Domestic Water Treatment

By

J. Paul Guyer, P.E., R.A.

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4 PDH HOURS

J. Paul Guyer, P.E., R.A.

Paul Guyer is a registered civil engineer, mechanical engineer, fire protection engineer, and architect with over 35 years experience in the design of buildings and related infrastructure. For an additional 9 years he was a senior advisor to the California Legislature on infrastructure and capital outlay issues. He is a graduate of Stanford University and has held numerous national, state and local positions with the American Society of Civil Engineers and National Society of Professional Engineers.

CONTENTS

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1. WATER TREATMENT. Treatment consists of adding and/or removing substances from water so as to bring about a desired change in quality. In general, treatment is provided to protect public health or to improve the acceptability (aesthetic quality) of the finished product. This section is a guide to basic information on most of the common water treatment processes.

2. REFERENCES. Publications containing additional information on water treatment are listed below. Subsequent references to these sources in this discussion use only the paragraph number shown in parentheses after the title. This number corresponds to the paragraph number of the document in the *Appendix: Applicable Documents*. Pertinent water treatment information can be found in the following published sources:

a) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources (par. A.2.46)

b) Identification and Treatment of Tastes and Odors in Drinking Water (par. A.3.6)

c) Lead and Copper Rule Guidance Manual-Vol. I: Monitoring (par. A.2.48)

d) Lead and Copper Rule Guidance Manual-Vol. II: Corrosion Control Treatment (par. A.2.49)

e) Lead Control Strategies (par. A.2.50)

f) Manual of Water Supply Practices: Automation and Instrumentation (par. A.2.1)

g) Manual of Water Supply Practices: Chlorination Principles and Practices (par. A.2.13)

h) Manual of Water Supply Practices: Flow Meters in Water Supply (par. A.2.24)

i) Manual of Water Supply Practices: Groundwater (par. A.2.14)

j) Manual of Water Supply Practices: Operational Control of Coagulation and Filtration Processes (par. A.2.26)

k) Manual of Water Supply Practices: Precoat Filtration (par. A.2.21)

l) Manual of Water Supply Practices: Problem Organisms in Water—Identification and Treatment (par. A.2.6)

m) Manual of Water Supply Practices: Reverse Osmosis and Nanofiltration (par. A.2.28)

n) Manual of Water Supply Practices: Water Fluoridation Principles and Practices (par. A.2.3)

o) Ozone in Water Treatment: Application and Engineering (par. A.3.12)

p) Principles and Practices of Water Supply Operations Series: Basic Science Concepts and Applications (par. A.1.1)

q) Principles and Practices of Water Supply Operations Series: Water Quality (par. A.1.2)

r) Principles and Practices of Water Supply Operations Series: Water Sources (par. A.1.3)

s) Principles and Practices of Water Supply Operations Series: Water Treatment (par. A.1.5)

t) Procedures Manual for Polymer Selection in Water Treatment (par. A.2.58)

u) Procedures Manual for Selection of Coagulant, Filtration, and Sludge Conditioning Aids in Water Treatment (par. A.2.59)

v) Reverse Osmosis: A Practical Guide for Industrial Users (par. A.3.15)

w) Standard Methods for the Examination of Water and Wastewater (par. A.2.62)

x) The U.S.A.I.D. Desalination Manual (par. A.2.64)

3. TREATING WATER AT THE SOURCE. Treatment of water supplies is generally done at a treatment plant where positive monitoring and control is possible. Sometimes, however, providing treatment at the source (in situ treatment) is more economical or practical. Treating reservoirs for algae or zebra mussel control is an example of in situ treatment. For detailed information on specific in situ treatment techniques.

4. UNIT TREATMENT PROCESSES. For each process, guidance and information is provided on fundamentals of how water treatment facilities and related equipment operate, common operating problems, process control tests, applicable regulations, recordkeeping, and safety precautions.

4.1 PRELIMINARY TREATMENT. Preliminary treatment (pretreatment) is used to remove objects or grit that could clog or damage downstream equipment. Pretreatment includes several processes that may be used alone or together.

4.2 COAGULATION AND FLOCCULATION. Suspended material that is too fine to be removed by plain sedimentation can be clustered into settleable particles through the process of coagulation and flocculation. Coagulation and flocculation, along with filtration, are sometimes referred to as “conventional” treatment.

4.3 SEDIMENTATION BASINS AND CLARIFIERS. In conventional water treatment, sedimentation is the step between flocculation and filtration. Sedimentation (or “clarification,” as it is sometimes called), is also used to remove the large quantities of chemical precipitates formed during lime softening. This reference also gives specific information on basin types (conventional rectangular basins, center-feed basins, peripheral-feed basins, spiral-flow basins, and shallow basins), as well as plate and tube settlers. Information on other clarification processes found in this reference include solids-contact basins, dissolved-air flotation, and contact clarifiers. In addition to the basic topics, information is provided on waste disposal and equipment maintenance.

4.4 FILTRATION. In conventional water treatment, filtration is used to remove floc, suspended matter, and microorganisms carried over from the preceding unit processes. When groundwater is treated to remove hardness, iron and manganese filtration removes chemical precipitates. Basic information on filter operation can be found in par. A.1.5. Topics include conventional filtration, direct filtration, slow sand filtration, diatomaceous earth filtration, filter media, underdrain systems, surface agitators, filter control equipment, backwashing procedures, and optimizing filter effluent quality.

Additional, related information is contained in the publications listed in pars. A.2.21, A.2.26, and A.2.46.

4.5 DISINFECTION. In water treatment, disinfection is usually the last barrier to prevent disease-causing organisms from reaching the consumer. Disinfection does not sterilize water—that is, completely destroy all living organisms. However, experience has shown that disinfection, in combination with effective filtration, can protect humans from most waterborne pathogens (disease-causing agents). This section focuses on chlorine and hypochlorite compounds, but information on other disinfectant/oxidants such as ozone, permanganate, and chlorine dioxide is provided. General topics include chlorine chemistry, application points, chlorine handling and storage, chlorine equipment, and regulations including trihalomethanes (THMs) and other disinfection byproducts (DBPs), as well as concentration and contact time (CT)..

4.6 FLUORIDATION. Fluoride ion is added to public water supplies to reduce tooth decay in children. Where fluoridation is practiced, it is strictly regulated by state and local health departments. Although there are no federal regulations requiring fluoridation, EPA endorses the practice. This section provides information on chemicals, chemical feed equipment, dosage requirements, and testing.

4.7 CONTROL OF CORROSION AND SCALING. A primary goal of water treatment is to produce stable water—that is, water that is neither corrosive nor scale-forming. Meeting this goal is not always easy. The focus of this section is on the characteristics and control of scale and internal corrosion of pipes. In 1991, the USEPA enacted a regulation called the Lead and Copper Rule. This rule is designed to reduce exposure to excessive lead and copper in drinking water. These sources also provide guidance on developing control strategies.

4.8 IRON AND MANGANESE CONTROL. Iron and manganese are natural contaminants found in many groundwater supplies and in stratified lakes and reservoirs. These elements are not normally harmful to human health, but relatively small amounts of iron and manganese can give water an undesirable taste, discolor plumbing fixtures, and stain laundry.

