Chapter 1  Wastewater Engineering: An Overview

1-1 Terminology

1-2 Impact of Regulations on Wastewater Engineering

1-3 Health and Environmental Concerns in Wastewater Management

1-4 Wastewater Characteristics
   Improved Analytical Techniques
   Importance of Improved Wastewater Characterization

1-5 Wastewater Treatment
   Treatment Methods
   Current Status
   New Directions and Concerns
   Future Trends in Wastewater Treatment

1-6 Wastewater Reclamation and Reuse
   Current Status
   New Directions and Concerns
   Future Trends in Biosolids Processing

1-7 Biosolids and Residuals Management
   Current Status
   New Directions and Concerns
   Future Trends in Technology

References
Chapter 2  Constituents in Wastewater

2-1  Wastewater Constituents
    Constituents Found in Wastewater
    Constituents of Concern in Wastewater Treatment

2-2  Sampling and Analytical Procedures
    Sampling
    Methods of Analysis
    Units of Measurement for Physical and Chemical Parameters
    Useful Chemical Relationships

2-3  Physical Characteristics
    Solids
    Particle Size Distribution
    Turbidity
    Color
    Absorption / Transmittance
    Temperature
    Conductivity
    Density, Specific Gravity, and Specific Weight

2-4  Inorganic Nonmetallic Constituents
    pH
    Chlorides
    Alkalinity
    Nitrogen
    Phosphorus
    Sulfur
    Gases
    Odors

2-5  Metallic Constituents
    Importance of Metals
    Sources of Metals
    Sampling and Methods of Analysis
    Typical Effluent Discharge Limits for Metals

2-6  Aggregate Organic Constituents
    Measurement of Organic Content
    Biochemical Oxygen Demand (BOD)
    Total And Soluble Chemical Oxygen Demand (COD and SCOD)
    Total and Dissolved Organic Carbon (TOC and DOC)
    UV-Absorbing Organic Constituents
    Theoretical Oxygen Demand
    Interrelationships between BOD, COD, and TOC
    Oil and Grease
    Surfactants
2-7 Individual Organic Compounds
   Priority Pollutants
   Analysis of Individual Organic Compounds
   Volatile Organic Compounds (VOCs)
   Disinfection Byproducts
   Pesticides and Agricultural Chemicals
   Emerging Organic Compounds

2-8 Biological Characteristics
   Microorganisms Found in Surface Waters and Wastewater
   Pathogenic Organisms
   Use of Indicator Organisms
   Enumeration and Identification of Bacteria
   Enumeration and Identification of Viruses
   Polymerase Chain Reaction (PCR)
   Development of Microorganisms Typing Techniques
   New and Reemerging Microorganisms

2-9 Toxicity Tests
   Toxicity Terminology
   Toxicity Testing
   Analysis of Toxicity Test Results
   Application of Toxicity Test Results
   Identification of Toxicity Components

Problems and Discussion Topics
References
Chapter 3  Analysis and Selection of Wastewater Flowrates and Constituent Loadings

3-1 Components of Wastewater Flows

3-2 Wastewater Sources and Flowrates
   Domestic Wastewater Sources and Flowrates
   Strategies for Reducing Interior Water Use and Wastewater Flowrates
   Water Use in Developing Countries
   Sources and Rates of Industrial (Nondomestic) Wastewater Flows
   Infiltration/Inflow
   Exfiltration from Collection Systems
   Combined System Flowrates

3-3 Statistical Analysis of Flowrates, Constituent Concentrations, and Mass Loadings
   Common Statistical Parameters
   Graphical Analysis of Data

3-4 Analysis of Wastewater Flowrate Data
   Definition of Terms
   Variations in Wastewater Flowrates
   Wastewater Flowrate Factors

3-5 Analysis of Constituent Mass Loading Data
   Wastewater Constituent Concentrations
   Variations in Constituent Concentrations
   Flow-Weighted Constituent Concentrations
   Calculation of Mass Loadings
   Effect of Mass Loading Variability on Treatment Plant Performance

3-6 Selection of Design Flowrates and Mass Loadings
   Design Flowrates
   Design Mass Loadings

