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Scientific Status Summary

"Just Add Water": Regulating and Protecting the Most Common Ingredient

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The Institute of Food Technologists has issued this Scientific Status Summary to provide readers with an overview of drinking water standards and regulations, freshwater resources, water pollution and predominant sources of contamination, and the effects of agriculture and food processing on water quality and wastewater treatment.

Keywords: agriculture, biochemical oxygen demand, fertilizers, food processing, ground water, irrigation, nitrogen, pesticides, phosphorus, sediment, surface water, wastewater, water pollution

Introduction

A safe and abundant supply of water is of paramount interest to everyone, including food scientists, food technologists, and food processing employees. Incontrovertibly, whether used as a primary ingredient in numerous food and beverage items (for example, canned soup, frozen vegetables, or soft drinks), as the source of irrigation for farmland and hydration for food animals, or as a means to quench the thirst of farmers, crop workers, and food plant employees, water is integral to every aspect of the food industry. Just as water is vital to the food industry, it is also inextricably linked to every other industry: Water is a component of countless other products such as household cleansers, perfume, and toothpaste and plays a role in the manufacturing of electricity, natural gas, and oil. Virtually no industry could operate without water; arguably, it is more crucial to modern day life than oil. Unfortunately, the world's supply of freshwater—the source supplying water to homes, businesses, farms, and utilities—is limited.

Approximately 97% of the earth's water is salty and unsuitable for drinking, leaving only 3% as freshwater. Of that 3%, two-thirds is frozen in ice caps and glaciers, which means only 1% of the earth's water is available for drinking and other uses. Factor in that the human body consists of up to 70% water and can survive for only a few days without it, and the rationale behind calling freshwater the most precious resource on the planet becomes clear. Ranked highly along with oxygen as being essential for life, water is constantly being recycled from one form to another through the hydrological cycle. Faced with a myriad of domestic and industrial activities that consume and pollute water, nature and the hydrological cycle can do only so much to maintain the purity of this vital resource. A safe water supply is therefore dependent on clean water standards, disinfection treatments, and conservation strategies.

In the United States, access to safe water for drinking, food preparation, personal hygiene, and other uses is made possible by the U.S. Environmental Protection Agency (EPA): Water of drinking quality is channeled to the faucets of kitchens and bathrooms, toilets, automatic dishwashers, garbage disposals, laundry facilities, lawn sprinklers, swimming pools, car washes, and food processing and manufacturing operations. Although hundreds of organizations in the United States assist in monitoring water quality, EPA provides oversight for ensuring the supply of safe water for aquatic habitats, businesses, and homes in the United States. In addition, EPA works with other countries and organizations such as the World Health Organization to protect water resources around the world and to improve worldwide access to safe drinking water (EPA 2006a). In fact, most of EPA's standards and regulations for safe and clean water are fundamentally identical to those of other developed countries such as Canada, Germany, and the United Kingdom.

Moreover, EPA enforces federal clean water and safe drinking water laws, provides support for municipal wastewater treatment plants, and takes part in pollution prevention efforts aimed at protecting watersheds and sources of drinking water. EPA oversees both regulatory and voluntary programs to fulfill its mission to protect the nation's waters. Because of EPA's position as an authority in the development and monitoring of water quality standards, this Scientific Status Summary focuses on U.S. water regulations and water treatment standards. More specifically, this article discusses different sources of drinking water (surface water and ground water) and the regulations in place to monitor them. In addition, the article comments on policies addressing clean water, water pollution and predominant sources of contamination relevant to the food and agriculture industries, wastewater management, and mechanisms in place to keep freshwater sources safe.

The Safe Drinking Water Act

A safe drinking water supply is dependent on proper water treatment and disinfection. Adopted by the U.S. Congress in 1974, the Safe Drinking Water Act (SDWA) regulates the quality of drinking water for the American public. The SDWA empowers EPA to set standards to prevent or limit exposure to natural or man-made

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contaminants in public drinking water systems. The law applies to all public water sources used for drinking purposes; it does not apply to private water sources serving fewer than 25 individuals (EPA 2003c, 2004b). Enhanced by amendments in 1986 and 1996, the SDWA emphasizes the quality of water from source to tap and thus addresses source water protection, operator training, funding for improvements of water systems, and public information (EPA 2004b).