4.9 LIME SOFTENING. Certain dissolved minerals, mainly calcium and magnesium, give water the property known as “hardness.” Hardness is a folk term inherited from when it was difficult or “hard” to wash with highly mineralized waters. While hardness minerals are not at all harmful to human health, they can cause scaling and adversely affect aesthetics. Reducing minerals that cause hardness is called “softening.” The focus of this paragraph is on lime and lime-soda softening. Other processes used for softening are ion exchange and membrane treatment. Ion exchange softening is covered in par. 4.10; membrane technology is covered in par. 4.13. Besides the general topics, subjects covered include basic chemistry of the lime-soda process and recarbonation, as well as description of treatment facilities.

4.10 ION EXCHANGE PROCESSES. Ion exchange is a common alternative for lime soda softening, especially for small water systems or for systems with dispersed water sources, such as supply wells. Ion exchange can also be used to demineralize water completely, but the focus of this paragraph is on softening.

4.11 ADSORPTION. Carbon adsorption has historically been used to improve the appearance and flavor of water. Today, the adsorption process is gaining wider use in the water works industry to remove a broad range of organic contaminants. Paragraph A.1.5 includes information on the principles of adsorption plus the facilities for applying powdered activated carbon (PAC) and granular activated carbon (GAC).

4.12 AERATION. Aeration is used to reduce the concentration of certain objectionable dissolved gases such as hydrogen sulfide, carbon dioxide, and volatile organic chemicals (VOCs) and to oxidize dissolved metals. Aeration is often the first process used in a water treatment plant. At other installations, aeration and disinfection may be the only treatment provided. Information on various types of aerators can be found in par. A.1.5.

4.13 MEMBRANE PROCESSES. In this process, water is forced through a porous membrane while contaminants are held back or rejected. The references listed in pars. A.1.5, A.2.28, and A.3.15 provide information on the types of membrane processes, operating principles, membrane types, feedwater concerns, post-treatment, membrane cleaning, and reject water disposal.

5. TASTE AND ODOR CONTROL. Controlling tastes and odors is one of the most troublesome problems in water treatment. Tastes and odors appear in both ground and surface water supplies. The main means of control are aeration, adsorption and oxidation.

6. CONTROLLING ORGANIC CHEMICALS. The SDWA regulates four categories of organic contaminants: pesticides, volatile organic compounds (VOCs), synthetic organic chemicals (SOCs), and DBPs. Effectively removing organic chemicals requires special treatment techniques.

6.1 PESTICIDES GROUP—TREATMENT. Activated carbon adsorption is the most effective method available for removing pesticides. Some pesticide removal occurs during conventional treatment by coagulation, sedimentation, and filtration. However, removals are very small, usually less than 10 percent. Chemical oxidation with chlorine, ozone, or potassium permanganate also removes pesticides, also generally less than 10 percent.

a) Conventional water treatment followed by activated carbon adsorption effectively removes pesticides from drinking water. PAC or GAC can be used for pesticide removal. The effectiveness of carbon adsorption depends on the concentrations of adsorbent and adsorbate, contact or residence time, and the competition for available adsorption sites, as well as the temperature and pH of the water. Because of these variabilities, no general rule can be given for carbon dosage or design criteria for activated carbon treatment. Dosage and design requirements are generally determined by laboratory methods or pilot plant operations.

b) Because pesticides and their carrier solvents have odors, water treatment for removing these odors can somewhat reduce pesticide levels. However, where a few milligrams per liter of PAC may be adequate for odor control, several more milligrams per liter are generally required to remove organics. Relying on odors to signal pesticide contamination or relying on intermittent odor control by PAC to ensure a safe pesticide level is risky and considered poor practice. Where PAC is used, multiple points of injection should be considered for maximum efficiency of the adsorbant (to maximize pesticide removal). A disadvantage of PAC is that the sludge formed after application is sometimes troublesome and difficult to manage.

c) The uncertainties involved in pesticide occurrence in water supplies make GAC beds that are continuously online the best protection against pesticide contamination. Organic pesticides have been demonstrated to be very strongly adsorbed both on virgin GAC and on exhausted GAC used for odor control. The life of a GAC bed for pesticide removal is not indefinite. However, if a GAC bed's usefulness has been exhausted from adsorbing odors that means it is generally time to replace it for pesticide control, too.

6.2 VOCS GROUP

6.2.1 SOURCES OF VOCS. Water supplies derived from groundwaters, as well as from surface waters, may contain VOCs. Contamination is most common in urban or industrial areas, and is generally believed to be from improper disposal of hazardous wastes and industrial discharges. Many of the regulated VOCs are suspected carcinogens, and the others may damage the kidneys, liver, or nervous system. The presence of one of these compounds, even at a low level, is a concern since these are manufactured chemicals (not naturally occurring in the environment), and their presence indicates the potential for further contamination of that source water. Groundwater is of particular concern in that these waters move very slowly and do not have a rapid natural cleansing mechanism. Thus, once groundwaters are contaminated, they will generally remain so for many years or decades.

6.2.2 TREATMENT. Methods for removing VOCs include aeration and GAC. PAC treatment or conventional drinking water treatment (coagulation, sedimentation, and filtration) have not proven effective. Methods such as reverse osmosis and macromolecular resins may eventually prove useful in removing VOCs. Before implementing a VOC control strategy, check local environmental regulations and permit requirements. Aeration could cause violation of air quality standards. Spent carbon from GAC adsorbers could be considered a hazardous waste.

6.3 DBPs GROUP

6.3.1 SOURCES OF DBPS. Chlorine, when used for bacterial and viral disinfection of water supplies, interacts with organic precursors present in natural waters to form a variety of chlorinated organic compounds collectively called disinfection byproducts. DBPs are associated with a number of chronic health problems, including cancer. Because the natural organic precursors are more commonly found in surface waters, water taken from a surface source is more likely than groundwater (with some exceptions) to have high DBP levels after chlorination. A number of DBPs have been targeted for regulation, including THMs and haloacetic acids (HAAs). Other oxidants used for disinfection, i.e., ozone and chlorine dioxide, can also form DBPs (although not to the same extent as chlorine).

6.3.2 TREATMENT. Treatment options available to meet DBP standards are to substitute new disinfectants for chlorine that do not generate DBPs or that produce fewer DBPs; to reduce organic precursor concentrations before chlorination; and to remove DBPs after formation.

a) Ozone, chlorine dioxide, and chloramine are possible alternate disinfectants. It is good practice to monitor carefully the microbiological quality of the treated and distributed water during the transition period to an alternate disinfectant.

b) Treatment processes to reduce or control precursor levels include offline raw water storage, aeration, improved coagulation, ion exchange resins, adsorption on PAC and GAC, ozone-enhanced biological activated carbon (BAC), and adjustment of the chlorine application point. Bench- and pilot-plant studies should be performed to determine which treatment process will most effectively reduce precursor levels. Carbon adsorption is considered effective in removing high levels of precursors.

(1) The air-water ratio required for aeration to effectively remove volatile organic precursors is higher than the air-water ratios needed for taste and odor control or iron and manganese removal. The high air-to-water ratio promotes the growth of aerobic organisms (such as algae) and can be a significant problem.

(2) Some organic precursors are removed during coagulation. These organics often adhere to the particulate matter that settles.