Problems and Discussion Topics
References
Chapter 4  Introduction to Process Analysis and Selection

4-1 Reactors Used for the Treatment of Wastewater
   Types of Reactors
   Application of Reactors
   Hydraulic Characteristics of Reactors

4-2 Mass-Balance Analysis
   The Mass-Balance Principle
   Preparation of Mass Balances
   Application of the Mass-Balance Analysis
   Steady-State Simplification

4-3 Modeling Ideal Flow in Reactors
   Ideal Flow in Complete-Mix Reactor
   Ideal Flow in Plug-Flow Reactor

4-4 Analysis of Nonideal Flow in Reactors Using Tracers
   Factors Leading to Nonideal Flow in Reactors
   Need For Tracer Analysis
   Types of Tracers
   Conduct of Tracer Tests
   Analysis of Tracer Response Curves
   Practical Interpretation of Tracer Measurements

4-5 Modeling Nonideal Flow in Reactors
   The Distinction between Molecular Diffusion, Turbulent Diffusion, and Dispersion
   Plug-Flow Reactor with Axial Dispersion
   Complete-Mix Reactors in Series

4-6 Reactions, Reaction Rates, and Reaction Rate Coefficients
   Types of Reactions
   Rate of Reaction
   Reaction Order
   Types of Rate Expressions
   Rate Expressions Used in Environmental Modeling
   Effects of Temperature on Reaction Rate Coefficients
   Analysis of Reaction Rate Coefficients
4-7 Modeling Treatment Process Kinetics
   Batcher Reactor with Reaction
   Complete-Mix Reactor with Reaction
   Complete-Mix Reactors in Series with Reaction
   Ideal Plug-Flow Reactor with Reaction
   Comparison of Complete-Mix and Plug-Flow Reactors with Reaction
   Ideal Plug-Flow Reactor with Retarded Reaction
   Plug-Flow Reactor with Axial Dispersion and Reaction
   Other Reactor Flow Regimes and Reactor Combinations

4-8 Treatment Processes Involving Mass Transfer
   Basic Principle of Mass Transfer
   Gas-Liquid Mass Transfer
   Liquid-Solid Mass Transfer

4-9 Introduction to Process Selection
   Important Factors in Process Selection
   Process Selection Based on Reaction Kinetics
   Process Selection Based on Mass Transfer
   Process Design Based on Loading Criteria
   Bench Tests and Pilot-Plant Studies
   Reliability Considerations in Process Selection

Problems and Discussion Topics
References
Chapter 5  Physical Unit Operations

5-1  Screening  
Classification of Screens  
Coarse Screens (Bar Racks)  
Fine Screens  
Microscreens  
Screenings Characteristics and Quantities

5-2  Coarse Solids Reduction  
Comminutors  
Macerators  
Grinders  
Design Considerations

5-3  Flow Equalization  
Description/Application  
Design Considerations

5-4  Mixing and Flocculation  
Continuous Rapid Mixing in Wastewater Treatment  
Continuous Mixing in Wastewater Treatment  
Energy Dissipation in Mixing and Flocculation  
Time Scale in Mixing  
Types of Mixers Used for Rapid Mixing in Wastewater Treatment  
Types of Mixers Used for Flocculation in Wastewater Treatment  
Types of Mixers Used for Continuous Mixing in Wastewater Treatment  
New Developments in Mixing Technology

5-5  Gravity Separation Theory  
Description  
Particle Settling Theory  
Discrete Particle Settling  
Flocculent Particle Settling  
Inclined Plate and Tube Settling  
 Hindered (Zone) Settling  
Compression Settling  
Gravity Separation in an Accelerated Flow Field

5-6  Grit Removal  
Types of Grit Chambers  
Horizontal-Flow Grit Chambers  
Aerated Grit Chambers  
Vortex-Type Grit Chambers  
Solids (Sludge) Degritting  
Grit Characteristics, Quantities, Processing, and Disposal

5-7  Primary Sedimentation  
Description  
Sedimentation Tank Performance  
Design Considerations  
Characteristics and Quantities of Solids (Sludge) and Scum
5-8 High-Rate Clarification
   Enhanced Particle Flocculation
   Analysis of Ballasted Particle Flocculation and Setting
   Process Application

