemicals, 22-43
    - stabilization, 25-231
    - stabilization, Class A biosolids, 20-8
  - Linear flow-through velocity, 12-26
  - Linear layout, 4-30
  - Liners, monofill, 27-26
  - Liquid lime handling/mixing, alkaline stabilization, 25-262
  - Liquid lime stabilization, 25-238
  - Liquid polymer feeders, organic polymers, 22-48
  - Liquid stream, 24-5
  - Liquid train treatment, 1-9
  - Liquid wastes, anaerobic digestion, 25-79
  - Liquid-phase treatment, odor control, 7-100
  - Loading cycles, rapid-infiltration systems, 18-39
  - Loading rate
    - anaerobic digesters, 25-86
    - dewatering, 24-16
  - Loading variability, 3-22
  - Local policies, 4-11
  - Local regulations, air emissions, 7-26
  - Location, screening, 11-31
  - Logan trickling filter model, 13-170
  - Low-pressure gas storage, 25-125
  - Low-pressure membrane, 16-119, 16-120, 16-128, 16-129
  - Low-profile scrubbers, odor control, 7-144
  - Low-rate anaerobic digestion, 25-30
  - Ludzack–Ettinger process, 14-91
- ## M
- Maintenance
    - aeration systems, 14-204
    - considerations, 4-33
    - disinfection reactors, 19-47
    - facilities, 4-33
    - heating, ventilating, and air conditioning costs, 9-61
    - materials of construction, 10-101
    - provisions, clarifiers, 12-27
    - shops, safety, 8-16
  - Management
    - biosolids practices, 20-10
    - dedicated land disposal, 27-34
    - odor emissions, 7-52
  - Mandatory regulatory constraints, 4-13
  - Mannich polymers, organic polymers, 22-28
  - Manning equation, 6-16
  - Manning roughness coefficient, 6-27
  - Marketing, biosolids products, 27-42, 27-54
  - Masonry, properties and applications, 10-77
  - Mass and energy balance, thermal oxidation, 26-47, 26-48
  - Mass balances, 3-29, 6-8, 20-24
  - Mass transfer, odorous compounds, 7-46
  - Material
    - balance, composting, 25-212
    - certification, 5-10
    - delivery, 4-37
    - disposal, 4-37
    - handling, 4-37
    - handling, composting, 25-216
    - handling/storage, safety, 8-16
    - selection
      - chemical-feed and chemical-distribution facilities, 10-73
      - electrical systems, 10-70
        - conduits and enclosures, 10-70
        - signal cables, 10-71
      - heating, ventilating, and air-conditioning systems, 10-68
        - air-handling units, 10-68
        - boilers, 10-69

- ductwork, 10-69
- fans and blowers, 10-69
- pipng, 10-69
- terminal heating equipment, 10-69
- instrumentation, 10-71
  - field instruments, 10-72
  - panel-mounted devices, 10-72
  - panels/enclosures, 10-71
- odor-control facilities, 10-72
- structural systems, 10-65
  - concrete, 10-65
  - fiber-reinforced concrete, 10-66
  - grout, 10-66
  - miscellaneous metal materials, 10-67
  - reinforcing steel, 10-66
- Materials of construction, 10-1
  - anaerobic digestion, 25-121
  - cathodic protection, 10-36, 10-94
    - galvanic anodes, 10-95
    - impressed-current systems, 10-97
  - construction testing and equipment
    - identification, 10-101
  - design of unit processes, 10-37
    - advanced treatment, 10-45
      - adsorption, 10-47
      - air stripping, 10-47
      - coagulation, 10-45
      - filtration, 10-46
      - sedimentation, 10-46
    - attached-growth biological treatment, 10-41
      - rotating biological contactors, 10-42
      - trickling filters, 10-41
    - disinfection and dechlorination, 10-43
      - chlorine, 10-43
      - ozone, 10-44
      - sodium metabisulfite, 10-44
      - sulfur dioxide, 10-44
    - effluent discharge, 10-60
      - building-reuse systems, 10-64
      - freshwater outfalls, 10-62
      - land sprinkling systems, 10-64
      - marine outfalls, 10-62
      - pipng, 10-61
      - pumps, 10-60
      - storage tanks, 10-63
    - gas collection, storage, and distribution, 10-56
    - natural systems, 10-43
      - constructed wetlands, 10-43
      - wastewater ponds, 10-43
    - preliminary treatment, 10-37
      - flow equalization, 10-38
      - grit removal, 10-38
      - screens, 10-37
    - primary treatment, 10-39
      - dissolved air flotation, 10-40
      - settling tanks, 10-39
    - solids conveyance, 10-51
    - solids dewatering, 10-52
      - belt filter presses, 10-52
      - centrifuges, 10-53
      - plate and frame presses, 10-53
    - solids handling and treatment, 10-47
    - solids processing, 10-48
      - degritting, 10-49
      - grinders, 10-48
      - screening, 10-50
    - solids pumping, 10-50
      - centrifugal pumps, 10-50
      - piston pumps, 10-50
    - solids stabilization, 10-53
      - aerobic digesters, 10-53
      - anaerobic digesters, 10-54
      - digester tanks, 10-55
      - gas-mixing systems, 10-55
      - mesophilic digestion, 10-54
      - mixing systems, 10-55
      - thermophilic aerobic digesters, 10-54
      - thermophilic digestion, 10-55
    - solids thickening, 10-51
      - flotation thickeners, 10-51
      - gravity belt thickeners, 10-51
      - gravity thickeners, 10-51
    - storage, 10-48
    - suspended-growth biological treatment, 10-40
    - thermal destruction, 10-58
      - fluid-bed furnace, 10-60
      - multiple-hearth furnace, 10-59
      - rabble arms and teeth, 10-59
      - refractory and insulation, 10-60
    - thermal processing, 10-56
      - thermal conditioning and wet-air oxidation, 10-56
      - thermal drying, 10-57

- design standards and review, 10-98
- design, 10-23
- dissolved air flotation, 23-30
- fire-protection regulations/toxic and hazardous chemicals, 10-28
- maintenance procedures, 10-101
- odor containment, 7-82
- plant exposures, 10-7
  - anaerobic conditions, 10-17
  - anoxic conditions, 10-17
  - carbon dioxide, 10-16
  - chemical environments, 10-11
  - coastal conditions, 10-17
  - hydrogen sulfide, 10-15
  - interior dry atmosphere, 10-14
  - marine conditions, 10-16
  - moist atmosphere, 10-12
  - outside atmosphere, 10-13
  - soil, 10-17
  - splash zone continuous or intermittent submerged exposure, 10-11
  - submerged and immersion conditions, 10-9
  - submergence in aerated or chlorinated wastewater, 10-11
  - submergence in raw or unaerated wastewater, 10-10
- properties and applications, 10-73
  - concrete, 10-75
  - geosynthetics, 10-87
  - glass, 10-87
  - masonry, 10-77
    - brick masonry, 10-77
    - concrete unit masonry, 10-77
  - metals, 10-77
    - aluminum, 10-78
    - aluminum oxide, 10-78
    - brass, 10-79
    - cadmium, 10-79
    - carbon steel, 10-79
    - cast iron, 10-80
    - chromium, 10-80
    - copper, 10-80
    - copper-nickel alloys, 10-81
    - ductile iron, 10-81
    - gold, 10-81
    - Hastelloy C (Haynes International), 10-82
    - Inconel 625 (Special Metals Corporation), 10-82
    - lead, 10-82
    - nickel alloys, 10-81
    - Ni-Hard, 10-82
    - platinum, 10-82
    - silver, 10-82
    - stainless steel, 10-82
    - stellite, 10-84
    - tantalum, 10-83
    - titanium, 10-83
    - tungsten carbide, 10-84
    - zinc, 10-84
  - plastics, 10-84
    - carbon black, 10-86
    - chlorinated polyvinyl chloride, 10-85
    - fiberglass-reinforced plastic, 10-86
    - polyethylene, 10-85
    - polypropylene, 10-85
    - polytetrafluoroethylene, 10-85
    - polyurethane, 10-85
    - polyvinyl chloride, 10-85
    - polyvinylidene fluoride, 10-86
  - pre-stressed concrete, 10-77
  - rubbers and elastomers, 10-86
    - Buna-N (nitrile butadiene), 10-86
    - ethylene propylene diene monomer, 10-87
    - Hypalon (chlorosulphonated polyethylene), 10-87
    - natural rubber, 10-87
    - neoprene (chloroprene), 10-87
  - wood, 10-88
- protective coatings, 10-36, 10-88, 10-90
  - selection, 10-89
  - surface preparation, 10-89, 10-91
    - atmospheric conditions and temperatures, 10-92
    - safety precautions, 10-92
    - thermosetting coatings, 10-88
    - use of paint for identification, 10-92
  - selection, 10-24
  - thermal drying, 26-23
  - thermal oxidation, 26-59
- Materials/equipment selection, sustainability, 5-11
- Mathematical models, biofilm, 13-23
- Maturation, composting, 25-202