(3) High doses of PAC removes only a portion of the precursors. High costs and sludge problems limit the use of PAC for precursor control.

(4) GAC can adsorb a wide spectrum of organics. Frequently, GAC adsorbs enough precursor material so that chlorine disinfection can be practiced following GAC treatment without forming excessive DBPs.

(5) One of the quickest and least expensive ways of maintaining low DBP levels in chlorine-treated water is to chlorinate the highest quality of water (water with the lowest possible organic content). If water is filtered, the highest quality of water is filter effluent. However, unless additional contact tanks are constructed, the contact time is not usually long enough for adequate disinfection. Chlorinating coagulated and settled water reduces (but does not eliminate) DBP levels in finished water. DBPs continue to form during distribution. Disinfection before filtration limits bacterial growth in the filters. The absence of a disinfectant at the beginning of treatment may cause problems because of the growth of algae, slime, and higher forms in the early part of water treatment plants.

c) Technology available for DBP reduction includes PAC, ozonation, GAC, and aeration.

(1) Very high doses of PAC and ozone are required to get substantial (but not complete) DBP removal. These processes would be too expensive in light of the removals obtained.

(2) GAC filters can effectively remove DBPs (as well as other organics) below contaminant levels.

(3) Locating the aeration process after chlorination will remove volatile DBPs from the finished water. However, organic precursors not removed in the water treatment process continue to react with the remaining chlorine residual after aeration to raise DBP levels in the distribution system. Therefore, removing volatile DBPs from finished water by aeration is not considered a viable control method.

6.3.3 STATE APPROVAL OF TREATMENT. A facility must obtain state approval before significantly modifying its treatment process to comply with DBP requirements. The facility is required to submit a detailed plan of proposed modifications and safeguards it will implement to ensure that the bacteriological quality of the drinking water serviced is not decreased by such changes. Each system must comply with the provisions set forth in the state-approved plan.

7. TREATMENT PLANT INSTRUMENTATION AND CONTROL (I&C). The references below include information on meters, recorders, alarms, and automatic control systems.

8. CHEMICALS AND CHEMICAL APPLICATION. Information about chemicals commonly used in the water works industry are listed in Table 1. For additional information on specific chemicals used in given unit processes—including application, storage, handling, and chemical safety—refer to the appropriate unit process heading in this section.

9. WATER TREATMENT PLANT RESIDUES. The most common residues from water treatment processes are designated as either “slurries” or “sludges.” Slurry solids are usually spent activated carbon or waste diatomaceous earth from diatomaceous filters. Sludges may be mud-like, natural sediments; gelatinous aluminum, magnesium, or iron oxides and hydroxides; or calcium carbonate (lime sludge). Water treatment processes that produce these sludges are presedimentation of raw water; chemical coagulation, flocculation, and sedimentation; lime-soda ash softening; iron and manganese removal; and filter backwashing. Other residues are surface water intake screenings; aqueous solutions of sodium, calcium, and magnesium chlorides that result from regeneration of cation exchange water softening resins; and reject stream from membrane processes. Refer to the applicable paragraphs in this section for a discussion of the residue characteristics and appropriate solids concentration and dewatering techniques for the various water treatment processes.

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Avail-able Forms	Weight, lb/ft^3	Solu-bility, lb/gal	Commercial Strength	Character-istics	AWWA Stan-dard
Coagulation									
Aluminum sulfate, $Al_2(SO_4)_3 \cdot 14H_2O$	Alum, filter alum, sulfate of alumina	100-, 200-lb bags; 300-, 400-lb bbls.; bulk (carloads)	Dry—iron, steel; solution—lead-lined rubber, silicon, asphalt, 316 stainless steel	Ivory-colored: powder granule lump	 38-45 60-63 62-67	4.2 (60°F)	15-22% Al_2O_3	pH of 1% solution, 3.4	B 403
	Liquid alum	Bulk; tank trucks, tank cars		Pale green liquid			8.3% Al_2O_3 liquid	Crystallizes at 5°F	
Ammonium aluminum sulfate, $Al_2(SO_4)_3(NH_4)_2SO_4 \cdot 24H_2O$	Ammonia alum, crystal alum	Bags; bbls.; bulk	Duriron, lead, rubber, silicon, iron, stoneware	Lump Nut Pea Powdered	64-68 62 65 60	0.3 (32°F), 8.3 (212°F)	11% Al_2O_3	pH of 1% solution, 3.5	
Bentonite	Colloidal clay, volclay, wilkinite	100-lb bags; bulk	Iron, steel	Powder, pellet, mixed sizes	60	(Insol-uble colloi-dal suspen-sion used)			
Ferric chloride, (a) $FeCl_3$(35-45% solution)	"Ferri-chlor," chloride of iron	5-, 13-gal carboys; trucks; tank cars	Glass, rubber, stoneware, synthetic resins	Dark brown syrupy liquid		Complete	37-47% $FeCl_3$, 20-21% Fe		
(b) $FeCl_3 \cdot 6H_2O$	Crystal ferric chloride	300-lb bbls.		Yellow-brown lump			59-61% $FeCl_3$, 20-21% Fe	Hygroscopic (store lumps and powder in tight containers); no dry feed; optimum pH, 4.0-11.0	

Table 1

Chemicals used in water treatment

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Avail-able Forms	Weight, lb/ft^3	Solu-bility, lb/gal	Commercial Strength	Character-istics	AWWA Stan-dard
(c) $FeCl_3$	Anhydrous ferric chloride	500-lb casks; 100-, 300-, 400-lb kegs		Green-black power			98% $FeCl_3$, 34% Fe		
Ferric sulfate $Fe_2(SO_4)_3 \cdot 9H_2O$	"Ferri-floc," Ferrisul	100-, 175-lb bags; 400-, 425-lb drums	Ceramics, lead, plastic, rubber, 18-8 stainless steel	Red-brown powder 70 or granule 72		Soluble in 2-4 parts cold water	90-94% $Fe_2(SO_4)_3$, 25-26% Fe	Mildly hygroscopic; coagulant at pH 3.5-11.0	B 406
Ferrous sulfate, $FeSO_4 \cdot 7H_2O$	Copperas, green vitriol	Bags; bbls.; bulk	Asphalt, concrete, lead, tin, wood	Green crystal granule, lump	63-66	0.5 (32°F), 1.0 (68°F), 1.4 (86°F)	55% $FeSO_4$, 20% Fe	Hygroscopic; cakes in storage; optimum pH, 8.5-11.0	B 402
Potassium aluminum sulfate, $K_2SO_4Al_2(SO_4)_3 \cdot 24H_2O$	Potash alum	Bags, lead-lined; bulk (carloads)	Lead, lead-lined, rubber, stoneware	Lump Granule Powder	62-67 60-65 60	3.0 (68°F), 3.3 (86°F)	10-11% Al_2O_3	Low, even solubility; pH of 1% solution, 3.5	
Sodium aluminate, $Na_2OAl_2O_3$	Soda alum	100-, 150-lb bags; 250-, 440-lb drums; solution	Iron, plastics, rubber, steel	Brown powder, liquid (27°Be)	50-60	Complete	70-80% $Na_2Al_2O_4$, min. 32% $NA_2A1_2O_4$	Hopper agitation required for dry feed	B 405
Sodium silicate, Na_2OSiO_2	Water glass	Drums; bulk (tank trucks, tank cars)	Cast iron, rubber, steel	Opaque, viscous liquid			38-42 Bé	Variable ratio of Na_2O to SiO_2; pH of 1% solution, 12.3	B 404
Disinfection and Dechlorinating Agents									
Ammonium aluminum sulfate, $Al_2(SO_4)_3(NH_4)_2SO_4 \cdot 24H_2O$	Ammonia alum, crystal alum	Bags; bbls.; bulk	Duriron, lead, rubber, silicon, iron, stoneware	Lump Nut Pea Powdered	64-68 62 65 60	0.3 (32°F), 8.3 (212°F)	11% Al_2O_3	pH of 1% solution, 3.5	

