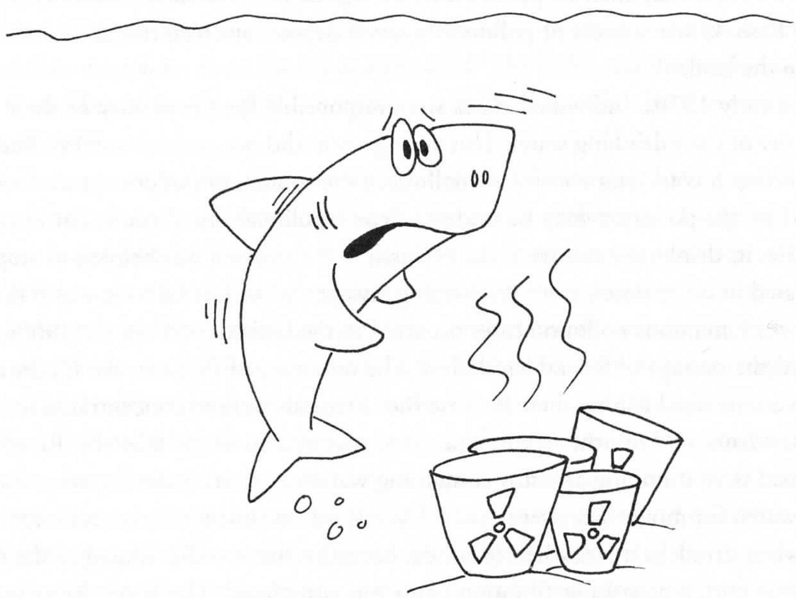
CHAPTER

21

Clean Water: A Limited Resource



Water Pollution

The importance of safe drinking water to public health has been clear since John Snow identified polluted water as the source of London's cholera epidemic in 1855, as described in Chapter 4. Major epidemics of cholera and other waterborne diseases broke out periodically in the United States until the end of the 19th century. Ninety thousand people died of cholera in 1885 in Chicago, persuading city officials to stop discharging the city's sewage into Lake Michigan, which was also the source of municipal drinking water.[1] While contaminated water is still a major cause of disease and death in developing countries, Americans expect that their tap water will be safe to drink and, for the most part, it is. Nevertheless, 647 outbreaks of waterborne diseases were documented by the Centers for Disease Control and Prevention (CDC) between 1971 and 1994, including the 1993 cryptosporidiosis outbreak in Milwaukee described in the Prologue.[2] Each year between 1991 and 2002, the CDC and the Environmental Protection Agency (EPA) recorded an average of seventeen outbreaks associated with contaminated drinking water.[3]

Common water pollutants include, in addition to microbial pathogens, a wide range of chemicals that may not only be toxic in drinking water, but have harmful effects on fish and wildlife. Many chemicals have been discharged into waterways as industrial wastes, such as the mercury in Minamata Bay or the polychlorinated biphenyls (PCBs) in the Hudson River (see Chapter 19). People may then be poisoned by eating the fish that have accumulated these toxins in their flesh. Other sources of pollution include deposition from the air, as in acid rain, or runoff from the land.

Until the early 1970s, individual states were responsible for the quality of their waterways and the purity of their drinking water. This arrangement did not control water pollution for the same reason that it could not control air pollution: the sources of pollution and the communities affected by the pollution may be under different political jurisdiction. For example, New Orleans draws its drinking water from the Mississippi River; yet it was helpless to stop cities upstream, located in other states, from discharging sewage and industrial wastes into the river.