- Mechanical mixers, MBBRs, 13-44
- Mechanical seals, 6-49
- Mechanical vortex, 11-55
- Media retention sieves, 13-42
- Media
  - BAFs, 13-87
  - FBBRs, 13-120
  - RBCs, 13-139
- Membrane biofilm reactors (MBfRs), 13-206
- Membrane bioreactors, 6-37, 16-128, 16-144
- Membrane bioreactors, suspended-growth
  - biological treatment, 14-142
- Membrane disinfection, 19-181
- Membrane gas-holder covers, 25-100
- Membrane separation, 16-120, 16-121, 16-124, 16-125, 16-144
- Membrane systems, 13-7
- Membrane systems, disinfection, 19-62
- Membranes, suspended-growth biological
  - treatment, 14-36
- Mercury, thermal processing, 26-84
- Mesh, screening media, 11-10
- Mesophilic aerobic digestion, 25-169
- Mesophilic digestion, 10-54, 25-32
- Metals loading rates, biosolids land
  - application, 27-13
- Metals
  - biosolids concentration, 27-8
  - properties and applications, 10-77
- Metering system, digester gas, 25-130
- Meters, 6-28
- Methanogenesis, anaerobic digestion, 25-18
- Microbial ecology, anaerobic digestion, 25-19
- Microbiology
  - anaerobic digestion, 25-16
  - composting, 25-199
  - suspended-growth biological treatment, 14-127
- Microconstituents, 1-4
- Microconstituents, reclaimed water, 2-19
- Microfiltration, 16-119, 16-120, 16-124, 16-126, 16-128, 16-129, 16-130, 16-134, 16-135, 16-137, 16-144, 16-146
- Microscreens, 11-23
- Minimum freeboard requirements, 6-9
- Minimum wet-well volume, 6-47
- Minor loss, 6-18
- Mitigation options, 4-21
- Mixing and aeration requirements, integrated
  - biological treatment, 15-25
- Mixing, 6-38
  - aerobic digestion, 25-157
  - alkaline stabilization, 25-264
  - chemicals, 9-77, 9-80
  - composting, 25-216
  - conditioning, 22-10
  - conditions, 4-33
  - equalization, 11-85
  - equipment
    - aerobic digestion, 25-164
    - anaerobic digestion, 25-121
  - nutrient control, 14-122
  - oxygen transfer, 14-196
  - requirements, alkaline stabilization, 25-278
  - systems
    - anaerobic digesters, 25-103
    - stabilization, 10-55
- Model calibration, 6-55
- Modeling
  - air emissions, 7-50
  - biofilm rate model, 15-50
  - disinfection, 19-28, 19-49, 19-107
  - energy management, 5-33
  - energy, heating, ventilating, and air
    - conditioning, 9-70
  - instrumentation and control systems
    - diagrams, 9-31
  - integrated design, 3-4
  - integrated fixed-film activated sludge
    - systems, 15-50
    - flux rates based on location along
      - aerobic zone, 15-51
      - quantify removal, 15-51
      - range of flux rates, 15-50
  - odor/air emission dispersion, 7-57, 7-64
  - ozone disinfection, 19-171
  - UV disinfection, 19-138
- Modular biofilters, odor control, 7-127
- Moisture content, compost, 27-48
- Moisture removal, digester gas, 25-127
- Molecular weight, organic polymers, 22-26
- Monitoring
  - alkaline stabilization, 25-270
  - anaerobic digesters, 25-117
  - biosolids, 20-11
  - digester gas pressure, 25-130

- Monod curve, solids production, 20-19
  - Monod kinetic model, RBCs, 13-137
  - Monofills, 27-22
  - Moody Diagram, 6-17
  - MotorMaster+ tool, 5-34
  - Moving bed biofilm reactors (MBBRs), 13-36
  - Moving bed bioreactors, 6-37
  - Multiple-hearth furnace, 26-34
  - Multiple-hearth furnace, materials of construction, 10-59
  - Multiple-rake screens, 11-16
  - Multiple-stage scrubbers, odor control, 7-144
  - Multirake screens, 11-12
  - Multitray vortex, 11-58
- N**
- Nanocomposite membrane, 16-126, 16-127
  - Nanofiltration, 16-119, 16-121, 16-124, 16-125, 16-129, 16-130, 16-131, 16-136
  - National Ambient Air Quality Standards (NAAQS), 7-19
  - National Biosolids Partnership (NBP), EMS, 5-11
  - National Emission Standards for Hazardous Air Pollutants (NESHAP), 7-25
  - National Fire Protection Association, 26-62
  - National Research Council formula, 13-161
  - Natural draft, trickling filters, 13-158
  - Natural resources, 4-18
  - Natural systems, 18-3
  - Natural systems, materials of construction, 10-43
  - Net environmental benefit, 5-16
  - Net liquid volume displacement, 13-38
  - Net positive suction head, 6-48
  - Net specific surface area, 13-38
  - Neutralization, 16-85, 16-97, 16-98, 16-99, 16-103, 16-104
  - New source performance standards, 7-25
  - Nitrate
    - addition, odor control, 7-105
    - contamination, surface disposal, 27-33
  - Nitrification, 14-36, 14-41
    - BAFs, 13-94,
    - FBBRs, 13-128
    - MBBRs, 13-49
    - RBCs, 13-139
  - Nitrifying trickling filters (NTFs), 13-178
  - Nitritation and denitritation, 14-99
  - Nitritation, sidestream treatment, 17-15
  - Nitrogen compounds, odor emissions, 7-43
  - Nitrogen loading rate, slow-rate systems, 18-27
  - Nitrogen oxides
    - emissions control, 7-161
    - removal, 14-76
      - aerobic digestion, 25-187
      - integrated biological treatment, 15-29
      - overland flow systems, 18-33
      - rapid-infiltration systems, 18-36
    - removal rate, FBBRs, 13-133
    - thermal processing, 26-71, 26-82
  - Nocardia foaming, integrated fixed-film activated sludge systems, 15-50
  - Noise
    - abatement, 4-41
    - control, 8-20
    - effects, 4-20
    - mitigation, 3-10, 4-20
  - Nonagricultural uses, biosolids land application, 27-21
  - Non-attainment new source review, 7-25
  - Non-bioaugmentation, sidestream treatment, 17-21
  - Nonresidential sources, septage, 11-70
  - Non-settleable total suspended solids, 12-10
  - NPDES, 2-9
  - Nutrient content, heat-dried biosolids, 27-51
  - Nutrient control (see also suspended-growth biological treatment), 14-55
  - Nutrient loading rates, biosolids land application, 27-13
  - Nutrient management
    - land application, 27-5
    - sidestreams, 17-3
  - Nutrient removal, 14-111
  - Nutrient removal, sidestreams, 17-4
  - Nutrient trading, 2-11
  - Nutrients, biosolids concentration, 27-9
  - N-Viro process, 25-243
- O**
- Objectives
    - design, 2-4
    - water quality, 2-8
  - Occupational Safety and Health Act, 8-5

## Design of Municipal Wastewater Treatment Plants

- Ocean discharge, 6-7
- Ocean disposal, 20-12
- Odor
  - control, 4-30, 4-42, 21-11, 21-12, 21-13, 21-42, 21-65, 21-82
    - alkaline stabilization, 25-271
    - clarifiers, 12-29
    - composting, 25-223
    - dewatering, 24-12
    - facilities, material selection, 10-72
    - gravity belt thickeners, 23-72
    - safety, 8-15
    - thermal drying, 26-22
  - heat-dried biosolids, 27-50
  - integrated biological treatment, 15-12
  - intensity, 7-14
  - management, biosolids land application, 27-19
  - mitigation, 3-10
  - reduction, alkaline stabilization, 25-274
  - sampling plans, 7-38
  - thermal processing, 26-68
- Odorants
  - industrial sources, 7-45
  - production, post-digestion solids, 25-68
  - wastewater sources, 7-41
- Offline flow equalization, 6-35
- One-dimensional biofilm, 13-25
- Online instrumentation, sidestream treatment, 17-14
- Open-channel flow, 6-16
- Open-source models, 6-55
- Open-weave media, 24-58
- Operability, 3-11
- Operating costs, 4-27
- Operating pressure, recessed-plate filter presses, 24-46
- Operational control, rotary presses, 24-92
- Operations
  - aerobic digestion, 25-184
  - gravity thickeners, 23-16
  - gravity thickeners
    - feed solids source and characteristics, 23-16
  - polymer, 23-17
  - underflow withdrawal, 23-17
  - heating, ventilating, and air conditioning costs, 9-61
  - safety and thermal drying, 26-24
  - sustainability, 5-12
  - thermal oxidation schedule and redundancy, 26-48
- Organic loading rate
  - anaerobic digestion, 25-21
  - rapid-infiltration systems, 18-39
- Organic matter content, compost, 27-48
- Organic polymers, 22-24
- Organic-sulfur compounds, odor emissions, 7-42
- Orifice equation, 6-23, 6-30
- Orifice headloss equation, 11-36
- Orifice loss, 6-12
- Outfalls, 6-29
  - freshwater, 10-62
  - marine, 10-62
- Outlet conditions, 12-16
- Overland flow systems, 18-29
- Overtopping, 6-9
- Oxidation ditch reactors, 14-16
- Oxidation
  - odor control, 7-153
  - thermal, 26-25
- Oxygen based, MBfRs, 13-209
- Oxygen requirements
  - thermal oxidation, 26-27
  - trickling filters, 13-157
- Oxygen transfer rate, 14-201
  - aerobic digestion, 25-157
  - suspended-growth biological treatment, 14-169
- Ozonation, 6-37
- Ozone disinfection, 19-23, 19-166
  - analytical methods for ozone measurement, 19-169
  - disinfection and dechlorination, 10-44
  - environmental effects, 19-175
  - modeling, 19-171
  - process design, 19-172
    - ozone contactors, 19-173
    - ozone demand and absorption, 19-174
    - ozone exhaust destruction, 19-175
    - ozone generators, 19-172
  - reaction kinetics, 19-169
  - safety and health, 19-175
  - shipment and handling safety, 19-176
- Ozone, odor control, 7-105

