

CONTENTS

Preface	xv
1. Criteria and Standards for Potable Water Quality	1
The History of Water Treatment	1
Trends in Raw-Water Quality	5
Legislative and Regulatory History	6
Approach to Contaminant Limits	13
Current Drinking Water Standards	14
Pending Regulations	21
Future Trends	21
List of Acronyms	26
Glossary of Terms Used in Drinking Water Treatment	29
2. Inorganic and Radionuclide Contaminants	32
Inorganic Contaminants of Health Concern	32
Inorganic Contaminants of Aesthetic Concern	52
Residual Disinfectants and Inorganic Disinfection By-Products	54
3. Organic Compounds in Drinking Water	62
Introduction	62
Organics Monitoring	62
Volatile Organic Compounds	62
Synthetic Organic Compounds	70
Natural Organic Matter	71
Disinfection By-Products	76
MTBE	83
4. Microbiology of Drinking Water	87
Introduction	87
Pathogenic Organisms	87
Waterborne Disease Outbreaks	88
Microbial Indicators of Water Quality	96
Current Regulations	97
Future Regulations	98
5. Water Chemistry	102
Introduction	102
Elements and Compounds	102

Solubility	108
Oxidation	111
Metal Corrosion	112
6. Specific Contaminant Removal Methodologies	114
Introduction	114
Inorganic Contaminants	114
Organic Contaminants	114
Radionuclides	116
Microbial Contaminants	116
7. Water System Planning	121
Introduction	121
Water System Description	122
Water Demand Forecast	124
Planning Data Memorandum	132
Conservation Plan	132
Evaluation of Sources of Supply	133
Water Rights Assessment	136
Source Protection Plan	136
Water Quality Monitoring	138
Water System Analysis	138
Capital Improvement Plan	143
Financial Plan	146
Operation and Maintenance Plan	148
Supporting Documents	151
8. Source Water Development	153
Overview	153
Integrated Water Resources Management	153
Alternative Sources	155
Design Periods for Water Sources	160
Surface Water Supplies	161
Development of Reservoirs	163
Reservoir Losses	167
Intakes	168
Contaminants in Supply Sources	173
Factors in the Location of Water Intakes	178
Pretreatment of Surface Water Supplies	179
Chemical Treatment of Reservoirs	184
Reservoir Outlets	185
Groundwater Supplies	186
Groundwater Conditions	188
Wells	192
Groundwater Quality Considerations	204
Evaluation of Water Supply Alternatives	206
Watershed Management	207

Wellhead Protection Programs	210
Develop Procedures to Reduce the Potential for Contamination	212
Contingency Plans	212
9. Aeration and Air Stripping	215
Introduction	215
Gas Transfer Fundamentals	215
Unit Processes	220
Applications	244
10. Coagulation and Flocculation	251
Introduction	251
What Are Coagulation and Flocculation?	251
Theories of Coagulation	253
Coagulation in Water Treatment	259
Rapid Mixing	266
Rapid Mixing Systems	268
Design Examples for Rapid-Mix Systems	273
Temperature Effects	276
Flocculation Systems	278
Flocculation Alternatives	281
Design Examples—Flocculation	282
Coagulation Control and Monitoring	289
Enhanced Coagulation Processes	296
11. Sedimentation and Other Clarification Processes	301
Sedimentation	301
High-Rate Clarification	333
Flotation	337
12. Filtration	351
Introduction	351
The Role of Filtration in Water Treatment	351
Filtration Technologies	352
The Evolution of Gravity Filtration	355
Water Filter Operation	361
Design of Filter Systems	368
Filter Problems and Potential Solutions	397
Direct Filtration	399
Biological Filtration	402
Other Types of Filters	405
13. Water Softening	412
Hardness	412
Softening Goals	413
Lime-Soda Softening	415

Process Design Considerations	421
Unit Process Design Criteria for Lime Softening	424
Recarbonation	427
Single-Stage vs. Two-Stage Recarbonation	428
Sources of Carbon Dioxide	428
Quantities of Carbon Dioxide Required	429
Nonpressurized Carbon Dioxide Generators	431
Compressor Selection	432
Pressure Generators and Underwater Burners	433
Liquid Carbon Dioxide	433
Carbon Dioxide Piping and Diffusion Systems	436
Carbon Dioxide Reaction Basins or Intermediate Settling Basins	437
Operation and Control of Recarbonation	439
Safety	439
Filter Media Rehabilitation	440
14. Iron and Manganese Removal	441
Introduction	441
Factors Influencing the Treatment of Iron and Manganese	442
Stabilization or Sequestering Methods	443
Physical/Chemical Removal of Iron and Manganese	452
Biological Removal of Iron, Ammonium, and Manganese	463
Design and Operation of Iron and Manganese Removal Systems	470
15. Membrane Treatment	476
Introduction	476
Membrane Processes for Drinking Water	476
Membrane Applications	477
Process Selection/Performance	478
Principles of Membrane Separation Processes	479
Microfiltration and Ultrafiltration	488
Nanofiltration and Reverse Osmosis	502
Electrodialysis	511
Disposal of Membrane Waste Streams	516
16. Oxidation	524
Introduction	524
Oxidation Chemistry	524
Oxidants Used in Water Treatment	528
Application of Oxidants in Water Treatment	534
Selection of an Oxidation Process	546
17. Activated Carbon Treatment	555
Past Practices	555
Recent Developments	555
Current Treatment Practices	556
Principles of Carbon Adsorption	557