A number of infamous pollution cases occurred in the United States in the 1960s and 1970s that inspired the passage of federal legislation. The discovery of PCBs in the Hudson River led to a ban on commercial fishing there because the chemicals were so concentrated in the flesh of the fish. Residents of Duluth, Minnesota, were alarmed to learn that the Reserve Mining Company had been dumping asbestos-containing wastewater into Lake Superior, the source of municipal water, for more than twenty years.[4] While no one knew whether asbestos was as carcinogenic when drunk as it was when breathed, bottled water was distributed to the population for over a year until a new water-filtration plant was completed. The James River was so badly polluted with the insecticide Kepone, discharged from a manufacturing plant in Hopewell, Virginia, between 1966 and 1975, that no practical way has ever been proposed to clean it up. The plant was closed, not because of the environmental damage it caused, but because so many of its employees suffered neurological, liver, and other damage from Kepone poisoning.[5] Perhaps the most dramatic call to action occurred in 1969, when the Cuyahoga River in Ohio caught fire because it had so much oil floating on its surface.[4]

The two goals of cleaning up lakes and rivers and ensuring safe drinking water are distinct but related, and Congress has addressed them in separate legislation: the Clean Water Act of 1972, amended in 1977 and several times since, and the Safe Drinking Water Act of 1974, which was rewritten in 1996.[1] Since half of the drinking water in the United States comes from lakes and rivers, success in meeting the goals of the Clean Water Act is obviously a help in achieving the goals of the Safe Drinking Water Act.

Clean Water Act

The Clean Water Act set national goals that lakes and rivers should be "fishable" and "swimmable" and that all pollutant discharges should be eliminated. First attempts at cleaning up the nation's waterways focused on "point-source" pollution—well-defined locations that discharge pollutants into lakes and rivers. Most point-source pollution comes from municipal sewage and industrial discharges. The 1972 and 1977 legislation imposed strict controls on these sources; it also provided billions of dollars of funding to assist municipalities in building wastewater treatment facilities. With the success of these efforts, it became apparent that a great deal of pollution washed into waterways from the air and the land. The 1987 reauthorization of the Clean Water Act focused on cleaning up non-point-source pollution, which has proven to be a much more difficult task.[1]

Laws governing point-source pollution set requirements for treating wastewater so that it can be discharged into waterways without causing human health problems or disrupting the aquatic environment. In the case of sewage treatment plants, this requires several steps. The primary step is to remove suspended solids by screening them and then allowing them to settle out by gravity in settling tanks. The secondary stage is to break down the remaining organic material using biological processes: the wastewater is mixed with bacteria and plenty of oxygen, resulting in conversion of the organic wastes into carbon dioxide, water, and minerals. The wastewater is then usually disinfected with chlorine before being discharged into the environment.[1]

While the treatment process produces a liquid discharge that meets standards of environmental safety, it also generates "sludge," the solid waste left behind on screens and at the bottom of settling tanks. Enormous amounts of sludge are generated by municipal sewage plants, creating a major disposal problem. In the past, sludge was often dumped in the ocean or incinerated, but these methods create other pollution problems. Congress prohibited the ocean dumping of sludge in 1992. Some communities bury it in landfills, but landfill space is running low, as discussed in Chapter 22. Since sludge is rich in nutrients, the Environmental Protection Agency (EPA) encourages the use of treated sludge as a fertilizer and soil conditioner to improve marginal lands and increase forest productivity. The EPA has developed strict regulations on sanitizing and removing hazardous contaminants from the sludge—known after treatment as biosolids—before it can be used on land. Currently, 54 percent of the six million tons of sewage sludge generated every year is used as fertilizer.[1]

About 70 percent of the U.S. population is served by sewage treatment plants. Most of the other 30 percent use onsite septic systems, which function as miniature sewage treatment plants including the use of bacteria to break down organic wastes. Like the larger plants, septic systems produce sludge, which must be pumped out periodically. Improperly constructed and poorly maintained septic systems contribute to pollution of waterways and often result in public health problems.[1]

Despite the laws and some occasional funding from the federal government, many cities have inadequate sewer systems that back up into basements or overflow and dump untreated sewage into waterways. In part the problems are due to population growth, which has placed additional burden on aging systems, and in part they occur because most systems combine rainwater runoff with sewage, overwhelming the system when it rains. According to an analysis of EPA data by *The New York Times*, sewage systems are the nation's most frequent violators of the Clean Water Act. The EPA and the Government Accountability Office have estimated that \$400 million in extra spending is needed over the next decade to fix the nation's sewage infrastructure.[6]