**P**

- P Index, biosolids land application, 27-5
- Packed-bed wet scrubbers, odor control, 7-132
- Packing, 6-49
- Paddle and hollow-flight dryers, 26-15
- Paints, identification of type of service, 10-93
- Pancake digesters, 25-95
- Parallel-flow type sedimentation tank, 12-8
- Parking, 4-38, 4-41
- Parshall flume, 6-28
- Part 503 Code of Federal Regulations, 20-4
- Partially submerged disc filter, 16-63, 16-64, 16-65
- Partial-mix, aerated ponds, 18-12
- Particle size
  - biosolids, 27-7
  - compost, 27-48
  - heat-dried biosolids, 27-49
- Particle surface charge, conditioning, 22-7
- Particulate removal, 7-159
- Partitions, drying beds, 24-77
- Pasteurization, 19-180, 25-241
- Pasteurization, Class A biosolids, 20-8
- Pathogens
  - anaerobic digestion, 25-30
  - biosolids concentration, 27-7
  - disinfection, 19-8, 19-9, 19-10, 19-12, 19-13, 19-15
  - limits, biosolids, 20-6
  - reduction
    - aerobic digestion, 25-186
    - composting, 25-201
    - surface disposal, 27-34
    - treatment, biosolids, 20-9,
- Paved drying beds, 24-83
- Peaking factors, 3-24
- Pelletizing processes, 20-9
- Peracetic acid disinfection, 19-23, 19-177
- Perforated plate, screening media, 11-9
- Performance
  - facultative ponds, 18-9
  - FBBRs, 13-133
  - grit removal, 11-66
  - odor control, 7-7
  - screening, 11-38
  - specifications, 2-35
- Peripheral pumps, 6-40
- Peristaltic hose pump, 21-36
- Permit application, air emissions, 7-24
- Permit requirements, 4-26
- Persistence, odor concentration, 7-8
- Personal protection equipment, 8-19
- pH
  - adjustment, odor control, 7-111
  - alkaline stabilization, 25-248
  - anaerobic digestion, 25-26, 25-118
  - compost, 27-47
  - elevation, alkaline stabilization, 25-237
  - suspended-growth biological treatment, 14-46
- Phases of site evaluation, 4-12
- Phosphorus and nitrogen removal, 14-99
- Phosphorus
  - index, biosolids land application, 27-14
  - limitations, MBBRs, 13-64
  - precipitation, 16-85, 16-86, 16-90, 16-91, 16-92, 16-93, 16-96, 16-97, 16-114
  - reduction, aerobic digestion, 25-188
  - removal, 16-86, 16-87, 16-88, 16-89, 16-90, 16-92, 16-93, 16-95, 16-103, 16-150
  - BAFs, 13-104
  - integrated biological treatment, 15-33
  - rapid-infiltration systems, 18-37
  - sidestream treatment, 17-26
- PhoStrip process, 14-59
- PhoStripII™ process, 14-110
- Physical characteristics, biosolids, 27-7
- Physical models, 6-56
- Physical treatment, odor control, 7-131
- Pilot testing
  - alkaline stabilization, 25-258
  - equipment design, 3-21
  - FBBRs, 13-126
- Piping
  - aerobic digestion, 25-166
  - anaerobic digesters, 25-116, 25-121
  - digester gas, 25-123
  - dissolved air flotation, 23-36
  - effluent discharge, 10-61
  - safety, 8-13
- Piston pumps, 10-50
- Pitched covers, odor containment, 7-71
- Planning, dedicated land disposal, 27-34
- Plant arrangement, 4-29
- Plant expansion, 4-31

- Plant headloss guidelines, 6-10
- Plant siting process, 4-4
- Plastic carriers
  - biofilm, 13-38
  - MBBRs, 13-66
- Plastics, properties and applications, 10-84
- Plate and frame presses, 10-53
- Plate and tube clarifiers, 12-9
- Plate pressurization, 24-62
- Plate settlers, 12-37
- Plate shifters, 24-59
- Plug flow reactor, 14-15
  - anaerobic digestion, 25-67
  - composting, 25-206
- Plumbing, 9-88
  - design, 9-88, 9-89
  - sanitary systems, 9-90
  - storm drainage, 9-91
  - water-supply systems, 9-89
- Plunger pump, 21-15, 21-30, 21-31, 21-32
- Pneumatic conveyor, 21-80, 21-81, 21-82
- Pneumatic ejector, 21-36
- Pneumatic pumps, 6-40
- Point sources, odors/air emissions, 7-58
- Pollutant limits
  - biosolids, 20-5
  - monofills, 27-25
  - surface disposal, 27-33
- Pollutant loading
  - air emissions, 7-6
  - trickling filters, 13-150
- Polycyclic organic matter, thermal
  - processing, 26-71
- Polymer addition manifold, 24-20
- Polymer addition, dissolved air flotation, 23-16
- Polymer feed rate, rotary drum thickeners, 23-75
- Polymer system and feed control, gravity belt thickeners, 23-70
- Polymer, gravity thickening, 23-17
- Polymer-assisted filter bed, 24-81
- Pond systems, 18-7
- Pond treatment system die-off, 19-180
- Ponds, materials of construction, 10-43
- Pool depth, centrifuges, 24-23
- Positive-displacement pump, 21-7, 21-8, 21-14, 21-15, 21-17, 21-18, 21-29, 21-30, 21-43, 21-51
- Post-aeration, 6-37
- Post-closure use, landfills, 27-31
- Post-digestion processing, solids, 25-68
- Post-lime stabilization, 25-239
- Potassium permanganate, odor control, 7-104
- Power
  - considerations, standby, 9-22
  - failure and load transfer, 9-25
  - output, 6-43
  - requirements, 6-43
  - source reliability, 9-7
  - supply capacity and redundancy, 9-12
  - supply, UV disinfection, 19-148, 19-149
  - ventilation, trickling filters, 13-159
- Preaeration, 12-30
- Preapplication treatment, 18-21
- Precoat system, 24-60
- Prefabricated biofilters, odor control, 7-127
- Pre-lime stabilization, 25-238
- Preliminary treatment, 11-3
  - BAFs, 13-105
  - materials of construction, 10-37
    - flow equalization, 10-38
    - grit removal, 10-38
    - screens, 10-37
  - MBBRs, 13-66
- Pre-pasteurization, anaerobic digestion, 25-46
- Prescriptive, specifications, 2-35
- Present value methodology, 2-63
- Preservation of available carbon, 12-58
- Press enclosures, belt presses, 24-36
- Pressate, screw presses, 24-110
- Pressure automatic control systems, 6-51
- Pressure boosters, digester gas, 25-128
- Pressure control valves, 6-25
- Pressure filter/vacuum dryer, 26-16
- Pressure flow, 6-16
- Pressure swing adsorption, 25-137
- Pressure zones, belt presses, 24-33
- Pressure, digester gas, 25-124
- Prethickening, aerobic digestion, 25-178
- Pretreatment
  - anaerobic digestion, 25-64
  - dewatering, 24-10
  - membrane bioreactors, 14-153
  - septage, 11-68
  - solids, 20-39