5-9 Large-Scale Swirl and Vortex Separators for Combined Wastewater and Stormwater

5-10 Flotation
   Description
   Design Considerations for Dissolved-Air Flotation Systems

5-11 Oxygen Transfer
   Description
   Evaluation of Oxygen Transfer Coefficient

5-12 Aeration Systems
   Types of Aeration Systems
   Diffused-Air Aeration
   Mechanical Aerators
   Energy Requirement for Mixing in Aeration Systems
   Generation and Dissolution of High-Purity Oxygen
   Postaeration

5-13 Removal of Volatile Organic Compounds (VOCs) by Aeration
   Emission of VOCs
   Mass Transfer Rates for VOCs
   Mass Transfer of VOCs from Surface and Diffused Air Aeration Process
   Control Strategies for VOCs

Problems and Discussion Topics
References
Chapter 6  Chemical Unit Processes

6-1 Role of Chemical Unit Processes in Wastewater Treatment
   Application of Chemical Unit Processes
   Considerations in the Use of Chemical Unit Processes

6-2 Fundamentals of Chemical Coagulation
   Basic Definitions
   Nature of Particles in Wastewater
   Development and Measurement of Surface Charge
   Particle-Particle Interactions
   Particle Destabilization with Potential-Determining Ions and Electrolytes
   Particle Destabilization and Aggregation with Polyelectrolytes
   Particle Destabilization and Removal with Hydrolyzed Metal Ions

6-3 Chemical Precipitation for Improved Plant Performance
   Chemical Reactions in Wastewater Precipitation Applications
   Enhanced Removal of Suspended Solids in Primary Sedimentation
   Independent Physical-Chemical Treatment
   Estimation of Sludge Quantities from Chemical Precipitation

6-4 Chemical Precipitation for Phosphorus Removal
   Chemistry of Phosphate Precipitation
   Strategies for Phosphorus Removal
   Phosphorus Removal Using Metal Salts and Polymers
   Phosphorus Removal Using Lime
   Comparison of Chemical Phosphorus Removal Process
   Estimation of Sludge Quantities from Phosphorus Precipitation

6-5 Chemical Precipitation for Removal of Heavy Metals and Dissolved Inorganic Substances
   Precipitation Reactions
   Coprecipitation with Phosphorus

6-6 Chemical Oxidation
   Fundamentals of Chemical Oxidation
   Applications
   Chemical Oxidation of BOD and COD
   Chemical Oxidation of Nonbiodegradable Organic Compounds
   Chemical Oxidation of Ammonia

6-7 Chemical Neutralization, Scale Control, and Stabilization
   pH Adjustment
   Analysis of Scaling Potential
   Scaling Control
   Stabilization

6-8 Chemical Storage, Feeding, Piping, and Control Systems
   Chemical Storage and Handling
   Dry Chemical-Feed Systems
   Liquid Chemical-Feed Systems
   Gas Chemical-Feed Systems
   Initial Chemical Mixing

Problems and Discussion Topics
References
Chapter 7  Fundamentals of Biological Treatment

7-1 Overview of Biological Wastewater Treatment
   Objectives of Biological Treatment
   Some Useful Definitions
   Role of Microorganisms in Wastewater Treatment
   Types of Biological Processes for Wastewater Treatment
   Attached Growth Processes

7-2 Composition and Classification of Microorganisms
   Cell Components
   Cell Composition
   Environmental Factors
   Microorganism Identification and Classification
   Use of Molecular Tools

7-3 Introduction to Microbial Metabolism
   Carbon and Energy Sources for Microbial Growth
   Nutrient and Growth Factors Requirements

7-4 Bacterial Growth and Energetics
   Bacterial Reproduction
   Bacterial Growth Patterns in a Batch Reactor
   Bacteria Growth and Biomass Yield
   Measuring Biomass Growth
   Estimating Biomass Yield and Oxygen Requirements from Stoichiometry
   Estimating Biomass Yield from Bioenergetics
   Stoichiometry of Biological Reactions
   Biomass Synthesis Yields for Different Growth Conditions
   Observed versus Synthesis Yield