Discharges from industrial sources are the second major category of point-source pollution, which is strictly regulated by the Clean Water Act. The EPA is required to develop standards for the release of various categories of pollutants into the environment. Industries that discharge directly into the nation's waterways are required to obtain a permit specifying allowable amounts and constituents of pollutants they may discharge. They must routinely monitor their discharges, and they must report regularly to the EPA.[1]

Industrial wastes may cause special problems if they are discharged into sewer systems and pass through a municipal sewage treatment plant, occasionally with disastrous consequences. In 1977, pesticide wastes illegally dumped into the sewers of Louisville, Kentucky, killed all the microbes responsible for the secondary treatment process, rendering the plant ineffective. For nearly 2 years while the plant was being cleaned up at a cost of millions of dollars, 100 million gallons of untreated sewage were discharged into the Ohio River every day. In 1981 in Cincinnati, a paint factory discharged hydrochloric acid into the city sewers, corroding the sewer pipe and causing it to collapse, leaving a hole in the street 24 feet in diameter.[7]

To prevent such problems, the Clean Water Act requires pretreatment of industrial wastes that are discharged into sewers. But standards have not been set for many smaller commercial establishments, including car washes and photo processing plants. Hazardous chemicals also enter sewer systems from residences, when people dispose of bleaches, toilet bowl cleaners, paint thinners, and other household substances by flushing them down the drain.

As strict limits have been set on pollution from sewage systems and industry, non-point-source pollution has become an increasingly important threat to water quality. These contaminants come from stormwater runoff from farmland, construction sites, and urban streets. Agriculture is the leading source of water pollution in the United States, contributing soil, manure fertilizers, and pesticides that wash into streams and lakes. Agricultural runoff is believed to have been the source of the Milwaukee cryptosporidiosis outbreak. Construction activities also contribute soil to runoff water, together with oil, tar, paint, and cleaning solvents. Contaminants contributed by urban street runoff include sand, dirt, road salt, oil, grease, heavy metal particles, pesticides and fertilizers from lawns, and animal and bird droppings.

A variety of approaches must be used to minimize pollution caused by stormwater runoff. These include preventing soil erosion by planting vegetation on exposed soil, incorporating more green space into urban areas, minimizing the use of chemical fertilizers and pesticides, and controlling litter.

Air pollution is also a source of water pollution. In addition to acid rain, a number of other chemicals are deposited into lakes, rivers, and oceans from the air. These include lead, asbestos, PCBs, and various pesticides. It has been shown that the major portion of PCBs in the Great Lakes comes from the air. Industrial accidents and spills also contribute to pollution of waterways.

To conform to the requirements of the Clean Water Act, the EPA regularly collects data from the states on water quality of rivers, lakes, and estuaries. The most recent report, using data from 2004, showed that the nation still has a long way to go meet the fishable and swimmable requirements. Forty-four percent of river miles, 64 percent of lake acres, and 33 percent of bay and estuaries square miles were found to be unfit for fishing and swimming.[8]

Safe Drinking Water

Almost half of the drinking water in the United States comes from rivers and lakes. Thus it is likely to be contaminated by the point-source and non-point-source pollutants discussed above. The other half comes from underground aquifers; these are generally of better quality but are increasingly susceptible to contamination by leaching from landfills, leaky oil and gas storage tanks, and other sources of toxic chemicals. Improvements in surface-water quality brought about by the Clean Water Act make the job easier for community water systems, which must, however, meet much higher standards to produce potable water—water that is safe for human consumption.

All community systems need to treat their water so that, theoretically, all contaminants are removed. The steps needed to produce potable water vary depending on the source of the water and the type of contaminants. The basic steps common to most systems include sedimentation, coagulation, filtration, and disinfection. Incoming water is first allowed to sit quietly while suspended material settles out. Then alum is added, causing small particles to coagulate and settle out. Filtration through beds of sand or similar materials removes the smaller particles that do not settle, and chlorine is added to kill remaining pathogens. In areas of the country where water is "hard"—containing high concentrations of dissolved calcium or magnesium—or where it has objectionable tastes or odors due to dissolved iron or gases, additional treatments may be used. As a last step, fluoride is often added to protect community residents from tooth decay. A typical drinking-water purification plant is diagramed in **Figure 21-1**.