EPA bases its drinking water standards on science, technology, and cost and has established 2 sets of national standards. Applicable to all public drinking water systems, the first set is the National Primary Drinking Water Regulations (NPDWRs), which are enforceable standards that protect public health by limiting the levels of contaminants in drinking water. NPDWRs set certain safe-level ranges known as maximum contaminant levels for approximately 90 different contaminants in drinking water. These 90 contaminants are grouped into 6 different categories: microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides (Table 1). NPDWRs also indicate required treatment procedures to remove contaminants from drinking water (EPA 2004b).

EPA's second set of drinking water standards, National Secondary Drinking Water Regulations, consists of nonenforceable guidelines regulating contaminants that may cause unintended cosmetic effects (such as skin or tooth discoloration) or unaesthetic effects (such as an unusual taste, an unpleasant odor, or an odd color). While these secondary standards are recommended by EPA, they are not mandatory (Table 2).

Although EPA sets standards for safe drinking water, states, tribes, and water systems are responsible for ensuring that public drinking water systems meet EPA's standards. Under the SDWA, states and water suppliers must assess their water sources to determine vulnerability to contamination. For this reason, EPA developed minimum testing schedules for specific pollutants in public drinking water systems to ensure that contaminants in drinking water do not exceed maximum contaminant levels. Using these minimum testing schedules as a framework, each state or region determines the frequency of drinking water tests (EPA 2003c). The SDWA also specifies that states must have programs to certify water system operators and to determine whether new water systems have the full capacity (that is, sufficient management, technology, and finances) to provide safe drinking water (EPA 2004b). Water systems that cannot meet the standards of the SDWA and the NPDWRs must notify their customers immediately. Moreover, if drinking water is contaminated by something that can cause immediate illness, water suppliers are required to inform residents as soon as possible. In addition, water suppliers have a 24-hour time frame to notify customers of any violation of EPA standards that could adversely affect human health in the short term.

Contributing to the oversight of safe drinking water are various specific EPA departments. The Office of Enforcement and Compliance Assurance works on enforcement activities related to drinking water; the Office of Water is responsible for EPA's water quality activities. More notably, it is EPA's Office of Ground Water and Drinking Water (OGWDW) that protects public health by ensuring safe drinking water and protecting ground water. In conjunction with EPA's 10 regional drinking water programs (Table 3), the OGWDW oversees implementation of the Safe Drinking Water Act.

Public Water Systems

EPA-regulated public water systems supply drinking water to 90% of America's population. A public water system is a water distribution system that provides drinking water via pipes or other constructed conveyances (such as canals or waterways) to at least 25 people or 15 service connections for at least 60 days a year (EPA 2003c). The United States has approximately 160,000 public water systems, which may be either publicly or privately owned (EPA 2004b). Public water systems that provide year-round drinking water service to people's residences are called community water systems whereas those that serve nonresidential sites (such as schools, churches, and rest stops) are called noncommunity water systems. Most people receive drinking water through one of 53,000 community water systems around the country, yet the bulk of the U.S. population (81%) receives water service from only 8% of the community water systems (EPA 2006c). More specifically, most Americans receive their drinking water from large municipal water systems, many of which are public water systems that make use of rivers, lakes, and reservoirs—surface water. Even though some public water systems frequently obtain water from underground wells and aquifers, wells that supply drinking water to less than 25 people are not subject to EPA regulations (EPA 2003c).

Surface water

An important source for drinking and recreation, surface water is any body of water that is exposed to the atmosphere. Lakes, oceans, ponds, rivers, and streams are all examples of surface water. Surface water has 2 forms: saltwater and freshwater. While both saltwater and freshwater are suitable for the sustenance of aquatic life and recreational activities such as swimming, only freshwater is suitable as a source for drinking water. (The benefits of ocean water desalination are outweighed by the cost, time, and expenditure of energy necessary to complete the process.) Moreover, most of the earth's water supply is salty, so freshwater is a finite source for drinking water. In general, large-scale public drinking water supply systems rely on freshwater surface waters: More U.S. residents receive their drinking water from a surface water source even though more community water systems use ground water as their source (EPA 2006c). Besides being the source for most drinking water in the United States, surface water is also the main source for irrigation systems such as dams, canals, and sprinkler systems; industrial purposes; mining; and thermoelectric power generation. Thus, approximately 74% of the freshwater used in the United States is surface water (Hutson and others 2004).