- Prevention of significant deterioration (PSD), 7-25
- Primary sedimentation, 6-35
- Primary sludge
  - collection and removal, 12-42
  - degritting, 11-59
  - production, 12-45
- Primary solids
  - characteristics, 20-37
  - production, 20-15
- Primary treatment
  - BAFs, 13-105
  - equalization, 11-78
  - integrated biological treatment, 15-10
  - materials of construction, 10-39
    - dissolved air flotation, 10-40
    - settling tanks, 10-39
  - MBBRs, 13-66
- Primary–secondary digestion, 25-34
- Privatization, energy management, 5-21
- Procedures, plant design, 2-28
- Process aeration, BAFs, 13-106
- Process and instrumentation diagrams, 9-31
- Process comparisons, composting, 25-207
- Process control
  - alkaline stabilization, 25-270
  - data, 3-17
  - instrumentation and control systems, 9-50
  - thermal oxidation, 26-60
- Process design, 4-32
  - energy management, 5-35
  - FBBRs, 13-116
- Process equipment, safety, 8-12
- Process flow, trickling filters, 13-151
- Process rates, anaerobic digestion, 25-17
- Process stability, anaerobic digestion, 25-22
- Processes that significantly reduce pathogens, 20-9
- Processes to further reduce pathogens, 20-8
- Processes, biofilm, 13-8
- Processing, grit slurry, 11-60
- Procurement, 2-33
  - alkaline stabilization, 25-275
  - sustainability plan, 5-42
- Product use, alkaline stabilization, 25-291
- Programmable logic controller systems, 9-44
- Progressing cavity pump, 21-8, 21-32, 21-33, 21-34, 21-36, 21-41, 21-43, 21-48, 21-49, 21-52, 21-53
- Propeller mixer, 16-105, 16-106, 16-108, 16-109, 16-112, 16-113
- Properties, septage, 11-71
- Proportional weirs, 6-13
- Protection of beneficial uses, 2-4
- Protective coatings, 10-88, 10-90
  - selection, 10-89
  - surface preparation, 10-89, 10-91
    - atmospheric conditions and temperatures, 10-92
    - safety precautions, 10-92
  - thermosetting coatings, 10-88
  - use of paint for identification and safety, 10-82
- Protozoa, disinfection, 19-13
- Public acceptance, biosolids land application, 27-12, 27-21
- Public access, 4-40
- Public communication, air emissions, 7-28
- Public education, 4-27
- Public education, sustainability, 5-45
- Public involvement, 4-16, 4-26
- Public opposition to site selection, 4-16
- Pulsed electric field, anaerobic digestion, 25-62
- Pumping, 6-39
  - actuation, 6-50
  - anaerobic digestion, 25-117, 25-121
  - applications, 6-45
  - centrifugal pumps, 10-50
  - centrifuges, 23-55
  - conditioning, 22-10
  - construction, 6-48
  - control systems, 6-50
  - curve, 6-41
  - cycle time, 6-47
  - dissolved air flotation, 23-37
  - effluent discharge, 10-60
  - gravity belt thickeners, 23-69, 23-71
  - materials of construction, 6-48, 10-50
  - operation, 6-41
  - piston pumps, 10-50
  - seals, 6-49
  - types, 6-45

Pumping stations  
 configuration, 6-45  
 trickling filters, 13-149  
 Pumping System Assessment Tool (PSAT),  
 5-34  
 Pump-monitoring guidelines, 6-52

## Q

Qualitative site selection, 4-16  
 Quality, biosolids-derived products, 27-46  
 Quantitative site selection, 4-16  
 Quantities of primary sludge, 12-46  
 Quantity, screening, 11-5

## R

Rabble arms and teeth, materials of  
 construction, 10-59  
 Railroad spur, 4-24  
 Rakes and skimmers, dissolved air flotation,  
 23-32  
 Rapid fill, 24-61  
 Rapid mixing, 12-34, 16-105, 16-108, 16-109,  
 16-110, 16-111, 16-112  
 Rapid-infiltration systems, 18-35  
 Rate-limiting substrate, 13-29  
 Reagents, alkaline, 25-248  
 Receiving station design, 11-72  
 Recessed plat filter press, conditioning, 22-22  
 Recessed-impeller pump, 21-14, 21-29, 21-38  
 Recessed-plate filter presses, 24-41  
 Reciprocating piston pump, 21-8, 21-37, 21-43,  
 21-48, 21-49, 21-52, 21-53, 21-54,  
 21-55, 21-56, 21-57  
 Reciprocating rake screen, 11-13  
 Recirculation, FBBRs, 13-117  
 Reclaimed water  
 chlorination, 19-90  
 disinfection, 19-33  
 UV disinfection, 19-163  
 Recognition threshold  
 odor concentration, 7-7  
 odorant, 7-11  
 Recordkeeping, biosolids, 20-11  
 Recreational water, waterborne disease  
 outbreaks, 19-17  
 Rectangular clarifiers, 12-5, 14-231

Rectangular weirs, 6-13  
 Recuperative thermal oxidizers, 7-156  
 Recuperative thickening, 25-35  
 Recycle streams, 24-12  
 Redevelopment, 4-18  
 Reduced voltage starters, 6-51  
 Redundancy  
 heating, ventilating, and air conditioning,  
 9-61  
 instrumentation and control systems, 9-51  
 power supply, 9-12  
 secondary clarifiers, 14-227  
 thermal oxidation operations, 26-48  
 treatment unit, 3-13  
 UV disinfection systems, 19-147  
 Reed beds, 24-84  
 Refractory and insulation, materials of  
 construction, 10-60  
 Regenerative thermal oxidizers, 7-155  
 Regulations  
 air emissions, 7-25  
 biosolids-derived products, 27-45  
 disinfection, 19-8, 19-11, 19-20  
 Canada, 19-20  
 China, 19-21  
 European, 19-21  
 hazardous air pollutant, 7-18  
 heating, ventilating, and air conditioning,  
 9-53  
 incinerator ash, 27-38  
 land application, 27-4  
 landfill liners, 27-25  
 landfills, 27-22  
 odor control, 7-9  
 safety, 8-5  
 solids management, 20-4  
 state biosolids, 20-12  
 surface disposal, 27-33  
 sustainability, 5-24  
 thermal oxidation, 26-61  
 thermal processing emissions, 26-71  
 future, 26-74  
 local prohibitory rules, 26-74  
 National Emission Standard for  
 Hazardous Air Pollutants, 26-72  
 new source performance standards,  
 26-72  
 new source review, 26-73

- nonregulated emissions (greenhouse gases), 26-76
    - prevention of significant deterioration, 26-72
    - source-specific standards, 26-75
    - Standards for the Use and Disposal of Sewage Sludge, 26-73
  - Regulations/fire protection, materials of construction, 10-28
  - Regulatory processes, 4-11
  - Relative sustainability, 5-6
  - Reliability
    - criteria, 9-6
    - power source, 9-7
  - Removal efficiencies, 12-10
  - Renewable energy systems, 5-46
  - Renewable energy, heating, ventilating and air conditioning, 9-71
  - Reoxygenation, 16-158, 16-159, 16-160, 16-161
  - Reporting requirements, biosolids, 20-12
  - Residential sources, septage, 11-70
  - Residuals, 4-38
  - Resource Conservation and Recovery Act, 2-52
  - Retrofitting
    - chemical systems, 9-80
    - instrumentation and control systems, 9-29
    - UV disinfection, 19-163
  - Return activated sludge requirements, suspended-growth biological treatment, 14-54
  - Reuse, 2-13
    - sustainability, 5-47
    - UV disinfection, 19-130
  - Reverse osmosis, 16-119, 16-120, 16-121, 16-122, 16-123, 16-124, 16-125, 16-126, 16-127, 16-129, 16-130, 16-131, 16-132, 16-133, 16-134, 16-135, 16-136, 16-137, 16-138, 16-139, 16-141, 16-144, 16-146, 16-147, 16-148, 16-150
  - Reynolds number, 6-17, 6-24, 12-38, 16-31, 16-109, 16-111
  - Rheology, 22-8
  - Risk analysis, sustainability, 5-44
  - Road access, 4-35
  - Road gradient, 4-36
  - Roadways, 4-35
  - Rollers, belt presses, 24-35
  - Rose equation, 6-38
  - Rotary drum dryer, 26-12
  - Rotary drum thickening, 23-73, 23-74
    - ancillary equipment and controls, 23-77
    - conditioning, 22-38
    - design example, 23-77
    - evaluation and scale-up, 23-74
    - mechanical features, 23-77
    - process design, 23-74
      - drum speed, 23-76
      - polymer feed rate, 23-75
      - pool depth, 23-76
      - solids feed rate, 23-75
  - Rotary lobe pump, 21-34, 21-36
  - Rotary press dewatering, conditioning, 22-40
  - Rotary presses, 24-89
  - Rotary pumps, 6-40
  - Rotating biological contactors (RBCs), 13-136
  - Rotating biological contactors, materials of construction, 10-42
  - Rotation speed, screw presses, 24-108
  - Roughing filter activated sludge process, 15-7
  - Roughing-filter activated sludge process, integrated biological treatment, 15-37
  - Rubbers and elastomers, properties and applications, 10-86
- ## S
- Sack screens, 11-15
  - Safety and health
    - aerobic digestion, 25-168
    - alkaline stabilization, 25-270
    - anaerobic digestion equipment, 25-122
    - belt presses, 24-36
    - centrifuges, 24-24
    - composting, 25-230
    - conditioning, 22-53
    - dechlorination, 19-95
    - disinfection, 19-65
      - chlorine gas, 19-65
      - containers, 19-67
      - hypochlorites, 19-66
      - vaporizer facilities, 19-70
    - dryer equipment, 26-24
    - dryer operations, 26-24