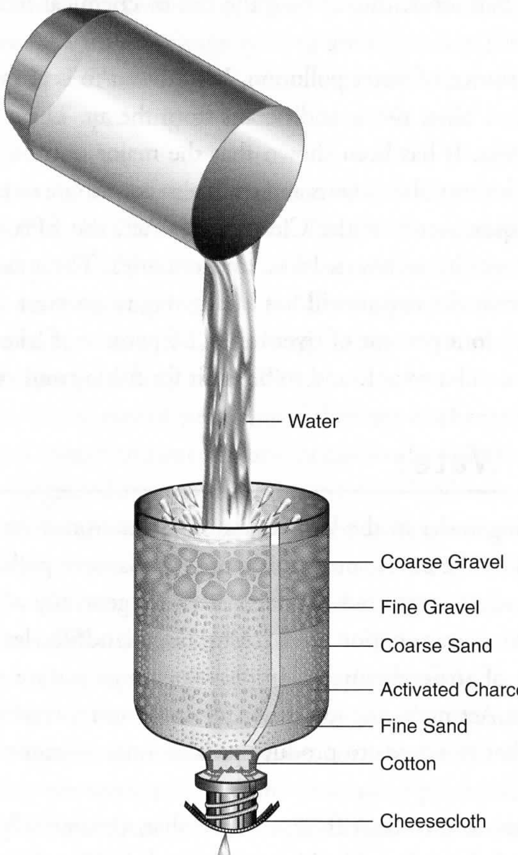


FIGURE 21-1 Drinking and Wastewater Treatment.
Source: U.S. Environmental Protection Agency, "The Water Sourcebooks," p. 2–9. www.epa.gov/safewater/kids/wsb/pdfs/9122.pdf. February 28, 2006. (Accessed November 9, 2009).

To ensure that the treatment process is working effectively, regular laboratory tests are generally done on the final product. The traditional measures of water purity are turbidity and coliform levels. Turbidity indicates the presence of suspended particles, a failure of the sedimentation and filtration steps. Suspended particles may interfere with the germicidal action of the chlorine. After the cryptosporidiosis outbreak, which accompanied an increase in the turbidity of Milwaukee's water, national turbidity standards were tightened. If coliform bacteria are detected, there has probably been a failure of disinfection. These bacteria are common inhabitants of the intestines of humans and other animals and, while they are usually not pathogenic themselves, their presence indicates that other, more harmful microorganisms may have survived the treatment process.[1]

The general approach to water treatment described above is directed primarily against bacterial diseases, the most common and historically devastating type of waterborne disease. It is not very effective, however, against viruses and the parasites *Cryptosporidia* and *Giardia*, which are resistant to chlorine. Furthermore, it does nothing to address the problem of contamination with common chemical pollutants such as pesticides, herbicides, fertilizers, PCBs, lead, and other metals that may be harmful to health. Most community water systems are totally unprepared even to test for these pollutants.

The Safe Drinking Water Act of 1974 required the EPA to set standards for local water systems and mandated that states enforce the standards. Uniform guidelines were set for drinking-water treatment, and regular monitoring and testing were required, with the results to be reported to state governments. However, no deadlines were established for the standard setting, and state agencies were lax in enforcing the requirements that were in place. The 1986 reauthorization of the Safe Drinking Water Act specified 83 contaminants to be regulated by the EPA and set deadlines for action. In addition, it required water systems to take measures to prevent contamination with *Giardia* and *Cryptosporidia*.[1] The EPA stepped up the pace of regulation. Now, maximum contaminant levels have been set for 87 identified contaminants, including microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides. A selected list of these contaminants is shown in **Table 21-1**. In addition, secondary standards have been set for fifteen contaminants that do not cause health risks but that may affect taste, odor, or color, or that cause discoloration of skin or teeth.

In 1996, Congress again strengthened the Safe Drinking Water Act. New measures required that community water systems provide annual Consumer Confidence Reports to their customers on the source of the water, water contaminants, and the health effects of these contaminants.[9] The law also included requirements for source water protection, tightened standards for training and certification of operators, and provided funding to help localities improve their systems. The "right-to-know" measure was expected to evoke public pressure that would result in better compliance with standards.