7-5 Microbial Growth Kinetics
   Microbial Growth Kinetics Terminology
   Rate of Utilization of Soluble Substrates
   Other Rate Expressions for the Utilization of Soluble Substrate
   Rate of Soluble Substrate Production from Biodegradable Particulate Organic Matter
   Rate of Biomass Growth With Soluble Substrates
   Kinetic Coefficients for Substrate Utilization and Biomass Growth
   Rate of Oxygen Uptake
   Effects of Temperature
   Total Volatile Suspended Solids and Active Biomass
   Net Biomass Yield and Observed Yield
7-6 Modeling Suspended Growth Treatment Processes
   Description of Suspended Growth Treatment Processes
   Biomass Mass Balance
   Substrate Mass Balance
   Mixed Liquor Solids Concentration and Solids Production
   The Observed Yield
   Oxygen Requirements
   Design and Operating Parameters
   Process Performance and Stability
   Model Plug-Flow Reactors

7-7 Modeling Attached Growth Treatment Processes
   Substrate Flux In Biofilms
   Substrate Mass Balance for Biofilm
   Substrate Flux Limitations

7-8 Aerobic Biological Oxidation
   Process Description
   Microbiology
   Stoichiometry of Aerobic Biological Oxidation
   Growth Kinetics
   Environmental Factors

7-9 Biological Nitrification
   Process Description
   Microbiology
   Stoichiometry of Biological Nitrification
   Growth Kinetics
   Environmental Factors

7-10 Biological Denitrification
   Process Description
   Microbiology
   Stoichiometry of Biological Denitrification
   Growth Kinetics
   Environmental Factors

7-11 Biological Phosphorus Removal
   Process Description
   Microbiology
   Stoichiometry of Biological Phosphorus Removal
   Growth Kinetics
   Environmental Factors
7-12 Anaerobic Fermentation and Oxidation

   Process Description
   Microbiology
   Stoichiometry of Anaerobic Fermentation and Oxidation
   Growth Kinetics
   Environmental Factors

7-13 Biological Removal of Toxic and Recalcitrant Organic Compounds

   Development of Biological Treatment Methods
   Anaerobic Degradation
   Aerobic Biodegradation
   Abiotic Losses
   Modeling Biotic and Abiotic Losses

7-14 Biological Removal of Heavy Metals

   Problems and Discussion Topics
   References
Chapter 8  Aerobic Suspended Growth Biological Treatment Processes

8-1  Introduction to the Suspended Growth Activated-Sludge Process
    Historical Development
    Description of Basic Process
    Evolution of the Activated-Sludge Process
    Recent Process Developments

8-2  Wastewater Characterization
    Key Wastewater Constituents for Process Design
    Measurement Methods for Wastewater Characterization
    Recycle Flows And Loadings

8-3  Fundamentals of Process Analysis and Control
    Process Design Considerations
    Process Control
    Operational Problems
    Activated-Sludge Selector Processes

8-4  Processes for BOD Removal and Nitrification
    Process Design Considerations
    Complete-Mix Activated-sludge Process
    Sequencing Batch Reactor Process
    Staged Activated Sludge Process
    Alternative Processes for BOD Removal and Nitrification
    Process Design Parameters
    Process Selection Considerations

8-5  Processes for Biological Nitrogen Removal
    Overview of Biological Nitrogen-Removal Processes
    Single-Sludge Biological Nitrogen-Removal Processes
    Process Design Considerations
    Anoxic / Aerobic Process Design
    Step-Feed Anoxic / Aerobic Process Design
    Intermittent Aeration Process Design
    Postanoxic Endogenous Denitrification
    Sequencing Batch Reactor Process Analysis
    Postanoxic Denitrification with an External Carbon Source
    Nitrogen Removal in Anaerobic Digestion Recycle Streams
    Alternative Process Configurations for Biological Nitrogen Removal
    Process Design Parameters
    Process Selection Considerations
8-6 Processes for Biological Phosphorous Removal

- Biological Phosphorus-Removal Processes
- Process Design Considerations
- Process Control
- Solids Separation Facilities
- Methods to Improve Phosphorus-Removal Efficiency in BPR Systems
- Biological Phosphorus-Removal Process Performance
- Alternative Processes for Biological Phosphorus Removal
- Process Design Parameters
- Process Selection Considerations
- Dissolved Oxygen Control
- Return Activated Sludge Control
- Sludge Wasting
- Oxygen Uptake Rates
- Microscopic Observations