Many surface waters serve as both suppliers of drinking water and receptors of wastewater. Impervious surfaces and structures such as concrete, asphalt, buildings, and houses increase the amount of runoff from precipitation. Cultivating land for agriculture also affects the amount and quality of runoff by reducing the rate of ground water recharge and adding fertilizers, pesticides, and sediment to runoff (Winter and others 1998). Surface runoff and any accompanying pollutants come in direct contact with surface water. In fact, certain rivers and streams are specifically used for the assimilation, dilution, and transport of waterborne wastes (for example, treated sewage), which may make them unsuitable for skin contact (Winter and others 1998). Federal and state regulations require public water systems to treat and test surface water before distribution.

Ground water

While most of the United States obtains freshwater from surface water sources (lakes, rivers, streams, and so on), approximately 26% of U.S. freshwater comes from ground water sources (Hutson and others 2004). Located underground in the crevices and spaces between sand, soil, and rocks, ground water is the only source of drinking water for many parts of the United States that have limited or no access to surface water: Approximately 46% of U.S. residents

Table 1 — Maximum contaminant levels for drinking water.

Contaminant	Contamination Source	Maximum Contaminant Level (MCL)[a]	Potential Health Effects if MCL Exceeded in Drinking Water
Microorganisms			
Cryptosporidium	Human and animal fecal waste	0	Gastrointestinal illness (for example, diarrhea, vomiting, cramps)
Giardia lamblia	Human and animal fecal waste	0	Gastrointestinal illness
Heterotrophic plate count	HPC measures a range of bacteria that are naturally present in the environment	n/a	n/a
Legionella	Found naturally in water; multiplies in heating systems	n/a	Legionnaire's disease
Total coliforms (including fecal coliform and *E. coli*)	Naturally present in the environment and in feces; however, fecal coliforms and *E. coli* come only from human and animal fecal waste	5% of samples per month	Not a direct health threat; used to indicate whether potentially harmful bacteria are present
Turbidity (cloudiness of water)	Soil runoff	Turbidity level $\leq$ 1 nephelolometric turbidity units (NTU)	As a measure of the cloudiness of water, high turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites, and certain bacteria.
Viruses (enteric)	Human and animal fecal waste	0	Gastrointestinal illness
Disinfectants			
Chloramines	Additive for controlling microbes	4[b]	Eye or nose irritation, stomach discomfort, anemia
Chlorine	Additive for controlling microbes	4[b]	Eye or nose irritation, stomach discomfort
Chlorine dioxide	Additive for controlling microbes	0.8[b]	Anemia; nervous system effects in infants and young children
Disinfection byproducts			
Bromate	Byproduct of drinking water disinfection	0.01	Increased risk of cancer
Chlorite	Byproduct of drinking water disinfection	1	Anemia; nervous system effects in infants and young children
Haloacetic acids (HAA5)	Byproduct of drinking water disinfection	0.06	Increased risk of cancer
Total trihalomethanes (TTHMs)	Byproduct of drinking water disinfection	0.10	Liver, kidney, or central nervous system problems; increased risk of cancer
Inorganic chemicals			
Antimony	Discharge from petroleum refineries, fire retardants, ceramics, electronics, and solder	0.006	Increased blood cholesterol, decreased blood sugar
Arsenic	Erosion of natural deposits; runoff from orchard, runoff from glass and electronics production	0.01	Skin damage or problems with circulatory systems; possible increased risk of cancer
Asbestos	Decay of asbestos cement in water mains; erosion of natural deposits	7 million fibers per liter[c]	Increased risk of benign intestinal polyps
Barium	Discharge of drilling wastes, discharge from metal refineries, erosion of natural deposits	2	Increased blood pressure
Beryllium	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004	Intestinal lesions
Cadmium	Corrosion of galvanized pipes, erosion of natural deposits, discharge from metal refineries, runoff from waste batteries and paints	0.005	Kidney damage
Chromium (total)	Discharge from steel and pulp mills, erosion of natural deposits	0.1	Allergic dermatitis
Copper	Corrosion of household plumbing systems, erosion of natural deposits	Action level = 1.3[d]	For short-term exposure: gastrointestinal distress For long-term exposure: liver or kidney damage
Cyanide (as free cyanide)	Discharge from steel/metal factories, plastic factories, fertilizer factories	0.2	Nerve damage or thyroid problems

Continued.

Table 1 — Continued.