Table 21-1 EPA National Primary Drinking Water Standards

Microorganisms

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Cryptosporidium	zero	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal 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; multiplies in heating systems
Total Coliforms (including fecal colifrom 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.
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

(continues)

Table 21-1 *(Continued)*

Disinfection Byproducts

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
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)	n/a[6]	0.080	Liver, kidney, or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection

Disinfectants

Contaminant	MRDLG[1] (mg/L)[2]	MRDL[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Chloramines (as Cl_2)	MRDLG = 4[1]	MRDL = 4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes
Chlorine (as Cl_2)	MRDLG = 4[1]	MRDL = 4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes
Chlorine dioxide (as ClO_2)	MRDLG = 0.8[1]	MRDL = 0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes

Inorganic Chemicals

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
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 may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes

(continues)

Table 21-1 *(Continued)*

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
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 which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories

(continues)

Table 21-1 *(Continued)*

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 6 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
Nitrite (measured as Nitrogen)	1	1	Infants below the age of 6 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

(continues)

Table 21-1 *(Continued)*

Organic Chemicals				
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**
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
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

(continues)

Table 21-1 *(Continued)*

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 kidney 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

(continues)

Table 21-1 *(Continued)*

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
Hexachloro-cyclopentadiene	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

(continues)

Table 21-1 *(Continued)*

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

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

Source: U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations." www.epa.gov/safewater/contaminants/index.html. May 2009. (Accessed February 13, 2010).

Ongoing surveillance for waterborne disease by the CDC provides data useful for evaluating the adequacy of existing water treatment technologies and the effectiveness of drinking water regulations. The CDC publishes its findings every two years, analyzing the outbreaks by causative agent, type of water system, type of deficiency in the system, and source of water. The data probably understate the incidence of waterborne diseases, because most cases go unrecognized or unreported.

The most recent available report found twenty outbreaks in the 2-year period 2005–2006, affecting 612 people and causing 4 deaths.[10] Eighteen of the outbreaks were caused by known infectious agents: three by viruses, two by parasites, twelve by bacteria, and one by both viruses and bacteria. As part of a recent trend, about half the outbreaks in 2005–2006 were caused by *Legionella* bacteria, which caused respiratory disease. Most of these outbreaks occurred in healthcare settings—hospitals and a long-term care facility—with large, complex plumbing systems. The finding raises an alarm, indicating the need for special measures to prevent legionellosis in such buildings.

In 1978, CDC's surveillance for waterborne disease outbreaks expanded to include outbreaks associated with recreational water, such as swimming pools, water parks, and beaches. These sources now account for more outbreaks than drinking water sources. In 2005–2006, there were 78 outbreaks, affecting 4412 people and causing 5 deaths.[11] Most of the illnesses were gastrointestinal, caused by infectious agents or chemicals.

Enforcement by state and local governments of safe drinking water laws has been spotty. An investigation by *The New York Times*, which analyzed data from the EPA and the states, found that 40 percent of the nation's community water systems violated the Safe Drinking Water Act at least once in just the one year of the study. More than 23 million people received substandard drinking water.[12] Many of the violations are due to chemicals that may, even at low concentrations, cause cancer or other chronic diseases that take years or decades to develop. Often politicians resist enforcing these laws, concerned about the economic impact or bad publicity. Under the Bush administration, the EPA did not push state and local governments to meet standards or punish industries that dumped pollutants into lakes and rivers.[12] Moreover, recent studies have found new, unregulated chemicals in water supplies and have revealed that some regulated chemicals are harmful at low concentrations that meet current federal standards. For example, according to *The New York Times* analysis, a community could drink perfectly legal water containing arsenic at a level such that roughly one in every 600 residents would likely develop bladder cancer over their lifetimes. The EPA has not tightened standards or added to the list of regulated chemicals since President Bush was elected in 2000.[13] Lisa Jackson, the EPA administrator appointed by President Obama, has made enforcement of clean water laws a priority.[14]