8-7 Selection and Design of Physical Facilities for Activated-Sludge Processes

- Aeration System
- Aeration Tanks and Appurtenances
- Solids Separation
- Design of Solids Separation Facilities

8-8 Suspended Growth Aerated Lagoons

- Types of Suspended Growth Aerated Lagoons
- Process Design Considerations for Flowthrough Lagoons
- Dual-Powered Flowthrough Lagoon System

8-9 Biological Treatment with Membrane Separation

- Overview of Membrane Biological Reactors
- Process Description
- Membrane Fouling Control
- Process Capabilities

8-10 Simulation Design Models

- Model Matrix Format, Components, and Reactions
- Model Applications

Problems and Discussion Topics

References
Chapter 9  Aerobic Attached Growth and Combined Biological Treatment Processes

9-1  Background

   Evolution of Attached Growth Processes
   Mass Transfer Limitations

9-2  Trickling Filters

   Trickling Filter Classification and Applications
   Design of Physical Facilities
   Process Design Considerations
   Nitrification Design

9-3  Rotating Biological Contractors

   Process Design Consideration
   Physical Facilities For RBC Process
   RBC Process Design

9-4  Combined Aerobic Treatment Processes

   Trickling Filter – Solids Contact and Trickling Filter – Activated-Sludge Processes
   Activated Biofilter and Biofilter-Activated Sludge Processes
   Series Trickling-Filter Activated-Sludge Process
   Design Considerations for Combined Trickling-Filter Activated Sludge-Systems

9-5  Activated Sludge with Fixed Film Packing

   Processes with Internal Suspended Packing for Attached Growth
   Processes with Internal Fixed Packing for Attached Growth

9-6  Design of Submerged Attached Growth Processes

   Downflow Submerged Attached Growth Processes
   Upflow Submerged Attached Growth Processes
   Fluidized Bed Bioreactors (FBBR)

Problems and Discussion Topics
References
Chapter 10  Anaerobic Suspended and Attached Growth Biological Treatment Processes

10-1  The Rationale for Anaerobic Treatment

Advantages of Anaerobic Treatment Processes
Disadvantages of Anaerobic Treatment Processes
Summary Assessment

10-2  Biological Denitrification

Downflow Packed-Bed Postanoxic Denitrification Processes
Upflow Packed-Bed Postanoxic Denitrification Reactors
Fluidized-Bed Reactors for Postanoxic Denitrification
Submerged Rotating Biological Contactors
Suspened Growth Postanoxic Denitrification Process
Attached Growth Preanoxic Denitrification Processes

10-3  General Design Considerations for Anaerobic Treatment Processes

Characteristics of the Wastewater
Sulfide Production
Ammonia Toxicity
Liquid-Solids Separation
Solids Retention Time
Expected methane gas production
Treatment Efficiency Needed

10-4  Anaerobic Suspended Growth Processes

Complete-Mix Process
Anaerobic Contact Process
Anaerobic Sequence Batch Reactor
Design of Anaerobic Suspended Growth Processes

10-5  Anaerobic Sludge Blanket Processes

Upflow Sludge Blanket Reactor Process
Design Considerations for UASB Process
Anaerobic Baffled Reactor
Anaerobic Migrating Blanket Reactor

10-6  Attached Growth Anaerobic Processes

Upflow Packed-Bed Attached Growth Reactor
Upflow Attached Growth Anaerobic Expanded-Bed Reactor
Attached Growth Anaerobic Fluidized-Bed Reactor
Downflow Attached Growth Processes

10-7  Other Anaerobic Treatment Processes

Covered Anaerobic Lagoon Process
Membrane Separation Anaerobic Treatment Process

Problems and Discussion Topics
References
Chapter 11  Advanced Wastewater Treatment