Table 1 (continued)

Chemicals used in water treatment

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Avail-able Forms	Weight, lb/ft^3	Solu-bility, lb/gal	Commercial Strength	Character-istics	AWWA Stan-dard
Ammonium sulfate, $(NH_4)_2SO_4$	Sulfate of ammonia	100-lb bags	Ceramics, plastics, rubber, iron (dry)	White or brown crystal		42.5	6.3 (68°F)	Cakes in dry feed; add $CaSO_4$ for free flow	B 302
Anhydrous ammonia, NH_3	Ammonia	50-, 100-, 150-lb cylinders; in bulk (tank cars and trucks)	Glass, iron, monel metal, nickel, steel	Colorless gas		3.9 (32°F) 3.1 (60°F) 1.8 (125°F)	99-100% NH_3		
Aqua ammonia, NH_4OH	Ammonia water, ammonium hydrate, ammonium hydroxide	Carboys; 750-lb drums; 8,000-gal tank cars or trucks	Glass, iron, monel metal, nickel, steel	Colorless liquid		Complete	29.4% NH_3 (26° Bé)		
Calcium hypochlorite, $CaOCl_2 \cdot 4H_2O$	"HTH," Per-chloron, "Pitt-chlor"	5-lb cans; 100-, 300-, 800-lb drums	Glass, rubber, stoneware, wood	White granule, powder	52.5		70% available Cl_2	1-3% available $C1_2$, solution used	B 300
Chlorinated lime, CaO $2CaOC1_2 \cdot 3H_2O$	Bleaching power, chloride of lime	100-, 300-, 800-lb drums	Glass, rubber, stoneware, wood	White powder	48		25-37% available Cl_2	Deteriorates	
Chlorine, Cl_2	Chlorine gas, liquid chlorine	100-, 150-lb cylinders; 1-ton containers; 16-, 30-, 55-, 85-, and 90-ton tank cars; tank trucks (about 15-16 tons)	Dry-black iron, copper, steel; wet gas-glass, hard rubber, silver	Liquefied gas under pressure	91.7	0.07 (60°F), 0.04 (100°F)	99.8% Cl_2		B 301
Chlorine dioxide, ClO_2	Chlorine dioxide	Generated as used	Plastics, soft rubber (avoid hard rubber)	Yellow-red gas		0.02 (30 mm)	26.3% available Cl_2		

Table 1 (continued)

Chemicals used in water treatment

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Avail-able Forms	Weight, lb/ft^3	Solu-bility, lb/gal	Commercial Strength	Character-istics	AWWA Stan-dard
Ozone, O_3	Ozone	Generated at site of applica-tion	Aluminum, ceramics, iron, steel, wood	Colorless gas					
Pyrosodium sulfite $Na_2O_5S_2$	Sodium meta-bisulfite	Bags; drums; bbls.	Iron, steel, wood	White crystal-line powder		Complete in water	Dry, 67% SO_2; sol. 33.3% SO_2	Sulfurous odor	
Sodium chlorite, $NaClO_2$	Technical sodium chlorite	100-lb drums	Metals (avoid cellulose materials)	Light orange powder, flake			82% $NaClO_2$, 30% available Cl_2	Generates ClO_2 at pH 3.0	B 303
Sodium hypochlorite, NaOCl	Sodium hypo-chlorite	5-, 13-gal carboy; 1,300-2,000-gal tank trucks	Ceramics, glass, plastics, rubber	Light yellow liquid			12-15% available Cl_2		B 300
Sodium sulfite, Na_2SO_3	Sulfite	Bags; drums; bbls.	Iron, steel, wood	White crystal-line powder		Complete in water	23% SO_2	Sulfurous taste and odor	
Sulfur dioxide, SO_2	Sulfurous acid anhydride	Steel cylinders; ton contain-ers; tank cars or trucks	Aluminum, brass, Durco D-10, stainless steel 316	Colorless gas		20% at 32°F, complete in water	99% SO_2	Irritating gas	
Fluoridation and Fluoride Adjustment									
Ammonium silico fluoride, $(NH_4)_2SIF_6$	Ammonium fluor-silicate	100- and 400-lb drums	Steel, iron, lead	White crystals		1.7 (63°F)	100%	White, free-flowing solid	
Calcium fluoride, CaF_2	Fluorspar	Bags; drums; bbls.; hopper cars; trucks	Steel, iron, lead	Powder		Very slight	85% CaF_2, less than 5% SIO_2		

Table 1 (continued)

Chemicals used in water treatment

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Avail-able Forms	Weight, lb/ft^3	Solu-bility, lb/gal	Commercial Strength	Character-istics	AWWA Stan-dard
Hydro-fluosilicic acid, H_2SiF_6	Fluo-silicic acid	Rubber-lined drums; trucks; or R.R. tank cars	Rubber-lined steel, PVC	Liquid		Approx. 1.2 (68°F)	Approx. 35%		B 703
Hydrogen fluoride, HF	Hydro-fluoric acid	Steel drums; tank cars	Steel	Liquid			70%	Below 60%, steel cannot be used	
Sodium fluoride NaF_5	Fluoride	Bags; bbls.; fiber; drums; kegs	Iron, lead, steel	Nile blue or white powder; light dense	50 75	0.35 (most temps.)	90-95% NaF	pH of 4% solution, 6.6	B 701
Sodium silicofluoride, Na_2SiF_6	Sodium silico-fluoride	Bags; bbls.; fiber; drums	Iron, lead, steel	Nile blue or yellowish-white powder	75	0.03 (2°F), 0.06 (72°F), 0.12 (140°F)	99% Na_2SiF_6	pH of 1% solution, 5.3	B 702
Fluoride Adjustment									
Aluminum oxide, Al_2O_3	Activated alumina	Bags; drums	Iron, lead, steel	Powder, granules (up to 1-1/2-in. diam)	Vari-able	Insol-uble	100%		
Bone charcoal C	"Fluo-Carb"	Bags; drums; bulk	Wood, iron, steel	Granules	Vari-able			Black; best used in beds for presolution	
Tricalcium phosphate $Ca_3O_8P_2$	"Fluorex"	Bags; drums; bulk; bbls.	Iron, steel	Granular technical	50-63	Insol-uble		Also available as white powder	
High-magnesium lime $CaMgO_2$	Dolomitic lime	Bags; bbls; bulk	Wood, iron, steel	Lump, pebble, ground		Slakes slowly	58% CaO; 40% MgO$_2$		