Adsorptive Characterization of Activated Carbons	558
Physical Characterization of Activated Carbons	561
Design of Activated Carbon Facilities for Water Treatment	563
Carbon Adsorption Enhancement with Ozone	574
Experiences with Activated Carbon	576
18. Ion Exchange and Activated Alumina Sorption	587
Introduction	587
Ion Exchange	587
Sorption on Activated Alumina	606
19. Disinfection	614
Regulatory Requirements	615
General Design Issues	617
Disinfection Alternatives	618
Disinfectant Selection	657
20. Fluoridation and Defluoridation	667
Introduction	667
Fluoride Research	667
Fluoridation Standards and Recommendations	670
Fluoridation	670
Fluoridation Systems	673
Defluoridation	675
21. Distribution System Corrosion: Monitoring and Control	680
Introduction	680
Corrosion Basics	681
Corrosion Assessment	689
Mitigating Corrosion	708
General Chemical Information	716
22. Water Quality Control in Distribution Systems	722
Introduction	722
Traditional Concerns	723
Emerging Concerns	724
Control of Distribution System Water Quality Problems	727
Operation and Maintenance to Improve Water Quality in Distribution Systems	731
Water Quality Modeling in Distribution Systems	732
23. Residuals Management	742
Introduction	742
Characterization of Residuals	742
Minimizing Residuals Production	763
Thickening and Dewatering Alternatives	766

Recovery of Coagulants	791
Ultimate Solids Disposal	794
Radioactive Waste Disposal	804
Membrane Concentrate Disposal	807
24. Chemical Storage and Feeding Systems	819
Introduction	819
Chemical Selection	819
Design Considerations	826
25. Package Water Treatment Systems	866
Introduction	866
Conventional Package Systems	867
Contact Clarification-Filtration Package Systems	871
High-Rate Clarification-Filtration Package Systems	880
Application Criteria and Requirements	886
Operational Considerations	886
26. Plant Hydraulics	888
Introduction	888
General Design Considerations	888
Component Design Considerations	889
Flow Measurement—Open Channel	932
Flow Measurement—Closed Conduits	940
Filters	944
Pressure Surge	947
Tracer Studies	949
27. Storage	953
Introduction	953
Capacity	953
Number and Location of Reservoirs	958
Types of Storage Reservoirs	959
Design Considerations for Conventional Storage	959
28. Distribution Systems	971
Introduction	971
System Capacity	971
System Design	972
Water Distribution System Modeling and Hydraulic Analysis	973
Pipeline Location, Protection, and Materials of Construction	979
29. Pumping Systems	983
Introduction	983
Specific Speed	983

Affinity Laws	986
Net Positive Suction Head	990
Pumping System Curve	991
Power	993
Suction Conditions	999
Centrifugal Pumps	1000
Positive-Displacement Pumps	1004
Variable-Speed Pumping	1008
Other Issues	1008
Pump Layout	1008
30. Energy Management for Water Treatment Facilities	1011
Introduction	1011
Electrical Energy Fundamentals	1011
Energy Consumption in Water Treatment Plants	1012
Energy Efficiency Considerations for Water Systems: An Overview	1013
Energy Optimization Studies	1014
Electric Motors	1022
Variable-Speed Drives	1025
Electric Utility Billing Schedules	1031
Energy Management Systems	1032
Supervisory Control and Data Acquisition Systems	1036
Optimum Conveyance Systems	1038
Pumping Considerations	1039
Lighting	1041
Water Conservation	1046
31. Electrical Design Considerations	1049
Introduction	1049
Electrical Planning	1049
Loads and Voltage Level	1049
Serving Utility and Available Electrical Services	1051
Auxiliary Power Systems	1051
Support Systems	1052
Site Layout	1053
Major Electrical Equipment and Space	1054
Hazardous and Corrosive Areas	1054
Instrumentation	1054
32. Economic and Financial Issues	1057
Economic Evaluation of Alternatives	1057
Funding Sources and Mechanisms	1063
Appendix A: Financial Statistics Tables	1069
Appendix B: Periodic Table of the Elements	1077

Appendix C: Atomic Weights	1078
Appendix D: Metric Conversion Units	1081
Appendix E: Physical Properties of Water	1083
Appendix F: Compatibility of Various Chemicals	1085
Appendix G: Chemicals Used in Treatment of Water and Wastewater	1095
Index	1124