- equipment, 8-19
- equipment, digester gas, 25-132
- ozone disinfection, 19-176
- program responsibilities, 8-7
- recessed-plate filter presses, 24-59
- sidestream treatment, 17-14
- surface preparation of protective coatings, 10-92
- thermal drying, 26-23
- thermal drying, industry standards, 26-25
- thermal oxidation, 26-61
- use of paint for identification of type of service, 10-93
- UV disinfection, 19-145
  - electrical hazards, 19-146
  - exposure to UV light, 19-145
- Salt Index
  - compost, 27-47
  - heat-dried biosolids, 27-53
- Sampling
  - anaerobic digesters, 25-117
  - odors, 7-30
  - protocols, 3-15
  - results, interpretation, 3-14
- Sand drying beds, 24-67
- Sand layer, drying beds, 24-77
- Sanitary systems, plumbing, 9-90
- Scale control, 16-131, 16-133
- Scaling, anaerobic digesters, 25-115
- Schulze formula, 13-166
- Scour velocity, 12-26
- Screen retention value, 11-39
- Screening, 6-31, 11-4
  - anaerobic digestion, 25-65
  - composting, 25-223
  - materials of construction, 10-37, 10-50
  - media, 11-8
  - screw presses, 24-103
  - solids pretreatment, 20-42
  - types, 11-10
- Screenings
  - capture, 11-47
  - organics test, 11-39
  - processing, 11-24
- Screw augers, screening, 11-29
- Screw conveyor, 21-43, 21-57, 21-62, 21-63, 21-64, 21-65, 21-70, 21-71, 21-73, 21-74, 21-76
- Screw press dewatering, conditioning, 22-39
- Screw presses, 24-97, 24-102
- Screw pumps, 6-40, 21-37, 21-38, 21-39
- Scroll tip linings, 24-26
- Scum
  - characteristics, 12-51
  - collection, 12-49
  - quantities, 12-51
- Secondary clarification, 14-205
  - design example, 14-307
  - integrated biological treatment, 15-14
  - wet-weather considerations, 14-169
- Secondary sedimentation, 6-36
- Secondary solids
  - characteristics, 20-37
  - production, 20-17
- Secondary treatment equivalency, 2-9
- Secondary treatment, 1-2
  - BAFs, 13-90
  - equalization, 11-78
- Second-order model, RBCs, 13-138
- Security, 4-37
  - camera surveillance, 9-87
  - chemical systems, 9-80
  - fence detection, 9-87
  - site, 9-86
  - vulnerability assessment, 9-86
- Sediment traps, 25-127
- Sedimentation, 12-4
- Sedimentation, materials of construction, 10-46
- Seismic activity, 4-23
- Seismic protection, electrical systems, 9-26
- Semi-empirical models, biofilm, 13-20
- Septage, 4-38, 11-68
- Sequence, project, 2-25
- Sequencing batch reactors, 14-31, 14-32
- Series-flow type sedimentation tank, 12-7
- Setbacks, 4-19, 4-41
- Settling characteristics, 12-11
- Settling tanks, materials of construction, 10-39
- Shared savings approach, energy management, 5-22
- SHARON® process, 17-22
- Sharp-crested weir, 6-14
- Shellfish, waterborne disease outbreaks, 19-19

- Shipment and handling safety
  - dechlorination, 19-95
  - disinfection, 19-67
  - ozone disinfection, 19-176
- Shock treatment, 16-136, 16-138
- Short-circuit capacity, 9-14
- Side overflow formula, 6-24
- Sidestream treatment, 17-4,
- Sidestreams
  - aerobic digestion, 25-191
  - alkaline stabilization, 25-273
  - thermal drying, 26-22
- Sidewalls, drying beds, 24-75
- Sieves, 12-41
- Silo digesters, 25-94
- Siloxanes, digester gas, 25-134
- Silviculture, biosolids, 27-21
- Single-rake screens, 11-13
- Single-train operation, pond systems, 18-18
- Site access, 4-24
- Site
  - considerations
    - biosolids land application, 27-10
    - integrated biological treatment, 15-15
    - sustainability, 5-12
  - constraints, 4-32
  - drainage, 4-37
  - evaluation phases, 4-12
  - land use, 4-17
  - layout types, 4-29
  - layout, composting, 25-215
  - permits, land application, 27-5
  - requirements, land treatment, 18-22
  - safety, 4-40, 8-10
  - selection, 4-3
- Siting
  - dedicated land disposal, 27-35
  - monofills, 27-23
- Size guide number, fertilizer, 27-49
- Sizing criteria, anaerobic digesters, 25-82
- Sizing parameters
  - secondary clarifiers, 14-215
  - thermal dryers, 26-18
  - thermal oxidation furnace, 26-39
  - thermal oxidation systems, 26-42
- Skimmers and rakes, dissolved air flotation, 23-32
- Slide gate control, 11-45
- Sloping beach scum collector, 12-52
- Sloughing, integrated biological treatment, 15-11
- Slow-rate systems, 18-23
- Sludge
  - disposal, 12-59
  - drying beds, 4-9
  - recirculation, 12-40
- Sludge volume index, dissolved air flotation, 23-23
- Sluice channels, screening, 11-29
- Slurry carbonization, 26-6, 26-7
- Snails, integrated biological treatment, 15-14
- Snow, 4-39
- Social equity, 4-26
- Sodium hypochlorite
  - disinfection, 19-22
  - onsite generation and disinfection, 19-61
- Sodium metabisulfite, Disinfection and dechlorination, 10-44
- Software types, 6-53
- Soil absorption, 18-3
- Soils, 4-23
- Solar disinfection, 19-179
- Solar drying, 24-82, 26-18
- Solid bowl centrifuges, 24-17
- Solid destruction, anaerobic digesters, 25-87
- Solids
  - blending, anaerobic digesters, 25-87
  - capture rate, 24-6
  - capture, dissolved air flotation, 23-28
  - characteristics, 20-36, 24-7
  - composition, thermal oxidation, 26-44
  - concentration
    - alkaline stabilization, 25-254
    - conditioning, 22-10
  - contact, 12-40
  - content, composting, 25-198
  - conveyance, materials of construction, 10-51
  - disintegration processes, 25-62
  - distribution channel, drying beds, 24-78
  - drying, digester gas, 25-142
  - generation/production rates, 20-13
  - handling and treatment, materials of construction, 10-47
  - handling, alkaline stabilization, 25-260

- loading rate
  - belt presses, 24-31
  - dissolved air flotation, 23-23
  - rotary presses, 24-92
  - screw presses, 24-106
- management, chemical systems, 9-81
- processing
  - materials of construction, 10-48
  - reliability standards, 3-20
- production and settleability, integrated
  - biological treatment, 15-26
- production variability, 3-28
- production, integrated biological treatment, 15-10
- pumping
  - centrifugal pumps, 10-50
  - materials of construction, 10-50
  - piston pumps, 10-50
- recycle, integrated biological treatment, 15-11
- reduction, aerobic digestion, 25-186
- separation, MBBRs, 13-72
- settling, alkaline stabilization, 25-274
- thickening, anaerobic digestion, 25-64
- treatment, 1-9
- Solids residence time, anaerobic digestion, 25-20
- Solids retention time
  - aerobic digestion, 25-187
  - anaerobic digesters, 25-82
  - integrated biological treatment, 15-21
  - thermal drying, 26-19
- Solids-amendment mixture, composting, 25-210
- Soluble salts
  - compost, 27-47
  - heat-dried biosolids, 27-53
- Space requirements, alkaline stabilization, 25-267
- Specialty models, 6-55
- Specific oxygen uptake rate (SOUR), aerobic digestion, 25-185
- Specification Requirements for Testing and Acceptance
- Specifications, field instruments, 9-31
- Spill prevention, 21-11
- Spiral blade clarifier, 12-44
- Splitting structures, 6-20
- Spreadsheet-based models, 6-54
- Sprinkler systems
  - effluent discharge, 10-64
  - fire protection, 9-84
- Stability, compost, 27-48
- Stabilization processes, comparison, 25-13
- Stabilization, materials of construction, 10-53
  - aerobic digesters, 10-53
  - anaerobic digesters, 10-54
  - digester tanks, 10-55
  - gas-mixing systems, 10-55
  - mesophilic digestion, 10-54
  - mixing systems, 10-55
  - thermophilic aerobic digesters, 10-54
  - thermophilic digestion, 10-55
- Stabilized solids, conditioning, 22-11
- Stacked sedimentation tanks, 12-6
- Stack-gas reheat, thermal processing, 26-85
- Staff facilities, 4-33
- Staffing, thermal drying, 26-21
- Staged digestion, 25-36
- Staged operation, aerobic digestion, 25-184
- Stair screens, 11-17
- Stakeholders, 4-26
- Standards
  - heating, ventilating, and air conditioning, 9-53
  - instrumentation and control systems, 9-29
  - ISO, 5-10
  - materials of construction, 10-98
  - olfactometry, 7-37
  - safety and thermal drying, 26-25
  - safety, 8-7
  - sustainable design, 5-7
  - thermal oxidation, 26-61, 26-63
- Standby power considerations, 9-22
- Startup considerations, alkaline stabilization, 25-269
- State operating permit, air emissions, 7-27
- State regulations
  - air emissions, 7-26
  - biosolids-derived products, 27-45
  - land application, 27-5
- Static screens, 11-22
- Station configuration, 6-45
- Stay-bosses, 24-55
- Steam heating systems, anaerobic digesters, 25-113
- Step screens, 11-17