Table 1 (continued)

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Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Avail-able Forms	Weight, lb/ft^3	Solu-bility, lb/gal	Commercial Strength	Character-istics	AWWA Stan-dard
Stabilization and Corrosion Control									
Carbon dioxide, CO_2	Carbon dioxide gas, liquid carbon dioxide	20-, 50-lb cylinders. Bulk; tank trucks, tank cars			47.4 @ 70°F				
Disodium phosphate, $Na_2HPO_4 \cdot 12H_2O$	Basic sodium phos-phate, DSP, secondary sodium phosphate	125-lb kegs; 200-lb bags; 325-lb bbls.	Cast iron, steel	Crystal	60-64	0.4 (32°F), 6.4 (86°F)	19.5% P_2O_5	Precipitates Ca, Mg; pH of 1% solution, 9.1	
Sodium hexameta-phosphate, $(NaPO_3)_n$	"Calgon," glassy phos-phate, vitreous phosphate	100-lb bags	Hard rubber, plastics, stainless steel	Crystal, flake, powder	47	1-4.2	66% P_2O_5 (unadjusted)	pH of 0.25% solution, 6.0-8.3	
Sodium hydroxide, NaOH	Caustic soda, soda lye	100-, 700-lb drums; bulk (trucks, tank cars)	Cast iron, rubber, steel	Flake Lump Liquid		2.4 (32°F) 4.4 (68°F), 4.8 (104°F)	98.9% NaOH, 74-76% NaO_2	Solid; hygroscopic; pH of 1% solution, 12.9	
Sulfuric acid, H_2SO_4	Oil of vitriol, vitriol	Bottles; carboys; drums; trucks, tank cars	Concen-trated—iron, steel; dilute—glass, lead, porcelain, rubber	Solution (60-66° Bé)		Complete	77.7% H_2SO_4 (60° Bé); 93.2% H_2SO_4 (66° Bé)	Approx. pH of 0.5% solution, 1.2	
Tetrasodium pyrophosphate, $Na_4P_2O_7 \cdot 10H_2O$	Alkaline sodium pyrophos-phate, TSPP	125-lb kegs; 200-lb bags; 300-lb bbls.	Cast iron, steel	White powder	68	0.6 (80°F), 3.3 (212°F)	53% P_2O_5	pH of 1% solution, 10.8	

Table 1 (continued)

Chemicals used in water treatment

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Avail-able Forms	Weight, lb/ft^3	Solu-bility, lb/gal	Commercial Strength	Character-istics	AWWA Stan-dard
Trisodium phosphate, $Na_3PO_4 \cdot 12H_2O$	Normal sodium phos-phate, tertiary sodium phos-phate, TSP	125-lb kegs; 200-lb bags; 325-lb bbls.	Cast iron, steel	Crystal: coarse medium standard	 56 58 61	0.1 (32°F), 13.0 (158°F)	19% P_2O_5	pH of 1% solution, 11.9	
				Softening					
Calcium hydroxide, $Ca(OH)_2$	Hydrated lime, slaked lime	0-lb bags; 100-lb bbls.; bulk (carloads) trucks	Asphalt, cement, iron, rubber, steel	White powder: light dense		0.014 (68°F) 0.012 (90°F)	85-99% $Ca(OH)_2$ 63-73% CaO	Hopper agitation required for dry feed of light form	B 202
Calcium oxide, CaO	Burnt lime, chemical lime, quick-lime, unslaked lime	50-lb bags; 100-lb bbls; bulk (carloads	Asphalt, cement, iron, rubber, steel	Lump, pebble, granule		Slakes to form hydrated lime	75-99% CaO	pH of saturated solution, 12.4; detention time, temperature, amount of water all critical for effluent slaking	B 202
Sodium carbondate, Na_2CO_3	Soda ash	Bags; bbls.; bulk (carloads, trucks)	Iron, rubber, steel	White powder: extra-light light dense	 23 35 65	1.5 (68°F), 2.3 (86°F)	99.4% Na_2CO_3, 58% Na_2O	Hopper agitation required for dry feed of light and extra-light forms; pH of 1% solution, 11.3	B 201
Sodium chloride, NaC1	Common salt, salt	Bags; bbls.; bulk (carloads)	Bronze, cement, rubber	Rock fine		2.9 (32°F), 3.0 (68°F), 86°F	98% NaC1		B 200

Table 1 (continued)

Chemicals used in water treatment

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Avail-able Forms	Weight, lb/ft^3	Solu-bility, lb/gal	Commercial Strength	Character-istics	AWWA Stan-dard
Taste and Odor Control									
Activated carbon, C	"Aqua Nuchar," "Hydro-darco," "Norite"	Bags; bulk	Dry—iron, steel; wet—rubber, silicon, iron, stainless steel	Black granules power	15	Insol-uble (suspen-sion used)			B 600 & B 604
Chlorine, $C1_2$	Chlorine gas, liquid chlorine	100-, 150-lb cylinders; 1-ton tanks; 16- 30-, 55-ton tank cars	Dry—black iron, copper, steel; wet gas—glass, hard rubber, silver	Liquefied gas under pressure	91.7	0.07 (60°F), 0.04 (100°F)	99.8% $C1_2$		B 301
Chlorine dioxide, ClO_2	Chlorine dioxide	Generated as used	Plastics, soft rubber (avoid hard rubber)	Yellow-red gas		0.02 (30 mm)	26.3% available $C1_2$		
Copper sulfate, $CuSO_4 \cdot 5H_2O$	Blue vitriol, blue stone	100-lb bags; 450-lb bbls.; drums	Asphalt, silicon, iron, stainless steel	Crystal Lump Power	75-90 73-80 60-64	1.6 (32°F), 2.2 (68°F), 2.6 (86°F)	99% $CuSO_4$		B 602
Ozone O_3	Ozone	Generated at site of appli-cation	Aluminum, ceramics, glass	Colorless gas					
Potassium permanganate, $KMnO_4$	Purple salt	Bulk; bbls.; drums	Iron, steel, wood	Purple crystals		0.23 (32°F) 0.54 (68°F) 1.05 (104°F)	100%	Danger of explosion on contact with organic matters	B 603

Table 1 (continued)

Chemicals used in water treatment

Type of Waste	Quantities and Characteristics	Treatment Required	Disposal Possibilities
Screenings	Vary widely; evaluate particular water source; check other plants using same water source or other similar plants.	None.	Return to watercourse if quantities are small. Truck to landfill along with other plant solid waste. Investigate disposal with wastewater treatment plant screenings.
Presedimentation sludges	Vary widely; evaluate particular water source; check other plants using same water source or other similar plants.	Dewatering in lagoon, sand drying bed, or mechanical unit may be required.	Dredging or draglining and hauling to landfill; multiple, drainage basins make cleaning easier.
Chemical clarification sludges	Composed of raw water impurities and coagulation chemicals. Solids content - 0.1% to 2%; 75-90% of total is suspended; 20-40% of total is volatile. Dry unit weight 75-95 lbs/ft^3. Gelatinous.	Gravity thickening is often desir-able, recycling supernatant to plant influent. (3) Sludge concentrations of 0.5-1.0% can be obtained. In addition to gravity thickening, dewatering processes may also be used: Drying beds. Freeze/thaw treatment processes are effective for alum sludge dewatering but expensive except in climates where sludges can be lagooned and frozen naturally.	Send concentrated sludge or continuously withdrawn sludge to wastewater treatment plant.(1) Haul dried sludge to landfill