Contaminant	Contamination Source	Maximum Contaminant Level (MCL)[a]	Potential Health Effects if MCL Exceeded in Drinking Water
Fluoride	Additive promoting strong teeth; also from erosion of natural deposits or discharge from fertilizer factories, aluminum factories	4	Bone disease, mottled teeth in children
Lead	Corrosion of household plumbing systems, erosion of natural deposits	Action level = 0.015[d]	For infants and children: delays in physical or mental development, slight deficits in attention span, learning disabilities For adults: kidney problems, high blood pressure
Mercury	Erosion of natural deposits, discharge from refineries and factories, runoff from landfills and croplands	0.002	Kidney damage
Nitrate (measured as nitrogen)	Sewage, runoff from fertilizers, leaching from septic tanks, erosion of natural deposits	10	In infants younger than 6 mo in age, serious illness or death; shortness of breath and blue-baby syndrome
Nitrite (measured as nitrogen)	Sewage, runoff from fertilizers, leaching from septic tanks, erosion of natural deposits	1	In infants younger than 6 mo in age, serious illness or death; shortness of breath and blue-baby syndrome
Selenium	Discharge from petroleum refineries or mines, erosion of natural deposits	0.05	Hair or fingernail loss, numbness in fingers or toes, circulatory problems
Thallium	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems
Organic chemicals			
Acrylamide	Added to water during sewage/wastewater treatment	0	Nervous system or blood problems, increased risk of cancer
Alachlor	Herbicide runoff	0.002	Eye, liver, kidney, or spleen problems; anemia, increased risk of cancer
Atrazine	Herbicide runoff	0.003	Cardiovascular or reproductive system problems
Benzene	Discharge from factories, leaching from gas storage tanks and landfills	0.005	Anemia, decrease in blood platelet count, increased risk of cancer
Benzo(a)pyrene (PAHs)	Leaching from lining of water storage tanks and distribution lines	0.0002	Reproductive difficulties, increased risk of cancer
Carbofuran	Leaching of soil fumigant used on rice and alfalfa	0.04	Blood, nervous system, or reproductive system problems
Carbon tetrachloride	Discharge from chemical plants and other industrial activities	0.005	Liver problems, increased risk of cancer
Chlordane	Residue of a banned termiticide	0.002	Liver or nervous system problems, increased risk of cancer
Chlorobenzene	Discharge from chemical and agricultural chemical factories	0.1	Liver or kidney problems
2,4-D	Herbicide runoff	0.07	Kidney, liver, or adrenal gland problems
Delapon	Herbicide runoff	0.2	Kidney problems
1,2-Dibromo-3-chloropropane (DBCP)	Runoff and leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	0.0002	Reproductive problems, increased risk of cancer
o-Dichlorobenzene	Discharge from industrial chemical factories	0.6	Liver, kidney, or circulatory system problems
p-Dichlorobenzene	Discharge from industrial chemical factories	0.075	Anemia; liver, kidney, or spleen damage; changes in blood
1,2-Dichloroethane	Discharge from industrial chemical factories	0.005	Increased risk of cancer
1,1-Dichloroethylene	Discharge from industrial chemical factories	0.007	Liver problems
cis-1,2-Dichloroethylene	Discharge from industrial chemical factories	0.07	Liver problems
trans-1,2-Dichloroethylene	Discharge from industrial chemical factories	0.1	Liver problems
Dichloromethane	Discharge from drug and chemical factories	0.005	Liver problems, increased risk of cancer
1,2-Dichloropropane	Discharge from industrial chemical factories	0.005	Increased risk of cancer
Di(2-ethylhexyl) adipate	Discharge from chemical factories	0.4	Weight loss, liver problems, or possible reproductive difficulties
Di(2-ethylhexyl) phthalate	Discharge from rubber and chemical factories	0.006	Reproductive and liver problems, increased risk of cancer
Dinoseb	Herbicide runoff	0.007	Reproductive problems
Dioxin (2,3,7,8-TCDD)	Emissions from waste incineration and other combustion; discharge from chemical factories	0.00000003	Reproductive problems, increased risk of cancer

Continued.

Table 1 — Continued.