Private wells are not regulated under the Safe Drinking Water Act, although the EPA issues recommendations for ensuring that wells are safe. About 43 million Americans get their drinking water from private wells and, according to a study by the U.S. Geological Survey, more than one in five of these wells contain at least one contaminant at a concentration high enough to be a health concern. Different contaminants are more common in different regions of the country. The study authors note that these findings underscore a continuing need for public education and for the testing of domestic wells.[15]

Many Americans choose to drink bottled water, believing that it is purer and tastes better than tap water. In most cases, this is not the case. According to a study published in 1999 by the Natural Resources Defense Council, many of the 103 brands tested contained chemical or biological contaminants, though not in concentrations high enough to cause health problems.[1] In 2000, however, CDC surveillance recorded a multistate outbreak affecting 84 people, caused by *Salmonella* in bottled water.[16] Bottled water is regulated by the Food and Drug Administration (FDA), which requires it to meet EPA's drinking water standards. Enforcement is not strict, however. Many, but not all, states impose additional regulations. An estimated 25 to 30 percent of bottled water sold in the United States is obtained directly from municipal water supplies.[1]

Dilemmas in Compliance

A dilemma currently faced by New York City illustrates why it is so difficult to ensure safe drinking water for many Americans. New York gets most of its tap water from six reservoirs in the Catskill Mountains built in the 1950s and 1960s. For many years, the city was justly proud of the purity and taste of its water. However, the population in the watershed region has grown, and the quality of the water began to suffer in the 1970s and 1980s. More than 100 community sewage treatment plants discharged into the watershed area, many in violation of discharge permit standards. Substandard septic tanks also contributed to the problem. Dairy farms contributed tons of manure to the watershed. The amount of coliform bacteria measured in New York's water frequently violated EPA standards, and the amount of chlorine added to control bacteria increased to the level that it has affected the water's taste. *Cryptosporidia* have also been found in the city's water. The EPA ordered New York to clean up the pollution or to build a filtration plant for the water from upstate reservoirs, setting a deadline of December 1996.[17]

New York City does not now filter its water, and the cost of constructing a filtration plant was estimated at up to $8 billion, a painful price for a city struggling with chronic financial difficulties. As an alternative, the city proposed a plan to protect the watershed by helping communities to upgrade their sewage plants, buying sensitive land near the reservoirs, and making changes in the way farmers dispose of manure. The upstate communities, already angry at the city for taking so much of their land for the reservoirs, were concerned that New York's plan would further harm the region's economy by discouraging development. While most experts believe that all water systems should include filtration, they agree that watershed protection is also important. Milwaukee's cryptosporidiosis outbreak occurred despite the fact that its system filters the water. In early 1997, New York City reached an agreement with the upstate region to implement the watershed protection plan.[18,19] After years of further negotiation, the City reached an agreement in 2007 with the EPA and the upstate counties for a ten-year Filtration Avoidance Determination.[20] The City has been buying land in the watershed region, which can be used for recreational purposes like hunting, fishing, and hiking, but cannot be developed. The agreement also calls for the City to work with communities to upgrade wastewater treatment plants and septic systems. It is also working with agricultural groups to develop pollution prevention programs for farmers. Meanwhile, New York is under a court order to build a filtration plant for the older, more polluted reservoirs in the Croton system, located in suburban areas close to the city, which supply up to 10 percent of its water.[21] That plant, highly controversial, is now being built underground in the Bronx and is scheduled to be completed in 2012 at a cost of nearly $3 billion.[22]

The cost of ensuring safe drinking water is a major obstacle for many communities, large and small. While the federal government has provided some funds to assist states and localities in regulatory and remediation activities required by the Safe Drinking Water Act, the amount provided is never sufficient. In a report called *The Clean Water and Drinking Water Infrastructure Gap Analysis*, the EPA has shown that spending on water and sewage systems is inadequate to cope with such problems as leaks in aging water pipelines and failures in aging urban sewage systems.[23] In the absence of adequate funding, attempts to upgrade water supplies always involve disputes over who should pay for improvements.