Table 2

Water Treatment Plant Residue Disposal Summary

Type of Waste	Quantities and Characteristics	Treatment Required	Disposal Possibilities
		Centrifuges and vacuum filters dewater sludges up to about 15% solids. Pre-coat vacuum filters dewater sludge up to 25% solids. Pressure filtration dewaters sludge to 25-40% solids, often requiring lime as conditioner.	
Filter wash water (2)	Normal wash generates about 150 gal/ft^2 filter area. Chemically-precipitated raw water impurities and coagulation chemicals. For alum plants, total solids varies with time up to 1,000 mg/L, average 400 mg/L. Plants removing iron and manganese may be 4 times higher in total solids.	Flow equalization and concentration through sedimentation and decanting.	Same as for coagulation sludges. Combine with coagulation sludge where applicable. Where no coagulation used, dispose as softening sludge. Gradually return entire flow to plant influent. (3)
Lime softening sludges	Assume 3 lb dry sludge solids per lb quicklime added.	Dewatering lime softening sludges is not particularly difficult. The following methods can be used following thickening:	Discharge to wastewater treatment plants. (1)

Table 2 (continued)

Water Treatment Plant Residue Disposal Summary

Type of Waste	Quantities and Characteristics	Treatment Required	Disposal Possibilities
	Clarifier underflow.	1. Lagooning (up to 50% solids). 2. Vacuum filtration (40-50% solids). 3. Centrifuging (50-60% solids). Return to water plant influent.	Dewatered sludge hauled to landfill (agricultural applications possible).
	Solids concentration is generally approximately 5%, but may range from 2 to 30%.		Recalcining generally limited to large plants (>20 mgd) by economic considerations.
	Non-gelatinous. Typically 85-95% calcium carbonate, with some magnesium hydroxide.		
Diatomaceous earth sludges	See filter manufacturer's literature for quantities. Solids normally 60-70% diatomaceous earth; remainder raw water impurities; dry density about 10 lb/ft^3; specific gravity 2.	Lagooning, with supernatant recycled to plant influent.	Haul solids from lagoon to landfill.
Carbon slurries	Quantities and characteristics variable.	Granular carbon can be regenerated and recycled. Powdered carbon cannot be regenerated; dispose of powdered carbon following dewatering.	Haul solids to landfill. Incinerate dewatered solids (high heating value).

Table 2 (continued)

Water Treatment Plant Residue Disposal Summary

Type of Waste	Quantities and Characteristics	Treatment Required	Disposal Possibilities
Cation exchange resin regeneration brines	See manufacturer's literature for quantities. Total dissolved solids up to 45,000 mg/L. Chlorides up to 112,000+ mg/L. Almost no suspended solids.	Evaporation lagoons where concentration is desired and climate permits	Best solution is ocean disposal. Return to watercourse only if brine can be greatly diluted. Discharge to wastewater treatment plant only if greatly diluted. Disposal wells possible but suitability is site-specific.

(1)For discharge to sanitary sewers, avoid cross connections and slug flow and always check:
- (a)Possible damage to sewer system from residue discharge.
- (b) Effects of residues on liquid and solids treatment processes at the wastewater treatment plant.
- (c) Hydraulic capacity of the wastewater treatment facilities.

(2) Sedimentation basins or solids contact reactions ahead of filters will generally remove 70-90% of total plant solids. The remainder of solids will appear in the filter wash water.

(3) Returning filter backwash and thickener overflow streams to plant influent may be viewed with disfavor by regulators because of the possibility of recycling pathogens.

Table 2 (continued)

Water Treatment Plant Residue Disposal Summary

9.1 DISPOSAL METHODS. It is preferable to dispose of residues in a way that is both economically and environmentally acceptable. Recovery and disposal systems often require increasing the solids content of a residue by removing water. The required solids concentration (and the method of concentration) depends on the chemical recovery or final disposal alternatives used. Table 2 summarizes water treatment plant residue-handling systems currently in use. Note: Do not discharge residue to a natural water course or public sewer without the approval of the applicable federal, state, and local authorities.

9.2 RECOVERY PROCESSES. Alum, ferric chloride, ferrous sulfate, magnesium carbonate, and lime can be recovered from waste sludge by various methods. However, recovery is not usually economical except at the largest municipal facilities and, thus, is not considered viable for many installations. However, manufacturers of alum and ferric coagulants will sometimes agree to accept waste sludges for reprocessing.

9.3 ULTIMATE DISPOSAL. Traditionally, water treatment plant wastes have been disposed of by discharge to rivers and lakes, either directly or by way of a storm sewer. Current environmental laws do not allow this because such discharge harms the receiving body of water (cloudy water, toxicity to aquatic life, formation of sludge banks). Following are alternative methods of ultimate sludge disposal, which, in some cases, may be economical and environmentally sound solutions.

9.3.1 DISCHARGE TO SANITARY SEWER. In general, water treatment plant residues can be disposed of by discharge to a sanitary sewer without upsetting the wastewater treatment processes. However, problems can result if the amount of sludge is too great.

a) The sewer can be overloaded hydraulically by large batch dumps of sludge. This problem can be handled by storing the sludge in a holding tank, then bleeding the sludge slowly into the sewer during periods of low wastewater flow (such as after midnight). However, sewer flow needs to be sufficient to prevent sludge solids from accumulating in the sewer, since the solids may then clog the sewer.

b) The water treatment sludge solids increase the amount of sludge to be disposed of at the sewage treatment plant. Therefore, the dewatering and disposal problems are not eliminated, but simply shifted elsewhere. Water treatment plant sludge is not affected by sludge digestion processes at the sewage treatment plant but does take up digester volume. In some cases, water plant sludges have been reported to clog digesters.

9.3.2 LANDFILL. Modern sanitary landfills are designed and operated to keep the amount of water leaching from the filled material to a minimum. For this reason, landfill regulations often require that sludges contain at least 20 percent dry solids, and sometimes require as high as 50 to 60 percent. Wet sludges are not acceptable because they are difficult to mix well with other solid wastes before covering, and because the large amount of water could percolate through the soil and pollute water supplies.

9.3.3 LAGOONS. Disposal lagoons are simply dewatering lagoons that are never cleaned out, thus eliminating the main operating problem of drying lagoons. The main disadvantage is that large land areas are permanently committed for use as lagoons. For plants with small sludge quantities and plentiful land, lagoons can be practical for sludge disposal.

9.3.4 LAND SPREADING OF LIME SLUDGE. In many agricultural areas, particularly in the Midwest, farming practices require that lime or limestone be added to the fields periodically to control soil pH. Sludge from lime water softening processes can be used for this purpose if it is sufficiently dewatered to allow easy handling.

9.4 LABORATORY CONTROL TESTS. The main control tests involved in sludge handling and disposal are the solids tests (total solids and suspended solids) used to determine the effectiveness of dewatering processes. Some recycling processes require testing for hazardous materials. Ocean disposal may require bioassay testing to determine the effect on the aquatic environment.