- Stirling cycle engines, 25-145
- Storage
  - alkaline stabilization, 25-257
  - biosolids, 27-20
  - biosolids land disposal, 27-36
  - chemicals, 9-77
  - composting, 25-223
  - conditioning, 22-9
  - digester gas, 25-125
  - facilities, 4-33
  - lagoons, 21-12, 24-87
  - materials of construction, 10-48
  - post-digestion solids, 25-69
  - requirements, 21-8, 21-42
  - reuse, 2-19
  - septage, 11-75
  - slow-rate systems, 18-29
  - tanks, effluent discharge, 10-63
  - thermal drying, 26-20
- Storm drainage, plumbing, 9-91
- Stormwater
  - flow screens, 11-23
  - handling, 4-37
  - management, sustainability, 5-13
- Structural design, 4-32
- Structure, biofilm, 13-8
- Structured polymers, organic polymers, 22-27
- Struvite
  - anaerobic digesters, 25-115
  - precipitation, 17-28
- Submerged aerated filter, 13-84
- Submerged fixed covers, 25-102
- Submerged flow conditions, 6-15
- Submerged launders, 6-25, 12-20
- Subsurface flow, wetlands, 18-44
- Sulfatreat, odor control, 7-152
- Sulfite salts, chlorination and dechlorination, 19-58
- Sulfur dioxide
  - chlorination and dechlorination, 19-57
  - dechlorination, 19-94
  - disinfection and dechlorination, 10-44
- Sulfur oxides, thermal processing, 26-84
- Supernatant, aerobic digestion, 25-191
- Supervisory control and data acquisition systems, 9-43
  - human-machine interface systems, 9-43
  - independent data-acquisition systems, 9-43
- Supply-side management, energy, 5-36
- Support facilities, 4-33
- Support systems, 9-1
- Surface geometry, 12-26
- Surface overflow rate, 12-10
- Surface water control, monofills, 27-28
- Surge protection and lightning, electrical systems, 9-27
- Surrounding land use, 4-18
- Survivability, pathogens and disinfection, 19-16, 19-17
- Suspended growth biological reactor stage, integrated biological treatment, 15-20
- Suspended growth, sidestream treatment, 17-22
- Suspended solids loading, overland flow systems, 18-33
- Suspended-biofilm reactors, 13-210
- Suspended-growth biological treatment, 14-1
  - activated carbon addition, 14-34
  - aerated lagoons, 14-49
  - anaerobic treatment, 14-125
    - microbiology, 14-127
    - process configurations, 14-128
    - upflow anaerobic sludge blanket, 14-128
  - clarifiers, 14-35
  - contact stabilization, 14-25
  - conventional, 14-25
  - design considerations, 14-45
  - design example, 14-294
    - addressing nutrients, 14-309
    - aeration basin volume, 14-297
    - aeration requirements, 14-301
    - secondary clarification, 14-307
    - summary for the base case, 14-308
  - design parameters, 14-23
  - dissolved oxygen, 14-45
  - feeding and aeration patterns, 14-24
  - flotation, 14-36
  - influent characteristics, 14-46
  - integrated systems, 14-35
  - loading rates, 14-21
  - materials of construction, 10-40
  - membrane bioreactors, 14-142
    - components and configurations, 14-142
    - design, 14-154
    - pretreatment, 14-153

- process and equipment and design, 14-147
    - system equipment, 14-159
  - membranes, 14-36
  - nutrient control, 14-55
    - adding external carbon to nutrient removal, 14-111
    - baffles, 14-120
    - enhanced biological phosphorus removal, 14-55
    - fermentation, 14-115
    - mixing, 14-122
    - nitritation and denitritation, 14-99
    - nitrogen removal, 14-76
    - phosphorus and nitrogen removal, 14-99
  - nutrients, 14-46
  - operational characteristics, 14-22
  - oxygen demand, 14-52
  - oxygen transfer, 14-169
    - aeration system maintenance, 14-204
    - aerator design and testing, 14-197
    - air supply system, 14-187
      - air filtration, 14-188
      - air piping design, 14-193
      - blowers, 14-190
      - pure-oxygen generation, 14-194
    - clean water testing, 14-200
    - diffused aeration, 14-172
    - equipment, 14-198
    - mechanical surface aerators, 14-180
    - mixing requirements, 14-196
    - oxygen transfer rate, 14-201
  - pH, 14-46
  - process configurations and types, 14-12
    - aerated lagoon, 14-18
    - complete mix, 14-13
    - deep shaft, 14-20
    - oxidation ditch, 14-15
    - plug flow, 14-14, 14-15
  - process design for carbon oxidation and nitrification, 14-36
  - process water testing, 14-203
  - pure oxygen, 14-29
  - return activated sludge requirements, 14-54
  - secondary clarification, 14-205
    - circular and other radial flow designs, 14-249
      - diameter, 14-251
      - flow patterns, 14-250
      - inlet geometry, 14-253
      - interior baffles, 14-269
      - scum removal, 14-271
      - side wall depth, 14-252
      - sludge withdrawal, 14-277
      - outlets, 14-274
    - control strategy and facilities design, 14-286
    - concentration and density measurement, 14-289
    - equipment and instrumentation, 14-293
    - key parameters, 14-287
    - return and waste activated sludge, 14-287
    - sludge blanket depth measurement, 14-290
  - rectangular design, 14-231
    - dimensions, 14-234
    - flow patterns, 14-231
  - suspension characteristics and settleability, 14-205
  - sizing approaches, 14-215
    - batch and other clarification, 14-230
    - effect of flow variations, 14-228
    - overflow rate, 14-215
    - shapes, 14-230
    - sidewater depth, 14-227
    - solids loading rate, 14-217
    - weir loading, 14-227
  - selectors, 14-27
  - sequencing batch reactors , 14-31, 14-32
  - solids separation, 14-35
  - solids/liquid separation, 14-54
  - step feed, 14-26
  - submerged turbine aerators, 14-185
  - tapered aeration, 14-26, 14-27
  - temperature, 14-45
  - toxic and inhibitory wastes, 14-46
  - volume of aerobic reactor basins, 14-47
  - waste sludge generation, 14-51
  - wet-weather considerations, 14-165
    - aeration tanks, 14-166
    - flow reduction, 14-166
    - secondary clarifiers, 14-169
- Sustainability, 3-3, 4-25
- disinfection, 19-25
  - heating, ventilating and air conditioning, 9-62, 9-69

- Sustainable Water Infrastructure initiative, 5-6
  - Sutro weirs, 6-13
  - Swirl and vortex separators, 12-41
  - Symmetrical flow distribution layout, 6-21
  - System curve, 6-41
  - Systems dynamic modeling, 4-16
- T**
- Tanks
    - anaerobic digestion, 25-91, 25-121
    - digestion, 10-55
    - geometry, 4-32
  - Technologies
    - dewatering, 24-7
    - disinfection, 19-21
    - FBBRs, 13-115
  - Telescoping valves, 6-30
  - Temperature and building automation
    - controls, heating, ventilating and air conditioning systems, 9-68
  - Temperature
    - aerobic digestion, 25-155
    - alkaline stabilization, 25-248
    - anaerobic digestion, 25-23
    - composting, 25-199
    - composting, 25-212
    - effects, NTFs, 13-186
    - integrated biological treatment, 15-14
    - suspended-growth biological treatment, 14-45
    - swing adsorption, 25-137
    - thermal drying operation, 26-19
    - thermal oxidation, 26-28
    - thermal oxidation furnace sizing, 26-39
  - Temperature-phased anaerobic digestion, 25-38
  - Tensioning, belt presses, 24-39
  - Tertiary denitrification
    - BAFs, 13-99
    - FBBRs, 13-129
  - Tertiary processes, 6-38
  - Testing
    - conditioning, 22-56
    - dewatering, 24-12
    - heating, ventilating and air conditioning systems, 9-69
    - materials of construction, 10-101
    - Thermal conditioning and wet-air oxidation, 10-56
    - Thermal conditioning, 26-6
    - Thermal conditioning, slurry carbonization, 26-6, 26-7
    - Thermal destruction, materials of construction, 10-58
      - fluid-bed furnace, 10-60
      - multiple-hearth furnace, 10-59
      - rabble arms and teeth, 10-59
      - refractory and insulation, 10-60
    - Thermal drying, 26-8
      - belt dryers, 26-17
      - conduction drying systems, 26-15
      - convection dryers, 26-11
      - convection dryers, 26-17
      - design example, 26-85
      - design guidelines, 26-18
        - selection, 26-20
          - labor requirements, 26-21
          - processing train unit capacity, 26-20
          - product quality and use, 26-20
        - sizing parameters, 26-18
          - evaporative capacity, 26-18
          - hours of operation, 26-19
          - operating temperatures, 26-19
          - solids retention time, 26-19
          - storage, 26-20
        - utility requirements, 26-21
          - electrical, 26-21
          - emissions and odor control, 26-22
          - sidestreams, 26-22
          - thermal, 26-21
          - water, 26-22
    - design practice, 26-22
      - materials of construction, 26-23
      - post-processing equipment, 26-23
      - pre-processing equipment, 26-22
      - safety, 26-23
        - dryer equipment, 26-24
        - dryer operations, 26-24
        - industry standards, 26-25
    - flash dryer, 26-12
    - fluidized bed dryer, 26-13
    - heat-transfer methods, 26-10
    - materials of construction, 10-57
    - paddle and hollow-flight dryers, 26-15
    - pressure filter/vacuum dryer, 26-16