Contaminant	Contamination Source	Maximum Contaminant Level (MCL)[a]	Potential Health Effects if MCL Exceeded in Drinking Water
Diquat	Herbicide runoff	0.02	Cataracts
Endothall	Herbicide runoff	0.1	Stomach and intestinal problems
Endrin	Residue of a banned insecticide	0.002	Liver problems
Epichlorohydrin	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	0	Increased cancer risk, stomach problems
Ethylbenzene	Discharge from petroleum refineries	0.7	Liver or kidney problems
Ethylene dibromide	Discharge from petroleum refineries	0.00005	Liver, stomach, reproductive, and kidney problems; increased risk of cancer
Glyphosate	Herbicide runoff	0.7	Kidney and reproductive problems
Heptachlor	Residue of a banned termiticide	0.0004	Liver damage, increased risk of cancer
Heptachlor epoxide	Breakdown of heptachlor	0.0002	Liver damage, increased risk of cancer
Hexachlorobenzene	Discharge from metal refineries and agricultural chemical factories	0.001	Liver, kidney, or reproductive problems; increased risk of cancer
Hexachlorocyclopentadiene	Discharge from chemical factories	0.05	Kidney or stomach problems
Lindane	Runoff or leaching from insecticide used on cattle, lumber, and gardens	0.0002	Liver or kidney problems
Methoxychlor	Runoff or leaching from insecticide used on fruits, vegetables, alfalfa, and livestock	0.04	Reproductive problems
Oxamyl (Vydate)	Runoff and leaching from insecticide used on apples, potatoes, and tomatoes	0.2	Nervous system problems
Polychlorinated biphenyls (PCBs)	Runoff from landfills, discharge of waste chemicals	0.0005	Skin changes and problems with thymus gland; immune, reproductive, or nervous system; increased risk of cancer
Pentachlorophenol	Discharge from wood preserving factories	0.001	Liver or kidney problems, increased risk of cancer
Picloram	Herbicide runoff	0.5	Liver problems
Simazine	Herbicide runoff	0.004	Problems with blood
Styrene	Discharge from rubber and plastic factories, leaching from landfills	0.1	Liver, kidney, or circulatory problems
Tetrachloroethylene	Discharge from factories and dry cleaners	0.005	Liver problems, increased risk of cancer
Toluene	Discharge from petroleum factories	1	Problems with nervous system, kidney, or liver
Toxaphene	Runoff and leaching from insecticide used on cotton and cattle	0.003	Problems with kidney, liver, or thyroid; increased risk of cancer
2,4,5-TP (Silvex)	Residue of banned herbicide	0.05	Liver problems
1,2,4-Trichlorobenzene	Discharge from textile finishing factories	0.07	Adrenal gland problems
1,1,1-Trichloroethane	Discharge from metal degreasing sites and other factories	0.2	Problems with liver, nervous systems, or circulatory system
1,1,2-Trichloroethane	Discharge from industrial chemical factories	0.005	Problems with liver, kidney, or immune system
Trichloroethylene	Discharge from metal degreasing sites and other factories	0.005	Liver problems, increased risk of cancer
Vinyl chloride	Leaching from PVC pipes, discharge from plastic factories	0.002	Increased risk of cancer
Xylenes (total)	Discharge from petroleum factories and chemical factories	10	Nervous system damage
Radionuclides			
Alpha particles	Erosion of natural deposits of certain minerals that are radioactive and may emit alpha radiation	15 picocuries per liter (pCi/L)	Increased risk of cancer
Beta particles and photon emitters	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit photons and beta radiation	4 millirems per year	Increased risk of cancer
Radium 226 and radium 228 (combined)	Erosion of natural deposits	5 picocuries per liter (pCi/L)	Increased risk of cancer
Uranium	Erosion of natural deposits	30 μg/L	Increased risk of cancer, kidney toxicity

[a]Units are in mg/L unless otherwise noted.
[b]This number represents the maximum residual disinfectant level, which is the highest allowable level of a disinfectant in drinking water.
[c]A fiber is greater than 10 μm.
[d]This reflects a treatment-technique level, which indicates the amount necessary to reduce the level of a contaminant in drinking water.
Source: U.S. Environmental Protection Agency, www.epa.gov.

rely on ground water for drinking water (EPA 2002c). Moreover, most of the water used for self-supplied domestic uses and agricultural purposes (that is, watering crops and livestock) is ground water. To facilitate self-supplied domestic use, about 15% of U.S. residents access ground water via private well systems. Unfortunately, ground water is susceptible to contamination from petroleum hydrocarbon compounds, volatile organic compounds, nitrates, pesticides, microorganisms, and metals. In fact, many states indicate that the most common threats to ground water quality are underground storage tanks, septic systems, landfills, industrial facilities, and agricultural operations (EPA 2002c).

