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INTRODUCTION

Healthy water is vital for humans and for our progress. Our body contains 65 percent water by weight, which enables the body to perform various life functions. For example, it carries oxygen and digested food to different body parts, brings wastes like carbon dioxide and urea from those parts to the lungs and kidneys for their disposal, and participates in a number of biochemical reactions. An average adult drinks 2 liters (2.1 quarts) of water per day to carry out the vital functions; however, other personal needs require 20 gallons of water. A public water supply provides water for drinking, preparation of food, washing, sanitation, fire protection, swimming, and industrial use. Due to these requirements, U.S. water consumption averages 150 gallons per person per day. Treatment of raw water (from rivers, lakes, and wells) is required to provide safe drinking water—water without any harmful chemicals and without any waterborne pathogens (disease-causing microorganisms). Ideally, drinking water should be sparkling clear, cool, good tasting, reasonably soft, stable (neither corrosive nor scaling), plentiful, and cheap.

BACKGROUND

In ancient times, the Egyptians treated the drinking water by keeping it in large containers to settle out the sediments to make it look and taste better. Chinese boiled water to purify it. In Greece, Hippocrates, the father of medicine, around 400 B.C., found water as the carrier of waterborne diseases and suggested its boiling and cloth filtering to make it safe to drink. These ideas were the foundation for present-day sedimentation, disinfection, and filtration, which are the three major phases of water treatment. Currently, water treatment is becoming more sophisticated for an effective removal of pathogens and harmful chemicals. Disinfection and filtration, in particular, are getting more attention. Disinfection is changing from plain chlorination to chlorine dioxide treatment, ozonation, or ultraviolet light treatment. Filtration is shifting from a commonly used high-rate sand filtration to membrane filtration.

A water treatment operator is responsible for treating the drinking water 24 hours a day to meet all the government requirements and the public expectations. The operator, therefore, needs a sound knowledge of fundamental concepts of water treatment and common problems with possible solutions during the treatment and related subjects, such as microbiology, chemistry, mathematics, and hydraulics. This book is intended to provide this information in a simplified manner. As a starting point, we will look at the primary regulation governing water quality—the Safe Drinking Water Act.

SAFE DRINKING WATER ACT

Although health agencies and the public were aware of the pollution of drinking water sources with contaminants such as waterborne pathogens and chemicals causing health problems, no serious action was taken until the 1970s. Until 1974, the drinking water quality in the United States was controlled by the U.S. Public Health Service (PHS), under water quality standards of 1962. These standards, originally developed in 1914, were revised twice in 1925 and again in 1962. Only 28 contaminants—including turbidity, coliform bacteria, lead, copper, and zinc—were regulated, and regulations were applicable only to the interstate water carriers. Other public water supplies used these regulations merely as guidelines for the drinking water quality.

Two reports, one by the PHS on Community Water Supply Study (CWSS) in 1970 and the other by the newly created U.S. Environmental Protection Agency (EPA) on the water quality study of the Mississippi River and New Orleans, Louisiana, in 1972, created serious concerns regarding the drinking water quality. The CWSS report showed that a large number of community water systems were not in compliance with the drinking water standards of 1962, and the EPA report showed the presence of a number of health-affecting synthetic organic compounds in the New Orleans drinking water supply. In 1974, the presence of cancer-causing trihalomethanes (THMs), formed by free-residual chlorine reacting with natural organic matter (NOM) in water, was also discovered.

Consequently, the U.S. Congress passed two major laws: the Clean Water Act (CWA) in 1972 and the Safe Drinking Water Act (SDWA) in 1974, the former to stop the pollution of water bodies and the latter to control the drinking water quality. The CWA requires wastewater treatment plants and industries to comply with the National Pollutant Discharge Elimination System (NPDES) to discharge the treated wastewater into the natural water bodies. The law was intended to improve, restore, and maintain the water quality of the water bodies for normal aquatic life and for recreational purposes, and assure a better quality of source water for drinking purposes.

The SDWA of 1974 (Public Law 93-523) regulated the drinking water quality with primary (enforceable) drinking water standards of various contaminants for all community water systems to protect the public health. Public water supply systems were designated as community water systems and noncommunity water systems. A *community water system* has 15 or more water connections, or 25 or more year-round customers. Noncommunity water systems were further classified as *nontransient noncommunity systems* if the same 25 or more people were served for at least six months of the year, such as schools, factories, and treatment plants; and *transient noncommunity systems* when people on transit were served (e.g., restaurants, gas stations, motels, and hotels). Water quality of noncommunity systems was classified as the responsibility of the supplier.

