
CONTENTS

| | |
|--|------------|
| Preface | xiii |
| Chapter 1 Wastewater Engineering: An Overview | 1 |
| 1-1 Wastewater Treatment | 2 |
| 1-2 Sludge Disposal and Reuse | 8 |
| 1-3 Wastewater Reclamation and Reuse | 9 |
| 1-4 Effluent Disposal | 10 |
| 1-5 The Role of the Engineer | 11 |
| Chapter 2 Wastewater Flowrates | 15 |
| 2-1 Components of Wastewater Flows | 15 |
| 2-2 Estimating Wastewater Flowrates from Water Supply Data | 16 |
| 2-3 Wastewater Sources and Flowrates | 26 |
| 2-4 Analysis of Wastewater Flowrate Data | 35 |
| 2-5 Reduction of Wastewater Flowrates | 41 |
| Chapter 3 Wastewater Characteristics | 47 |
| 3-1 Physical, Chemical, and Biological Characteristics of Wastewater | 47 |
| 3-2 Physical Characteristics: Definition and Application | 50 |
| 3-3 Chemical Characteristics: Definition and Application | 64 |
| 3-4 Biological Characteristics: Definition and Application | 90 |
| 3-5 Wastewater Composition | 108 |
| 3-6 Wastewater Characterization Studies | 111 |
| Chapter 4 Wastewater Treatment Objectives, Methods, and Implementation Considerations | 121 |
| 4-1 Wastewater Treatment Objectives and Regulations | 122 |
| 4-2 Classification of Wastewater Treatment Methods | 125 |
| 4-3 Application of Treatment Methods | 126 |
| 4-4 Selection of Treatment-Process Flow Diagrams | 130 |
| 4-5 Implementation of Wastewater Management Programs | 137 |
| 4-6 Financing | 142 |

| | | |
|------------------|---|------------|
| Chapter 5 | Introduction to Wastewater Treatment Plant Design | 147 |
| 5-1 | Impact of Flowrate and Mass-Loading Factors on Design | 148 |
| 5-2 | Evaluation and Selection of Design Flowrates | 148 |
| 5-3 | Evaluation and Selection of Design Mass Loadings | 153 |
| 5-4 | Process Selection | 166 |
| 5-5 | Elements of Conceptual Process Design | 181 |
| Chapter 6 | Physical Unit Operations | 193 |
| 6-1 | Flow Measurement | 195 |
| 6-2 | Screening | 200 |
| 6-3 | Flow Equalization | 203 |
| 6-4 | Mixing | 212 |
| 6-5 | Sedimentation | 220 |
| 6-6 | Accelerated Gravity Separation | 240 |
| 6-7 | Flotation | 242 |
| 6-8 | Granular-Medium Filtration | 248 |
| 6-9 | Gas Transfer | 276 |
| 6-10 | Volatilization and Gas Stripping of Volatile Organic Compounds (VOCs) from Wastewater Management Facilities | 287 |
| Chapter 7 | Chemical Unit Processes | 301 |
| 7-1 | Chemical Precipitation | 302 |
| 7-2 | Adsorption | 314 |
| 7-3 | Disinfection | 324 |
| 7-4 | Disinfection with Chlorine | 332 |
| 7-5 | Dechlorination | 343 |
| 7-6 | Disinfection With Chlorine Dioxide | 345 |
| 7-7 | Disinfection With Bromine Chloride | 347 |
| 7-8 | Disinfection With Ozone | 349 |
| 7-9 | Disinfection With Ultraviolet Light | 351 |
| 7-10 | Other Chemical Applications | 352 |
| Chapter 8 | Biological Unit Processes | 359 |
| 8-1 | Overview of Biological Wastewater Treatment | 359 |
| 8-2 | Introduction to Microbial Metabolism | 360 |
| 8-3 | Important Microorganisms in Biological Treatment | 364 |
| 8-4 | Bacterial Growth | 367 |
| 8-5 | Kinetics of Biological Growth | 369 |
| 8-6 | Biological Treatment Processes | 377 |
| 8-7 | Aerobic Suspended-Growth Treatment Processes | 378 |
| 8-8 | Aerobic Attached-Growth Treatment Processes | 403 |
| 8-9 | Anaerobic Suspended-Growth Treatment Processes | 420 |
| 8-10 | Anaerobic Attached-Growth Treatment Processes | 428 |
| 8-11 | Anaerobic Nutrient Removal | 429 |
| 8-12 | Pond Treatment Processes | 434 |