11-1  Need for Advanced Wastewater Treatment

11-2  Technologies Used for Advanced Treatment
   - Residual Constituents in Treated Wastewater
   - Classification of Technologies
   - Removal of Organic and Inorganic Colloidal and Suspended Solids
   - Removal of Dissolved Organic Constituents
   - Removal of Dissolved Inorganic Constituents
   - Removal of Biological Constituents
   - Process Selection and Performance Data

11-3  Introduction to Depth Filtration
   - Description of the Filtration Process
   - Filter Hydraulics
   - Analysis of the Filtration Process

11-4  Selection and Design Considerations for Depth Filters
   - Available Filtration Technologies
   - Performance of Different Types of Filter Technologies
   - Issues Related to Design and Operation of Treatment Facilities
   - Importance of Influent Wastewater Characteristics
   - Selection of Filtration Technology
   - Filter Bed Characteristics
   - Filter Flowrate Control
   - Filter Backwashing Systems
   - Filter Appurtenances
   - Filter Instrumentation and Control Systems
   - Effluent Filtration with Chemical Addition
   - Filter Problems
   - Need for Pilot-Plant Studies

11-5  Surface Filtration
   - Diskfilter ®
   - Cloth-Media Disk Filter ®
   - Performance Characteristics

11-6  Membrane Filtration Processes
   - Membrane Process Terminology
   - Membrane Process Classification
   - Membrane Configurations
   - Membrane Operation
   - Membrane Fouling
   - Application of Membranes
   - Electrodialysis
   - Pilot Studies for Membrane Applications
   - Disposal of Concentrated Waste Streams
11-7 Adsorption
Types of Absorbents
Fundamentals of Adsorption
Activated-Carbon Adsorption Kinetics
Activated-Carbon Treatment Process Applications
Analysis and Design of Granular Activated-Carbon Contactor
Small-Scale Column Tests
Analysis and Design of Powdered Activated-Carbon Contactor
Activated Sludge-Powdered Activated-Carbon Treatment

11-8 Gas Stripping
Analysis of Gas Stripping
Design of Stripping Towers
Application

11-9 Ion Exchange
Ion-Exchange Materials
Typical Ion Exchange Reactions
Exchange Capacity of Ion-Exchange Resins
Ion-Exchange Chemistry
Application of Ion Exchange
Operational Considerations

11-10 Advanced Oxidation Processes
Theory of Advanced Oxidation
Technologies Used to Produce Hydroxyl Radicals
Applications
Operational Problems

11-11 Distillation
Distillation Processes
Performance Expectations in Reclamation Applications
Operating Problems
Disposal of Concentrated Waste

Problems and Discussion Topics
References
Chapter 12  Disinfection Process

12-1  Regulatory Requirements for Wastewater Disinfection

12-2  Disinfection Theory
   Characteristics for an Ideal Disinfectant
   Disinfection Methods and Means
   Mechanisms of Disinfectants
   Factors Influencing the Action of Disinfectant

12-3  Disinfection with Chlorine
   Characteristics of Chlorine Compounds
   Chemistry of Chlorine Compounds
   Breakpoint Reaction with Chlorine
   Measurement and Reporting of Disinfection Process Variables
   Germicidal Efficiency of Chlorine and Various Chlorine Compounds
   Factors that Affect Disinfection Efficiency of Chlorine
   Modeling the Disinfection Process
   Review of the CRt Concept
   Required Chlorine Dosage for Disinfection
   Formation and Control of Disinfection Byproducts
   Environmental Impacts

12-4  Disinfection with Chlorine Dioxide
   Characteristics of Chlorine Dioxide
   Chlorine Dioxide Chemistry
   Effectiveness of Chlorine Dioxide as a Disinfectant
   By-Product Formation and Control
   Environmental Impacts

12-5  Dechlorination
   Need for Dechlorination
   Dechlorination of Wastewater Treated with Chlorine and Chlorine Compounds
   Dechlorination of Chlorine Dioxide with Sulfur Dioxide