The SDWA of 1974 was amended in 1986 (also called the 1986 amendments of SDWA, as PL 99-339) and again in 1996 (also known as reauthorization bill, as PL 104-182). According to the SDWA, the federal regulatory agency is the EPA and the enforcement body is the state health department. Under the current SDWA act, the EPA regulates all the problematic physical, biological, and chemical contaminants in the drinking water. This process involves the state and the public for setting standards and monitoring the water quality. Each state must have its own water quality control program, with drinking water standards equal to or more stringent than those of the EPA. The public is kept informed through public notification in case of a serious problem with the drinking water supply and a yearly consumer confidence report (CCR). There are serious penalties for violations of National Primary Drinking Water Regulation (NPDWR) standards. Therefore, water treatment has become a very serious business.

Various contaminants—microbiological and chemical—are regulated by different rules under the SDWA:

1. *Microbiological quality.* Microbiological contaminants are controlled under the Surface Treatment Rule and the Coliform Rule. These rules emphasize the proper filtration and disinfection of all surface waters for adequate removal or inactivation of waterborne pathogens. Water quality is monitored daily for turbidity, proper disinfection, and the presence of coliform bacteria.
2. *Chemical quality.* Chemical quality is controlled by various rules, depending on the type and source of chemicals. There are five major groups of chemical contaminants:
    1. *Disinfectants and disinfection byproducts.* Contaminants such as trihalomethanes and haloacetic acids (HAAs) are controlled by the Disinfectants and Disinfection Byproducts Rule.
    2. *Corrosion byproducts.* Corroded metals such as lead and copper are controlled by the Lead and Copper Rule.
    3. *Agricultural chemicals.* Pesticides and other agricultural chemicals are controlled by the Synthetic Organic Compounds (SOC) Rule.

4. *Volatile organic compounds* (*VOC*). These contaminants are controlled through the Volatile Organic Compounds Rule.
5. Radionuclides. These are regulated under the Radionuclide Rule.

The EPA selects and regulates all the contaminants showing health effects (candidate contaminants) by setting the maximum contaminant levels (MCL), and maximum contaminant level goal (MCLG) under different rules. It revises them periodically. MCL should be as close to MCLG as feasible. MCLG is set at a level where a contaminant has no known adverse health effects with an adequate margin of safety. The benefits of MCL should justify the treatment cost. Every state has primary responsibility for enforcement of all the rules. The EPA has the authority to take action against public water systems in violation of the SDWA. Since 1998, all public water systems have been required to prepare and mail a yearly CCR to all customers in July showing all the contaminants detected during the year in the drinking water, their levels, and health risks associated with them. In case of a violation, a water utility is required by law to take appropriate action, inform the state agency, and notify the public. Thus, the water quality is assured to be adequate and safe for the public health.

Table 1-1 shows all currently regulated contaminants, their MCL, MCLG, health effects, and sources.

This is a brief overview of the SDWA. It is important for a utility to know the latest information on the SDWA because new regulations are promulgated, old regulations are revised, and more regulations are anticipated. For the latest information, contact the State Public Health Department, the American Water Works Association (AWWA), and the U.S. EPA. Their phone numbers and Web sites are given in the Appendix A.

Besides the compliance with the primary drinking water standards, the public expects the drinking water to be colorless, odorless, good tasting, nonstaining, and nondepositing type, for cosmetic and aesthetic reasons. For that, there are nonenforceable standards, which are called National Secondary Drinking Water Standards. Mostly, these are used as treatment guidelines for good public relations. Table 1-2 presents a list of 15 contaminants and their standards.

A plentiful and healthy water supply made civilizations flourish, and lack of it made them perish. A knowledgeable public water utility, especially operating staff, is essential for a community.

Table 1-1 U.S. EPA National Primary Drinking Water Contaminant Standards

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
		Microorganisms		
Cryptosporidium	zero	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and fecal animal waste
Giardia lamblia	zero	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste
Heterotrophic plate count	n/a	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment.
Legionella	zero	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; it multiplies in heating systems.
Total Coliforms (*including fecal coliform and E. coli*)	zero	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present.[5]	Coliforms are naturally present in the environment, as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.