Another dilemma concerning drinking water is that the very chemicals used to kill microbes in water may themselves be harmful to health. Chlorine, the most common disinfectant, reacts with organic matter to form byproducts that, some evidence shows, may be carcinogenic. Other, more expensive disinfection methods include bubbling ozone through the water, but these treatments tend to form other byproducts that may be equally harmful to health. There is no simple solution to this problem—even bottled water is required to meet only the same standards of purity as tap water, as discussed above. General steps to prevent water pollution through eliminating point and non-point sources are helpful, however, since cleaner water sources require less treatment to meet drinking water standards.

A recent concern with implications that are still not known is the discovery in drinking water of trace amounts of a wide variety of hormones, pharmaceuticals, and household chemicals, most of which no one had thought to look for previously. Many of them probably get into wastewater when they are excreted by humans or animals and are not removed by sewage treatment systems. Some of the most frequently detected contaminants were steroids, insect repellants, antibiotics, and nonprescription drugs including caffeine and metabolites of nicotine. The health effects on humans of long-term exposure to low concentrations of these chemicals are not known, but there is evidence that they have ecological effects on fish and other aquatic species. For example, female hormones in very small concentrations have been found to cause feminization of male fish, and there is concern that human fetuses might similarly be affected.[24] It is not clear that this kind of contamination can be prevented, but it may be reduced by employing more care in disposal of medications and other chemicals, which should never be flushed down the drain.

Is the Water Supply Running Out?

Although water covers 71 percent of the earth's surface, most of it is in the form of salt water or ice in glaciers or polar ice caps. Less than 1 percent of the total amount consists of fresh water, potentially suitable for drinking, cooking, bathing, farming, and other human needs.[1] In many parts of the world, the supply of fresh water is inadequate for the demands of the local population. Already, political disputes are occurring in the United States over water shortages. Some heavily populated areas, including parts of Texas and New Mexico, are depleting finite underground water sources. In California, large quantities of water are transported to the central part of the state from the mountains for irrigation use while cities in the south complain of shortages. Water conservation measures of various kinds have been instituted throughout the United States, including legally mandated low-volume toilets and showerheads and limits on car washing and lawn watering in some areas during dry seasons.

As it becomes increasingly clear that pure water is a limited resource, it is also apparent that pure water is essential to public health. The difficulty of ensuring an adequate supply of potable water worldwide is discussed further in Chapter 24.

Conclusion

Although Americans take it for granted that their tap water is safe to drink, outbreaks of waterborne illness are not uncommon in the United States; the 1993 cryptosporidiosis outbreak in Milwaukee is the most dramatic. Two federal laws are aimed at keeping the water supply clean and safe.

The Clean Water Act specifies that lakes and rivers should be fishable and swimmable. It imposes controls on point-source pollution, mainly discharges from municipal sewage systems and from industry, and non-point-source pollution, which is washed into waterways from the air and the land. Laws governing point-source pollution set requirements for treating wastewater before it can be discharged. Non-point-source pollution is more difficult to control.

The Safe Drinking Water Act requires the EPA to set standards for local drinking water systems and requires states to enforce the standards. However, the EPA was lax in setting the regulations, and states have been lax in enforcing them. Legislation passed in 1996 requires that community water systems provide annual reports to their customers on water contaminants, in hopes that public pressure will force better compliance with the standards.

Complying with federal drinking water standards is expensive, and many communities do not comply, including New York City, which spent years trying to find a way to clean up its reservoirs without building a multibillion dollar filtration plant. In the most recent agreement with the EPA, reached in 2007, the City has agreed to work with upstate counties where its main reservoirs lie to protect the watershed. The City is also building a filtration plant in the Bronx to filter water from the more polluted reservoirs in areas closer to the City. Another dilemma concerning drinking water is that chlorine, the most common disinfectant used to kill microbes in the water, may itself cause harmful health effects. A recently discovered problem is that drinking water often contains pharmaceuticals and other household chemicals in low concentrations, the health effects of which are not known.

The supply of fresh water on earth is finite, and many areas of the world, including parts of the United States, suffer from shortages.

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