9.5 MAINTAINING RECORDS. The dewatering and ultimate disposal of water plant sludges and other residues can often be expensive. To manage water treatment plant residues adequately, maintain records on residue quantities and characteristics, chemical quantities used for residue treatment processes, results of laboratory control tests, and operating notes.

10. DESALINATION. Some geographic locations, including coastal areas, islands, and some inland regions, have little or no fresh water even though unlimited supplies of saline water are available. When it is necessary to establish and maintain installations in such areas, the water supply is generally derived by converting saline water into fresh water. Several methods are available, but they are all quite expensive and complicated to use. These methods include distillation, ion exchange, electrodialysis, and reverse osmosis. Other methods (such as freezing, hydrate formations, solvent extractions, and solar evaporation) are not considered practical desalination methods.

11. WATER SAMPLING AND ANALYSIS. Sampling and analysis for plant quality control differs from testing conducted to monitor compliance with the SDWA. Process tests are generally conducted by treatment plant personnel, are used to enhance and control plant performance, and are not required by law.

APPENDIX: APPLICABLE DOCUMENTS

A.1 BASIC LIST. Publications included in the basic list provide general information that is fundamental to the successful operation of all potable water systems. Publications on this list are updated periodically by the publisher; the latest edition of each is recommended for inclusion in the library of all fixed-base water systems.

A.1.1 PRINCIPLES AND PRACTICES OF WATER SUPPLY OPERATIONS SERIES: Basic Science Concepts and Applications (AWWA)

A.1.2 PRINCIPLES AND PRACTICES OF WATER SUPPLY OPERATIONS SERIES: Water Quality (AWWA)

A.1.3 PRINCIPLES AND PRACTICES OF WATER SUPPLY OPERATIONS SERIES: Water Sources (AWWA)

A.1.4 PRINCIPLES AND PRACTICES OF WATER SUPPLY OPERATIONS SERIES: Water Transmission and Distribution (AWWA)

A.1.5 PRINCIPLES AND PRACTICES OF WATER SUPPLY OPERATIONS SERIES: Water Treatment (AWWA)

A.2 SUPPLEMENTAL LIST. The supplemental list of references contains information on topics that do not apply to every installation. To the extent that the listed references do apply to an installation's water system, the latest editions of those selected publications are recommended for inclusion in the water utility's library. The single-topic references included in the supplemental list generally contain more detailed information than is found in references in the basic list.

A.2.1 MANUAL OF WATER SUPPLY PRACTICES: Automation and Instrumentation (AWWA M2)

A.2.2 MANUAL OF WATER SUPPLY PRACTICES: Safety Practices for Water Utilities (AWWA M3)

A.2.3 MANUAL OF WATER SUPPLY PRACTICES: Water Fluoridation Principles and Practices (AWWA M4)

A.2.4 MANUAL OF WATER SUPPLY PRACTICES: Water Utility Management Practices (AWWA M5)

A.2.5 MANUAL OF WATER SUPPLY PRACTICES: Water Meters— Selection, Installation, Testing and Maintenance (AWWA M6)

A.2.6 MANUAL OF WATER SUPPLY PRACTICES: Problem Organisms in Water—Identification and Treatment (AWWA M7)

A.2.7 MANUAL OF WATER SUPPLY PRACTICES: Concrete Pressure Pipe (AWWA M9)

A.2.8 MANUAL OF WATER SUPPLY PRACTICES: Steel Pipe—A Guide for Design and Installation (AWWA M11)

A.2.9 MANUAL OF WATER SUPPLY PRACTICES: Simplified Procedures for Water Examination (AWWA M12)

A.2.10 MANUAL OF WATER SUPPLY PRACTICES: Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14)

A.2.11 MANUAL OF WATER SUPPLY PRACTICES: Installation, Field Testing, and

Maintenance of Fire Hydrants (AWWA M17)

A.2.12 MANUAL OF WATER SUPPLY PRACTICES: Emergency Planning for Water Utility Management (AWWA M19)

A.2.13 MANUAL OF WATER SUPPLY PRACTICES: Chlorination Principles and Practices (AWWA M20)

A.2.14 MANUAL OF WATER SUPPLY PRACTICES: Groundwater (AWWA M21)

A.2.15 MANUAL OF WATER SUPPLY PRACTICES: Sizing Water Service Lines and Meters (AWWA M22)

A.2.16 MANUAL OF WATER SUPPLY PRACTICES: PVC Pipe Design and Installation (AWWA M23)

A.2.17 MANUAL OF WATER SUPPLY PRACTICES: Dual Water Systems (AWWA M24)

A.2.18 MANUAL OF WATER SUPPLY PRACTICES: Flexible-Membrane Covers and Linings for Potable Water Reservoirs (AWWA M25)

A.2.19 MANUAL OF WATER SUPPLY PRACTICES: External Corrosion—Introduction to Chemistry and Control (AWWA M27)

A.2.20 MANUAL OF WATER SUPPLY PRACTICES: Cleaning and Lining Water Mains (AWWA M28)

A.2.21 MANUAL OF WATER SUPPLY PRACTICES: Precoat Filtration (AWWA M30)

A.2.22 MANUAL OF WATER SUPPLY PRACTICES: Distribution System Requirements for Fire Protection (AWWA M31)

A.2.23 MANUAL OF WATER SUPPLY PRACTICES: Distribution Network Analysis for Water Utilities (AWWA M32)

A.2.24 MANUAL OF WATER SUPPLY PRACTICES: Flow Meters in Water Supply (AWWA M33)

A.2.25 MANUAL OF WATER SUPPLY PRACTICES: Water Audits and Leak Detection (AWWA M36)

A.2.26 MANUAL OF WATER SUPPLY PRACTICES: Operational Control of Coagulation and Filtration Processes (AWWA M37)

A.2.27 MANUAL OF WATER SUPPLY PRACTICES: Electrodialysis and Electrodialysis Reversal (AWWA M38)

A.2.28 MANUAL OF WATER SUPPLY PRACTICES: Reverse Osmosis and Nanofiltration (AWWA M40)

A.2.29 MANUAL OF WATER SUPPLY PRACTICES: Ductile-Iron Pipe Fittings (AWWA M41)

A.2.30 MANUAL OF WATER SUPPLY PRACTICES: Distribution Valves— Selection Installation, Field Testing, and Maintenance (AWWA M44)

A.2.31 SMALL WATER SYSTEM OPERATION AND MAINTENANCE (California State University, Sacramento Foundation)

A.2.32 WATER DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE (California State University, Sacramento Foundation)

A.2.33 WATER TREATMENT PLANT OPERATION, VOLUME 1 (California State University, Sacramento Foundation)

A.2.34 WATER TREATMENT PLANT OPERATION, VOLUME 2 (California State University, Sacramento Foundation)

A.2.35 AWWA STANDARD FOR VERTICAL TURBINE PUMPS: Line Shaft and Submersible Types (AWWA E101)

A.2.36 AWWA STANDARD FOR WATER WELLS (ANSI/AWWA A100)

A.2.37 CENTRIFUGAL PUMPS AND MOTORS: Operation and Maintenance (AWWA)

A.2.38 THE COMPLETE SWIMMING POOL REFERENCE (Mosby—Year Book, Inc.)