| | | |
|-------------------|---|------------|
| Chapter 9 | Design of Facilities for Physical and Chemical Treatment of Wastewater | 445 |
| 9-1 | Bar Racks and Screens | 445 |
| 9-2 | Comminution | 454 |
| 9-3 | Grit Removal | 456 |
| 9-4 | Flow Equalization | 468 |
| 9-5 | Other Preliminary Treatment Operations | 470 |
| 9-6 | Primary Sedimentation Tanks | 472 |
| 9-7 | Other Solids-Removal Operations | 485 |
| 9-8 | Chemical Precipitation | 486 |
| 9-9 | Disinfection with Chlorine Compounds | 494 |
| 9-10 | Other Means of Disinfection | 506 |
| 9-11 | Post Aeration | 508 |
| 9-12 | Odor Control | 512 |
| 9-13 | Control of VOCs Released from Wastewater Management Facilities | 518 |
| | | |
| Chapter 10 | Design of Facilities for the Biological Treatment of Wastewater | 529 |
| 10-1 | The Activated-Sludge Process | 531 |
| 10-2 | Selection and Design of Physical Facilities for Activated-Sludge Process | 556 |
| 10-3 | Activated-Sludge Process Design | 591 |
| ✓ 10-4 | Aerated Lagoons | 604 |
| ✓ 10-5 | Trickling Filters | 614 |
| ✓ 10-6 | Rotating Biological Contactors | 628 |
| ✓ 10-7 | Combined Aerobic Treatment Processes | 637 |
| ✓ 10-8 | Stabilization Ponds | 641 |
| | | |
| Chapter 11 | Advanced Wastewater Treatment | 663 |
| 11-1 | Need for Advanced Wastewater Treatment | 664 |
| 11-2 | Treatment Technologies Used for Advanced Wastewater Treatment | 666 |
| 11-3 | Removal of Residual Suspended Solids by Granular-Medium Filtration | 666 |
| 11-4 | Removal of Residual Suspended Solids by Microscreening | 689 |
| 11-5 | Control of Nutrients | 691 |
| 11-6 | Conversion of Ammonia by Biological Nitrification | 694 |
| ✓ 11-7 | Removal of Nitrogen by Biological Nitrification/Denitrification | 711 |
| ✓ 11-8 | Removal of Phosphorus by Biological Methods | 726 |
| ✓ 11-9 | Combined Removal of Nitrogen and Phosphorus by Biological Methods | 731 |
| ✓ 11-10 | Removal of Nitrogen by Physical and Chemical Processes | 735 |
| ✓ 11-11 | Removal of Phosphorus by Chemical Addition | 741 |
| 11-12 | Removal of Toxic Compounds and Refractory Organics | 749 |
| 11-13 | Removal of Dissolved Inorganic Substances | 756 |
| | | |
| Chapter 12 | Design of Facilities for the Treatment and Disposal of Sludge | 765 |
| 12-1 | Solids and Sludge Sources, Characteristics, and Quantities | 766 |
| 12-2 | Regulations for the Reuse and Disposal of Sludge | 777 |
| 12-3 | Sludge Treatment Flow Diagrams | 779 |

| | | |
|-------|---|-----|
| 12-4 | Sludge and Scum Pumping | 779 |
| 12-5 | Preliminary Operations | 796 |
| 12-6 | Thickening (Concentration) | 801 |
| 12-7 | Stabilization | 810 |
| 12-8 | Anaerobic Sludge Digestion | 813 |
| 12-9 | Aerobic Sludge Digestion | 835 |
| 12-10 | Composting | 842 |
| 12-11 | Conditioning | 850 |
| 12-12 | Disinfection | 854 |
| 12-13 | Dewatering | 855 |
| 12-14 | Heat Drying | 877 |
| 12-15 | Thermal Reduction | 881 |
| 12-16 | Preparation of Solids Mass Balances | 891 |
| 12-17 | Land Application of Sludge | 903 |
| 12-18 | Other Beneficial Uses of Sludge | 914 |
| 12-19 | Final Sludge and Solids Conveyance, Storage, and Disposal | 915 |