## Design of Municipal Wastewater Treatment Plants

- rotary drum dryer, 26-12
- solar dryers, 26-18
- tray dryers, 26-16
- Thermal energy requirements, drying, 26-21
- Thermal hydrolysis, 25-50
- Thermal oxidation, 26-25
  - design practice, 26-50
    - auxiliary equipment, 26-56
    - fans and blower equipment, 26-55
    - feed equipment and systems, 26-50
    - hazard and operability reviews, 26-65
    - insurance and other industry standards, 26-63
    - materials of construction, 26-59
    - process control, 26-60
    - process train equipment, 26-52
    - regulations, codes, and standards, 26-61
    - safety, 26-61
  - emerging technologies, 26-35
  - fluidized bed incinerator, 26-30, 26-31
    - cold (warm) wind box, 26-33
    - hot wind box, 26-32
  - heat and temperature, 26-28
  - heat recovery and reuse, 26-66
  - multiple-hearth furnace, 26-34
  - odor control, 7-152
  - oxygen requirements, 26-27
    - oxygen content, 26-28
    - stoichiometric air, 26-28
  - process design guidelines, 26-39
  - electricity requirements, 26-49
  - furnace sizing parameters, 26-39
    - evaporation/heat release limitations, 26-40
    - space velocity, 26-40
    - temperature, 26-39
    - time, 26-39
    - turbulence, 26-40
    - sufficient air, 26-41
  - selection and sizing, 26-42
    - air emission objectives, 26-47
    - ash handling, 26-49
    - effect of dewatered solids
      - characteristics, 26-44
    - equipment, 26-44
    - fuel optimization, 26-45
    - furnace, 26-42
    - inorganic sludge conditioning, 26-45
    - mass and energy balance, 26-47, 26-48
    - operating schedule and redundancy, 26-48
    - solids composition, 26-44
    - solids calorific values, 26-26
- Thermal processing, 26-1
  - biogasification, 26-67
  - design example, 26-85, 26-92
  - incineration, 26-92
    - thermal drying, 26-85
  - emissions control, 26-68
    - air pollution control, 26-77
      - acid gases, including sulfur oxides, 26-84
      - combustion modifications, 26-83
      - electrostatic precipitators, 26-82
      - fabric filters, 26-82
      - flue gas treatment, 26-83
      - mechanical collectors, 26-80
      - cury, 26-84
      - nitrogen oxides, 26-82
      - particulate and metals, 26-77
      - stack-gas reheat, 26-85
      - wet scrubbers, 26-81
    - combustion emissions, 26-69
      - carbon monoxide, 26-69
      - nitrogen oxides, 26-71
      - polycyclic organic matter, 26-71
      - volatile organic compounds, 26-70
  - odors, 26-68
  - regulations, 26-71
    - future, 26-74
    - local prohibitory rules, 26-74
    - National Emission Standards for Hazardous Air Pollutants, 26-72
    - new source performance standards, 26-72
    - new source review, 26-73
    - nonregulated emissions (greenhouse gases), 26-76
    - prevention of significant deterioration, 26-72
    - source-specific standards, 26-75
    - Standards for the Use and Disposal of Sewage Sludge, 26-73
  - materials of construction, 10-56

- thermal conditioning and wet-air oxidation, 10-56
- thermal drying, 10-57
- vitrification, 26-67
- Thermophilic aerobic digestion, Class A biosolids, 20-8
- Thermophilic digestion, 10-54, 10-55, 25-33
- Thickened residuals, 21-5, 21-16, 21-18, 21-21, 21-34
- Thickening, 23-1
  - aerobic digestion, 25-178
  - centrifuge, 23-41
    - abrasion areas, 23-55
    - back-drive, 23-55
    - base, 23-54
    - bearings, 23-54
    - bowl, 23-54
    - bowl geometry, 23-43
    - case, 23-54
    - chemical conditioning, 23-57
    - conveyor, 23-54
    - design example, 23-58
    - differential speed adjustment, 23-47
    - electrical controls, 23-55
    - evaluation and scale-up, 23-47
    - feed pipe, 23-54
    - motor type and size, 23-53
    - operating principle, 23-42
    - performance-control systems, 23-56
    - pond-depth adjustments, 23-57
    - process design, 23-50
    - pumps, 23-55
    - scroll configuration, 23-46
    - scroll drive features, 23-47
    - scroll geometry, 23-46
    - solids transportation, 23-56
    - variable-speed bowl and scroll, 23-57
    - vibration, 23-55
  - dissolved air flotation, 23-18
    - ancillary equipment and controls, 23-36
      - pipes, valves, and instruments, 23-36
      - pumps and compressors, 23-37
    - cothickening primary and secondary solids, 23-38
    - design example, 23-40
    - evaluation and scale-up, 23-19
    - flotation systems, 23-30
      - location, 23-32
      - materials of construction, 23-30
      - overflow weir, 23-33
      - pressurization system, 23-33, 23-34
      - pressurization tanks, 23-35
      - process design, 23-21
        - air-to-solids ratio, 23-25
        - feed-solids concentration, 23-24
        - float-blanket depth, 23-26
        - floating solids concentration, 23-27, 23-28
        - hydraulic loading rate, 23-23
        - mixed-liquor sludge volume index, 23-23
        - polymer addition, 23-26
        - solids capture, 23-28
        - solids loading rate, 23-23
        - solubilization efficiency, 23-29
        - type of solids, 23-23
      - skimmers and rakes, 23-32
  - flotation thickeners, 10-51
    - gravity belt thickeners, 10-51, 23-60, 23-61
      - ancillary equipment/controls, 23-68
        - belt washwater supply, 23-71
        - feed pumps and feed flow control, 23-69
        - odor control, 23-72
        - polymer system and feed control, 23-70
        - thickened-solids pumps, 23-71
      - belt washing, 23-68
      - design example, 23-72
      - discharge area, 23-67
      - drive, tracking, and tensioning, 23-68
      - evaluation and scale-up, 23-60
      - filtrate and wash water, 23-68
      - flocculation tank and feed distribution, 23-67
      - frame, 23-67
      - gravity drainage area, 23-67
      - process design, 23-62,
        - belt speed, 23-65,
        - discharge, 23-66,
        - flocculation, 23-64,
        - mixing, 23-64,
        - plow, 23-65,
        - unit sizing, 23-63,
      - solids polymer injection and mixer, 23-66