12-6  Design of Chlorination and Dechlorination Facilities
   Sizing Chlorination Facilities
   Application Flow Diagrams
   Dosage Control
   Injection and Initial Mixing
   Chlorine Contact Basin Design
   Outlet Control and Chlorine Residual Measurement
   Chlorine Storage Facilities
   Chemical Containment Facilities
   Dechlorination Facilities
12-7 Disinfection with Ozone
   Ozone Properties
   Ozone Chemistry
   Ozone Disinfection Systems Components
   Effectiveness of Ozone as a Disinfectant
   Modeling the Ozone Disinfection Process
   Required Ozone Dosages for Disinfection
   By-Product Formation and Control
   Environmental Impacts of Using Ozone
   Other Benefits of Using Ozone

12-8 Other Chemical Disinfection Methods
   Peracetic Acid
   Ozone/Hydrogen Peroxide (Peroxone)
   Combined Chemical Disinfection Processes

12-9 Ultraviolet (UV) Radiation Disinfection
   Source of UV Radiation
   UV Disinfection System Components and Configurations
   Germicidal Effectiveness of UV Radiation
   Modeling the UV Disinfection Process
   Estimating UV Dose
   Ultraviolet Disinfection Guidelines
   Selection and Sizing of a UV Disinfection System
   Troubleshooting UV Disinfection Systems
   Environmental Impacts of UV Radiation Disinfection

12-10 Comparison of Alternative Disinfection Technologies
   Germicidal Effectiveness
   Advantages and Disadvantages

Problems and Discussion Topics
References
Chapter 13  Water Reuse

13-1  Water Reclamation and Reuse: An Introduction
  Definition of Terms
  The Role of Water Recycling in the Hydrologic Water Cycle
  Historical Perspective
  Wastewater Reuse Applications
  Need for Water Reuse

13-2  Public Health and Environmental Issues in Water Reuse
  Constituents in Reclaimed Water
  Public Health Issues
  Environmental Issues
  The Evolution of Water Reuse Guidelines in The United States
  Water Reclamation Criteria in Other Countries
  What Level of Treatment is Necessary?

13-3  Introduction to Risk Assessment
  Risk Assessment
  Risk Management
  Ecological Risk Assessment
  Risk Assessment for Water Reuse

13-4  Water Reclamation Technologies
  Constituent Removal Technologies
  Conventional Reclamation Treatment Process Flow Diagrams for Water Reclamation
  Advanced Wastewater Treatment Process Flow Diagrams
  Performance Expectations for Water Reclamation Processes
  Predicting the Performance of Treatment Process Combinations
  Treatment Process Reliability

13-5  Storage of Reclaimed Water
  Need For Storage
  Meeting Water Quality Discharge Requirements
  Operation of Storage Reservoirs
  Problems Involved with Storage of Reclaimed Water
  Management Strategies for Open and Enclosed Reservoirs

13-6  Agricultural and Landscape Irrigation
  Evaluation of Irrigation Water Quality
  Miscellaneous Problems

13-7  Industrial Water Reuse
  Industrial Water Use
  Cooling Tower Makeup Water
  Water and Salt Balances in Cooling Tower
  Common Water Quality Problems in Cooling Tower Systems
13-8  Groundwater Recharge with Reclaimed Water
    Groundwater Recharge Methods
    Pretreatment Requirements for Groundwater Recharge
    Fate of Contaminants in Groundwater
    Groundwater Recharge Guidelines

13-9  Planned Indirect and Direct Potable Water Reuse
    Planned Indirect Potable Water Reuse
    Planned Direct Potable Water Reuse
    Planned Potable Water Reuse Criteria
    “From Toilet-to-Tap”: Is it the Ultimate Reuse Goal?

13-10 Planning for Wastewater Reclamation and Reuse
    Planning Basis
    Market Assessment
    Monetary Analyses
    Other Planning Factors
    Planning Report

13-11 Epilogue on Water Reuse Issues

    Problems and Discussion Topics
    References
Chapter 14  Treatment, Reuse, and Disposal of Solids and Biosolids

14-1  Solids Sources, Characteristics, and Quantities
   Sources
   Characteristics
   Quantities

14-2  Regulations for the Reuse and Disposal of Solids in The United States
   Land Application
   Surface Disposal
   Pathogen and Vector Attraction Reduction
   Incineration

14-3  Solids Processing Flow Diagrams

14-4  Sludge and Scum Pumping
   Pumps
   Headloss Determination
   Sludge Piping