Chapter 13 Natural Treatment Systems 927

| | | |
|------|--|------|
| 13-1 | Development of Natural Treatment Systems | 928 |
| 13-2 | Fundamental Considerations in the Application of Natural Treatment Systems | 938 |
| 13-3 | Slow-Rate Systems | 944 |
| 13-4 | Rapid Infiltration Systems | 967 |
| 13-5 | Overland-Flow Systems | 982 |
| 13-6 | Constructed Wetlands | 992 |
| 13-7 | Floating Aquatic Plant Treatment Systems | 1002 |

Chapter 14 Small Wastewater Treatment Systems 1017

| | | |
|-------|--|------|
| 14-1 | Special Problems Faced by Small Communities | 1017 |
| 14-2 | Small System Flowrates and Wastewater Characteristics | 1019 |
| 14-3 | Types of Small Wastewater Management Systems | 1021 |
| 14-4 | Onsite Systems for Individual Residences and Other Community Facilities in Unsewered Areas | 1024 |
| 14-5 | Selection and Design of Onsite Systems | 1041 |
| 14-6 | Onsite Wastewater Management Districts | 1070 |
| 14-7 | Wastewater Collection Systems for Small Communities | 1072 |
| 14-8 | Small Systems for Clusters of Homes and Very Small Communities | 1076 |
| 14-9 | Systems with Package (Pre-Engineered) Treatment Plants | 1080 |
| 14-10 | Individually Designed Treatment Facilities | 1088 |
| 14-11 | Septage and Septage Disposal | 1090 |

Chapter 15 Management of Wastewater from Combined Sewers 1103

| | | |
|------|---|------|
| 15-1 | History of Combined Sewer Systems | 1104 |
| 15-2 | Components of Combined Sewer Systems | 1105 |
| 15-3 | Combined Sewer Flowrates and Wastewater Characteristics | 1112 |

| | | |
|------|---|------|
| 15-4 | Methods for Controlling Overflows | 1125 |
| 15-5 | Treatment of Combined Sewer Overflows | 1129 |
| 15-6 | Future Directions in the Management of Combined Sewer Overflows | 1131 |

Chapter 16 Wastewater Reclamation and Reuse 1137

| | | |
|------|---|------|
| 16-1 | Wastewater Reclamation and Reuse: An Introduction | 1137 |
| 16-2 | Wastewater Reuse Applications | 1142 |
| 16-3 | Wastewater Reclamation Technologies | 1174 |
| 16-4 | Planning Considerations in Wastewater Reclamation and Reuse | 1184 |

Chapter 17 Effluent Disposal 1195

| | | |
|------|---------------------------------------|------|
| 17-1 | Water Quality Parameters and Criteria | 1196 |
| 17-2 | Fate Processes | 1198 |
| 17-3 | Disposal into Lakes and Reservoirs | 1209 |
| 17-4 | Disposal into Rivers and Estuaries | 1213 |
| 17-5 | Ocean Disposal | 1225 |

APPENDIXES

| | | |
|---|---|------|
| A | Conversion Factors | 1241 |
| B | Physical Properties of Air | 1249 |
| C | Physical Properties of Water | 1251 |
| D | Solubility of Gases Dissolved in Water | 1255 |
| E | Dissolved-Oxygen Concentration in Water as a Function of Temperature, Salinity, and Barometric Pressure | 1257 |
| F | MPN Tables and Their Use | 1261 |
| G | General Solution Procedure for Materials-Balance Equations for a Batch, Complete-Mix, and Plug-Flow Reactor | 1265 |
| H | Determination of Kinetic Coefficients | 1275 |
| I | Moody Diagrams for the Analysis of Flow in Pipes | 1281 |

INDEXES

| | |
|---------------|------|
| Name Index | 1285 |
| Subject Index | 1291 |