- gravity thickeners, 10-51, 23-4
    - ancillary equipment/controls, 23-17
    - design example, 23-17
    - evaluation and scale-up procedures, 23-5
    - operational considerations, 23-16
      - feed solids source and characteristics, 23-16
      - polymer, 23-17
      - underflow withdrawal, 23-17
    - process design, 23-12
      - drive mechanisms, 23-14
      - inlet, 23-13
      - loading rate, 23-12
      - overflow rate, 23-12
      - pickets, 23-13
      - rectangular thickeners, 23-16
      - skimmers and scrapers, 23-14
      - underflow piping, 23-15
    - materials of construction, 10-51
    - primary sludge, 12-47
    - rotary drum thickeners, 23-73, 23-74
      - ancillary equipment and controls, 23-77
      - design example, 23-77
      - evaluation and scale-up, 23-74
      - mechanical features, 23-77
      - process design, 23-74
        - drum speed, 23-76
        - polymer feed rate, 23-75
        - pool depth, 23-76
        - solids feed rate, 23-75
  - Tilting trough, 12-51
  - Time automatic control systems, 6-51
  - Time-temperature, Class A biosolids, 20-7
  - Title V permit, air emissions, 7-27
  - Topography, 4-21
  - Total life-cycle costs, 4-27, 4-29
  - Total suspended solids and biochemical
    - oxygen demand removal,
      - integrated biological treatment, 15-28
  - Total suspended solids removal efficiency, 12-11
  - Toxic and hazardous chemicals/fire-
    - protection regulations, materials of construction, 10-28
  - Toxic Substances Control Act, 2-54
  - Toxicity, 12-59
  - Toxicity, digesters, 25-26
  - Tracer testing, 6-56
  - Traffic mitigation, 3-10,
  - Training, EMS, 2-6
  - Transport of primary sludge, 12-49
  - Transport of scum, 12-54
  - Transportation, 4-24
  - Transportation, biosolids land application, 27-21
  - Trapezoidal weirs, 6-13
  - Trash racks, 11-10
  - Traveling bridge, 12-43
  - Tray dryers, 26-16
  - Treatability effect, 2-55
  - Treatability studies, 3-18
  - Treatment process arrangement, 4-29
  - Treatment processes, 4-29
  - Trickling filter activated sludge process, 15-9
  - Trickling filter activated sludge process,
    - integrated biological treatment, 15-38
  - Trickling filter/solids contact process, 15-5
  - Trickling filter/solids contact process,
    - integrated biological treatment, 15-34
  - Trickling filters, 6-36, 13-141
  - Trickling filters, materials of construction, 10-41
  - Triple-bottom-line accounting, 5-5
  - Troughs, 6-24
  - Tube settlers, 12-8, 12-37
  - Tunnels, 4-36
  - Turbine mixer, 16-106, 16-109, 16-112, 16-113
  - Turbines, digester gas use, 25-139
  - Turbulent flow, 21-16, 21-21, 21-24, 21-26
  - Two-phase anaerobic digestion, 25-44
  - Two-train operation, pond systems, 18-17
- U**
- U.S. criteria, reuse, 2-14
  - U.S. Environmental Protection Agency
    - four pillars, 5-6
    - Method 9095B, 11-28
  - U.S. regulations, reuse, 2-13
  - Ultimate disposal, biosolids, 22-12
  - Ultrafiltration, 16-119, 16-120, 16-124, 16-128,
    - 16-129, 16-130, 16-134, 16-135,
    - 16-137, 16-138, 16-144
  - Ultrasonics, anaerobic digestion, 25-62

- Underdrain system, trickling filters, 13-148
  - Underdrains, drying beds, 24-76
  - Uniformity index, fertilizer, 27-49
  - Unit electricity requirements, 5-31
  - Unit process
    - hydraulics, 6-30
    - liquid levels, 6-9
    - loading variability, 3-27
    - redundancy, 6-8
  - Unit redundancy, screw presses, 24-108
  - University of Cape Town process, 14-106, 14-108
  - Unstabilized solids, conditioning, 22-11
  - Upflow anaerobic sludge blanket, 14-128
  - Upflow, BAFs, 13-79
  - Upgrading
    - chemical systems, 9-80
    - conventional activated sludge plant, design example, 15-51
  - Urban water systems, sustainability, 5-16
  - Utilities
    - facilities, 4-35
    - heating, ventilating, and air conditioning, 9-58
    - requirements, thermal drying, 26-21
    - safety, 8-14
    - services, 4-24
  - UV disinfection, 19-23, 19-26, 19-97
    - actinometers, 19-107
    - bench and pilot testing, 19-158, 19-159
    - bioassays, 19-108
    - computational fluid dynamic modeling, 19-107
    - computational fluid dynamics, 19-142
    - design, 19-146
      - bypass channels and flooding, 19-147
      - facility requirements, 19-147
      - module lifting, 19-148
      - power conditioning, 19-149
      - power supply and harmonic distortion, 19-148, 19-149
      - reactors, 19-147
      - spare parts, 19-148
      - system redundancy, 19-147
    - dose (fluence), 19-106, 19-107, 19-110
    - effects of water quality and design, 19-154
      - effects of upstream processes, 19-157
      - effects of chemicals, 19-157
    - equipment, 19-149
      - horizontal systems, 19-151
      - low-pressure, high-intensity systems, 19-154
      - low-pressure, low-intensity systems, 19-150
      - medium-pressure, mercury-lamp systems, 19-153
      - vertical systems, 19-152
    - fouling and sleeve-cleaning systems, 19-143
    - inactivation kinetics, 19-110
    - intensity, 19-101, 19-102
    - mathematical models, 19-138
    - photoreactivation and dark repair, 19-119
    - point source-summation model, 19-107
    - reactor design and testing, 19-120
      - headloss, 19-123, 19-125
      - hydraulics, 19-120
      - inlet structure, 19-121
      - lamp output, 19-124, 19-125
      - longitudinal dispersion, axial dispersion, and turbulence, 19-120
      - outlet structure, 19-122
      - reactor validation and scale-up, 19-127
      - validation concerns, 19-136
      - validation testing for reuse, 19-130
    - safety and health, 19-145
      - electrical hazards, 19-146
      - exposure to UV light, 19-145
    - system sizing and configuration, 19-159
      - design guidelines, 19-164
      - disinfection of secondary effluent, 19-163
      - disinfection of reclaimed water, 19-163
      - emerging methods, 19-166
      - final design, 19-160
      - flow and dose pacing, 19-166
      - intensity monitoring, 19-165
      - retrofitting, 19-163
      - transmittance monitoring, 19-164
    - transmittance, 19-105
  - UV irradiation, 6-37
- V**
- Vacuum/pressure filter dryer, 26-16
  - Vacuum-assisted drying beds, 24-83
  - Value engineering, 2-31

- Value of water, 5-15
  - Value-added products, biosolids, 27-42
  - Valves, 6-25
  - Valves, dissolved air flotation, 23-36
  - Vaporizers, disinfection, 19-81, 19-82
  - Variable-speed operation, pumps, 6-52
  - Variable-speed pumps, 6-45
  - Variable-speed drives, 9-16
    - direct-current, 9-18
    - permanent-magnet, 9-18
    - variable-frequency, 9-16
  - Variable-volume press, 24-51
  - Vector-attraction reduction, biosolids, 20-10
  - Vectors
    - biosolids concentration, 27-7
    - surface disposal, 27-34
  - Vegetation, overland flow systems, 18-34
  - Vehicle storage, 4-38
  - Velocity control tanks, 11-59
  - Velocity gradient, 12-35
  - Velocity guidelines, 6-10
  - Velocity head, 6-18
  - Velz equation, 13-165
  - Ventilation rates, odor containment, 7-89
  - Ventilation
    - composting, 25-223
    - trickling filters, 13-148
  - Vermiculture, 27-44
  - Vertical drum screens, 11-21
  - Vertical pumps, reciprocating pumps, 6-40
  - Vertical velocity, 6-20
  - Vertical-flow, wetlands, 18-45
  - Virginia Initiative Plant, 14-108
  - Viruses, disinfection, 19-13
  - Viscosity, 6-44
  - Vitrification, 26-67
  - V-notch weirs, 6-13
  - Volatile fatty acids, 12-57
  - Volatile fatty acids, anaerobic digestion, 25-25
  - Volatile organic compounds, 4-42
  - Volatile organic compounds, thermal processing, 26-70
  - Volatile solids loading, anaerobic digestion, 25-21
  - Volatile solids reduction, aerobic digestion, 25-154, 25-186
  - Volatile solids, anaerobic digestion, 25-28
  - Voltage
    - distribution, 9-13
    - supply and distribution system, 9-12
  - Volume sources, odors/air emissions, 7-61
  - Volume, aerobic digester, 25-159
  - Volumetric flowrate, 6-12
  - Vortex grit removal, 6-34, 11-55
  - Vortex separators, 12-41
  - Vulnerability assessment, 9-86
- W**
- Walkways, 4-35
  - Washwater requirements
    - centrifuges, 24-29
    - rotary presses, 24-93
  - Washing system, recessed-plate filter presses, 24-63
  - Washwater, screw presses, 24-110
  - Waste load allocation, 2-9
  - Waste materials, 4-38
  - Wastewater cations, 22-8
  - Water conservation, 1-4
  - Water hammer, 4-29, 6-56
  - Water hyacinths, 18-41
  - Water quality, UV disinfection, 19-154
    - effects of chemicals, 19-157
    - effects of upstream processes, 19-157
  - Water requirements, thermal drying, 26-22
  - Water reuse, 1-3
  - Water-holding capacity, compost, 27-47
  - Weather conditions, 12-27
  - Wedge wire, screening media, 11-9
  - Wedge-wire drying beds, 24-83
  - Weir loading rate, 12-26
  - Weir loss, 6-13
  - Wet digestion, 25-77
  - Wet screenings, 11-6
  - Wet scrubbers, thermal processing, 26-81
  - Wet weather
    - considerations, 12-28
    - disinfection, 19-33
    - flow screens, 11-23
    - suspended-growth biological treatment, 14-165
    - treatment, equalization, 11-79

Wet-air oxidation and thermal conditioning,  
10-56  
Wetland filling, 4-26  
Wetlands, 18-42  
Wet-well sizing, 6-45  
Wild and Scenic Rivers Act, 4-18  
Wind effects, 4-32  
Windrow composting, 25-205  
Wood, properties and applications, 10-88  
Workplace injuries, 8-2

Worm castings, 27-44  
Wuhrmann process, 14-90

## Y

Yield, solids production, 20-18

## Z

Zero-regions, biofilm reactors, 13-25