14-5  Preliminary Operations
   Grinding
   Screening
   Degritting
   Blending
   Storage

14-6  Thickening
   Application
   Description and Design of Thickeners

14-7  Introduction to Stabilization

14-8  Alkaline Stabilization
   Chemical Reactions in Lime Stabilization
   Heat Generation
   Application of Alkaline Stabilization Processes

14-9  Anaerobic Digestion
   Process Fundamentals
   Description of Mesophilic Anaerobic Digestion Processes
   Process Design for Mesophilic Anaerobic Digestion
   Selection of Tank Design and Mixing System
   Methods for Enhancing Solids Loading and Digester Performance
   Gas Production, Collection, and Use
   Digester Heating
   Thermophilic Anaerobic Digestion
   Two-Phased Anaerobic Digestion

14-10  Aerobic Digestion
   Process Description
   Conventional Air Aerobic Digestion
   Dual Digestion
   Autothermal Thermophilic Aerobic Digestion (ATAD)
   High-Purity Oxygen Digestion
14-11 Composting
   Process Microbiology
   Process Description
   Design Considerations
   Cocomposting with Municipal Solid Wastes
   Public Health and Environmental Issues

14-12 Conditioning
   Chemical Conditioning
   Other Conditioning Methods

14-13 Dewatering
   Centrifugation
   Belt-Filter Press
   Filter Presses
   Sludge Drying Beds
   Reed Beds
   Lagoons

14-14 Heat Drying
   Heat Transfer Methods
   Process Description
   Product Characteristics
   Product Transfer and Storage
   Fire and Explosion Hazards
   Air Pollution and Odor Control

14-15 Incineration
   Fundamentals Aspects of Complete Combustion
   Multiple-Hearth Incineration
   Fluidized-Bed Incineration
   Coincineration with Municipal Solid Waste
   Air-Pollution Control

14-16 Solids Mass Balances
   Preparation of Solids Mass Balances
   Performance Data for Solids-Processing Facilities
   Impact of Return Flows and Loads

14-17 Application of Biosolids to Land
   Site Evaluation and Selection
   U.S. EPA Regulations for Beneficial Use and Disposal of Biosolids
   Design Loading Rates
   Application Methods
   Application to Dedicated Lands
   Landfilling

14-18 Biosolids Conveyance and Storage
   Conveyance Methods
   Storage

Problems and Discussion Topics
References
Chapter 15   Issues Related to Treatment Plant Performance

15-1  Need for Upgrading Treatment-Plant Performance

   Meeting Current and Future Needs
   Meeting More Stringent discharge Requirements

15-2  Odor Management

   Types of Odors
   Sources of Odors
   Movement of Odors from Wastewater Treatment Facilities
   Strategies for Odor Control
   Odor Treatment Methods
   Selection and Design of Odor Control Facilities
   Design Considerations for Chemical Scrubbers
   Design Considerations for Odor Control Biofilters

15-3  Treatment Process Reliability

   Variability of Influent Wastewater Characteristics
   Variability in Wastewater Treatment Processes
   Mechanical Process Reliability
   Selection of Process Design Parameters

15-4  Introduction to Automatic Process Control

   Process Disturbances
   Control Systems for Wastewater Treatment Plants
   Control Algorithms
   Description of Automatic Control System Elements

15-5  Energy Efficiency in Wastewater

   Overview of the Use of Electricity in Wastewater Treatment
   Measures for Improving Energy Efficiency

15-6  Upgrading Wastewater Treatment and Plant Performance

   Process Optimization
   Upgrading Existing Wastewater Treatment Facilities
   Options for Improving Energy Efficiency

15-7  Important Design Considerations for New Wastewater Treatment Plants

   Process Design Considerations for Liquid Streams
   Process Design Considerations for solids Processing
   Odor Control

Problems and Discussion Topics

References
Appendix A
Appendix B  Physical Properties of Selected Gases and the Composition of Air
Appendix C  Physical Properties of Water
Appendix D  Solubility of Dissolved Oxygen in Water as a Function of Salinity and Barometric Pressure
Appendix E  MPN Tables and Their Use
Appendix F  Moody Diagrams for the Analysis of Flow in Pipes

Name Index
Subject Index