Table 1-1 (*Continued*)

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Turbidity	n/a	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites, and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff
Viruses (enteric)	zero	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste
		Disinfection Byproducts		
Bromate	zero	0.010	Increased risk of cancer	Byproduct of drinking water disinfection
Chlorite	0.8	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection

Haloacetic acids (HAA5)	n/a[6]	0.060	Increased risk of cancer	Byproduct of drinking water disinfection
Total Trihalomethanes (TTHMs)	none[7] n/a[6]	0.10 0.080	Liver, kidney, or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection
Disinfectants				
Chloramines (as Cl_2)	4[1]	4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes
Chlorine (as Cl_2)	4[1]	4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes
Chlorine dioxide (as ClO_2)	0.8[1]	0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes
		Inorganic Chemicals		
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0[7]	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and possible increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes
Asbestos (fiber >10 micrometers)	7 million fibers per liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits

Table 1-1 (*Continued*)

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	TT[8]; Action level = 1.3	Short-term exposure: Gastrointestinal distress Long-term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits

Cyanide (*as free cyanide*)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive that promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	TT[8]; Action level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (*inorganic*)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate (*measured as Nitrogen*)	10	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits

Table 1-1 (*Continued*)

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Nitrite (measured as Nitrogen)	1	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories
Organic Chemicals				
Acrylamide	zero	TT[9]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney, or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops

Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene (PAHs)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards

Table 1-1 (*Continued*)

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1,1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-1,2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories
1,2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl) adipate	0.4	0.4	Weight loss, liver problems, or possible reproductive difficulties	Discharge from chemical factories
Di(2-ethylhexyl) phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables

Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Liver problems	Residue of banned insecticide
Epichlorohydrin	zero	TT[9]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals
Ethylbenzene	0.7	0.7	Liver or kidneys problems	Discharge from petroleum refineries
Ethylene dibromide	zero	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories

Table 1-1 (*Continued*)

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (*Vydate*)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (*PCBs*)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood-preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners

Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (*Silvex*)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.20	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (*total*)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories

Table 1-1 (*Continued*)

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
		Radionuclides		
Alpha particles	none[7] / zero	15 picocuries per liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and might emit a form of radiation known as alpha radiation
Beta particles and photon emitters	none[7] / zero	4 millirems per year	Increased risk of cancer	Decay of natural and manmade deposits of certain minerals that are radioactive and might emit forms of radiation known as photons and beta radiation
Radium 226 and Radium 228 (combined)	none[7] / zero	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
Uranium	zero	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits

Notes

[1] Definitions:

Maximum contaminant level (MCL). The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

Maximum contaminant level goal (MCLG). The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are nonenforceable public health goals.

Maximum residual disinfectant level (MRDL). The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum residual disinfectant level goal (MRDLG). The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Treatment technique. A required process intended to reduce the level of a contaminant in drinking water.

[2] Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

[3] EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium:* (as of January 1, 2002, for systems serving >10,000 and January 14, 2005, for systems serving <10,000) 99% removal.
- *Giardia lamblia:* 99.9% removal/inactivation.
- Viruses: 99.99% removal/inactivation.
- *Legionella:* No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter.
- Long-Term 1 Enhanced Surface Water Treatment (effective date: January 14, 2005): Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long-Term 1 Enhanced Surface Water Treatment Rule provisions (e.g., turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Filter backwash recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

[4] More than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E. coli* fecal coliforms, system has an acute MCL violation.

[5] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

[6] Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L). Chloroform is regulated with this group but has no MCLG.
- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L). Monochloroacetic acid, bromoacetic acid, and dibromoacetic acid are regulated with this group but have no MCLGs.

[7] MCLGs were not established before the 1986 amendments to the Safe Drinking Water Act. Therefore, there is no MCLG for this contaminant.

[8] Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

[9] Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

- Acrylamide = 0.05% dosed at 1 mg/L (or equivalent)
- Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)

Table 1-2 National Secondary Drinking Water Standards

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5–8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total dissolved solids	500 mg/L
Zinc	5 mg/L

QUESTIONS

1. Why is water so important for life?
2. Give three important uses of water.
3. What is the role of Hippocrates in water treatment?
4. Explain the role of the U.S. EPA and a state in the Safe Drinking Water Act enforcement.
5. What happened in the 1970s to make the U.S. Congress act and pass water pollution and water quality control bills?
6. Define the terms *community water systems* and *noncommunity water systems.*
7. Explain the terms CCR, MCL, and MCLG.
8. In case of a violation of the SDWA, what is the course of action for the water utility?