A.2.39 CROSS-CONNECTION AND BACKFLOW PREVENTION (AWWA)

A.2.40 DISINFECTING WATER MAINS (AWWA Standard C651-92)

A.2.41 DISTRIBUTION SYSTEM MAINTENANCE TECHNIQUES (AWWA)

A.2.42 DRINKING WATER HANDBOOK FOR PUBLIC OFFICIALS (AWWA)

A.2.43 DROUGHT MANAGEMENT PLANNING (AWWA)

A.2.44 EO 12902, ENERGY EFFICIENCY AND WATER CONSERVATION IN FEDERAL FACILITIES

A.2.45 EVALUATION AND RESTORATION OF WATER SUPPLY WELLS (American Water Works Association Research Foundation [AWWARF])

A.2.46 GUIDANCE MANUAL FOR COMPLIANCE WITH THE FILTRATION AND DISINFECTION REQUIREMENTS FOR PUBLIC WATER SYSTEMS USING SURFACE WATER SOURCES (AWWA)

A.2.47 INTERNATIONAL FIRE SERVICE TRAINING ASSOCIATION Manual 205 (International Fire Service Training Association [IFSTA])

A.2.48 LEAD AND COPPER RULE GUIDANCE MANUAL—VOL. I: Monitoring, NTIS PB92 112 101 (U.S. Environmental Protection Agency [USEPA])

A.2.49 LEAD AND COPPER RULE GUIDANCE MANUAL—VOL. II: Corrosion Control Treatment, EPA 811-B-92-002 *(*USEPA)

A.2.50 LEAD CONTROL STRATEGIES *(*AWWARF)

A.2.51 MAINTAINING DISTRIBUTION SYSTEM WATER QUALITY (AWWA)

A.2.52 MAINTENANCE MANAGEMENT (AWWA)

A.2.53 MANUAL OF CROSS-CONNECTION CONTROL (Foundation for Cross-Connection Control and Hydraulic Research, University of Southern California)

A.2.54 PAINTING AND REPAINTING STEEL TANKS, STANDPIPES, RESERVOIRS, AND ELEVATED TANKS FOR WATER STORAGE (AWWA Standard D102)

A.2.55 PLANT ENGINEERING Magazine's Exclusive Guide to Interchangeable Industrial Lubricants (Cahners Publishing)

A.2.56 PLANT ENGINEERING Magazine's Exclusive Guide to Synthetic Lubricants (Cahners Publishing)

A.2.57 POOL-SPA OPERATORS HANDBOOK (National Swimming Pool Foundation)

A.2.58 PROCEDURES MANUAL FOR POLYMER SELECTION IN WATER TREATMENT (AWWARF)

A.2.59 PROCEDURES MANUAL FOR SELECTION OF COAGULANT, FILTRATION, AND SLUDGE CONDITIONING AIDS IN WATER TREATMENT, (AWWA)

A.2.60 RECOMMENDED PRACTICE FOR FIRE FLOW TESTING AND MARKING OF HYDRANTS (National Fire Protection Association [NFPA] 291)

A.2.61 SDWA ADVISOR: REGULATORY UPDATE SERVICE *(*AWWA)

A.2.62 STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER (American Public Health Association [APHA], AWWA, Water Environment Federation [WEF])

A.2.63 SURFACE WATER TREATMENT: THE NEW RULES (AWWA)

A.2.64 THE U.S.A.I.D. DESALINATION MANUAL (Office of Engineering, U.S. Agency for International Development)

A.2.65 WATER CONSERVATION *(*AWWA)

A.2.66 WATER CONSERVATION MANAGERS GUIDE TO RESIDENTIAL RETROFIT (AWWA)

A.2.67 WORK PRACTICES FOR ASBESTOS-CEMENT PIPE *(*AWWA)

A.2.68 CORROSION CONTROL FOR OPERATORS (AWWA)

QUIZ

An Introduction to Domestic Water Treatment

1. Domestic water treatment consists of adding and/or removing substances from water so as to bring about a desired change in quality. In general, treatment is provided to protect public health or to improve the _________________________ of the finished product.

a. chemical oxygen demand
b. biodegradable oxygen demand
c. total dissolved solids
d. aesthetic quality

2. Treatment of water supplies is generally done at a treatment plant where positive monitoring and control is possible. Sometimes, however, providing treatment ________________ is more economical or practical.

a. at the point of utilization
b. at the source
c. within the distribution system
d. upon discharge

3. ______________________ is used to remove objects or grit that could clog or damage downstream equipment.

a. Post-treatment
b. Pretreatment
c. Primary treatment
d. Secondary treatment

4. Suspended material that is too fine to be removed by plain sedimentation can be clustered into settleable particles through the process of coagulation and ______________ .

a. condensation
b. screening
c. skimming
d. flocculation

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5. In conventional water treatment, ____________________ is the step between flocculation and filtration.

a. adsorption
b. filtration
c. sedimentation
d. liquifaction

6. In conventional water treatment, _________________ is used to remove floc, suspended matter, and microorganisms carried over from the preceding unit processes.

a. defloration
b. coagulation
c. filtration
d. condensation

7. In water treatment, _________________ is usually the last barrier to prevent disease-causing organisms from reaching the consumer.

a) ion replacement
b) flocculation
c) disinfection
d) coagulation

8. Iron and _______________ are natural contaminants found in many groundwater supplies and in stratified lakes and reservoirs. These elements are not normally harmful to human health, but relatively small amounts of iron and manganese can give water an undesirable taste, discolor plumbing fixtures, and stain laundry.

a. zinc
b. manganese
c. copper
d. lead

9. Certain dissolved minerals, mainly calcium and ______________, give water the property known as "hardness."

a. magnesium
b. iron
c. zinc
d. manganese

10. Activated carbon adsorption is the most effective method available for removing __________ .

a. volatile organic compounds (VOC)
b. dissolved solids
c. suspended solids
d. pesticides

11. Alum, ferric chloride, ferrous sulfate, magnesium carbonate, and ___________ can be recovered from waste sludge by various methods.

a. phosphates
b. lime
c. carbon dioxide
d. suspended solids

12. In general, water treatment plant residues can be disposed of by discharge to a sanitary sewer without upsetting the wastewater treatment processes. However, problems can result if the amount of ___________ is too great.

a. VOCs
b. metal oxides
c. fecal matter
d. sludge

13. Modern sanitary landfills are designed and operated to keep the amount of water leaching from the filled material to a minimum. For this reason, landfill regulations often require that sludges contain at least ___________ percent or higher dry solids.

a. 20
b. 15
c. 10
d. 5

14. The main control tests involved in sludge handling and disposal are the _______ tests used to determine the effectiveness of dewatering processes.

a. flow
b. solids
c. specific gravity
d. specific density

15. Some geographic locations, including coastal areas, islands, and some inland regions, have little or no fresh water even though unlimited supplies of saline water are available. When it is necessary to establish and maintain installations in such areas, the water supply is generally derived by converting saline water into fresh water. Several methods are available, but they are all quite expensive and complicated to use. These methods include distillation, ion exchange, electrodialysis, and ____________ .

a. activated carbon columns
b. microscreening
c. defoliation
d. reverse osmosis