The agricultural industry regularly leaves imprints on both ground water and surface water. Crop production operations repeatedly introduce contaminants to ground water and surface water. Even though healthy soil contains basic nutrients such as nitrogen, phosphorus, potassium, and trace minerals, which are essential for plants to grow, repetitive planting of the same crops on the same land routinely exhausts the natural supply of nutrients in soil. An improper or nonexistent schedule of crop rotation depletes the nutrient content of soil. Fertilizers, which are frequently employed to replenish the largest nutrient depletions in soil—nitrogen, phosphorus, and potassium—can be detrimental to water sources. In particular, biological processes occurring in soil convert nitrogen fertilizer to nitrate, which can leach into ground water and run off into surface water sources. Water containing a high concentration of nitrate can be toxic to not only humans but also aquatic life (Burkart and Jha 2007). For example, water contaminated with high concentrations of nitrate can cause illness in infants up to 6 months old and, if left untreated, can lead to death (EPA 2007d).

Contaminated ground water sources also result from surface runoff and underground leaching at livestock production facilities. The nation's consumption of beef, chicken, pork, eggs, milk, and cheese is responsible for more than 60% of sales in the agricultural industry (Helmers and others 2007). In addition to supplying juicy hams and steaks, spicy wings, and flavorful ice cream, livestock carry microorganisms that are pathogenic to humans. *Cryptosporidium*, *E. coli* O157:H7, *Giardia lamblia*, *Listeria*, and *Salmonella* are all harmless in livestock but pose human health hazards if present in the water supply. Gastroenteritis, meningitis, hepatitis, myocarditis, or even death may result from consumption of water containing microbial contaminants from livestock (EPA 2007d).

In October 2006, EPA enacted a new ground water rule to reduce the amount of disease-causing microorganisms in drinking water. Developed to target fecal contamination of ground water, the rule applies to all public water systems that use ground water as a primary source for drinking water. The ground water rule addresses risks by relying on the following 4 major components:

1. Periodic sanitary surveys of ground water systems, including the evaluation of 8 critical elements and the identification of significant deficiencies;
2. Source-water monitoring to test for the presence of *E. coli*, enterococci, or coliphage;
3. Mandatory corrective actions for any system with a significant deficiency or source water fecal contamination; and
4. Compliance monitoring to ensure that resultant drinking water is free of 99.99% of viruses (EPA 2006b).

Another nationwide effort to maintain the quality of ground water in the United States is the Underground Injection Control Program (UIC Program). The UIC Program involves the safe, controlled placement of waste fluids underground via methods that minimize or eliminate the interaction of waste fluids with underground sources of drinking water. Numerous facilities across the nation require the safe disposal of various hazardous and nonhazardous fluids. Even though this fluid waste could be released into surface water, treating surface water contaminated with industrial fluid waste is highly expensive. The UIC Program thus provides a safe, cost-effective alternative for agricultural, chemical, and petroleum businesses to dispose of fluids through injection wells. Injection wells receive more than 9 billion gallons of hazardous waste per year. Divided into 5 classes, injection wells are shafts or holes drilled or bored to a depth—in some cases—beyond that of the deepest underground source of drinking water. Each class groups wells with similar functions so that consistent constructive, operative, and technical requirements apply. The classes are as follows:

- Class I – technologically sophisticated wells that inject hazardous and nonhazardous industrial and municipal fluid into deep, isolated rock formations beneath the lowest underground source of drinking water. Industries using class I wells include food processing, metal, pharmaceutical, commercial, municipal, and petroleum.
- Class II – wells that inject brine, crude oil, and other fluids associated with the production of oil and natural gas.
- Class III – wells that inject super-hot steam, water, or other fluids into formation for the purpose of extracting minerals.

Table 2—Contaminant levels for National Secondary Drinking Water Regulations.

Contaminant/characteristic	Recommended level
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 color units
Copper	1 mg/L
Corrosivity	Non-corrosive
Fluoride	2 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 to 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, www.epa.gov.

Table 3—EPA's 10 regional drinking water programs.

Region 1	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, and Indian lands within Region 1
Region 2	New Jersey, New York, Puerto Rico, Virgin Islands, and Indian lands within Region 2
Region 3	Delaware, Maryland, District of Columbia, Pennsylvania, Virginia, West Virginia
Region 4	Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Indian lands within Region 4
Region 5	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin, and Indian lands within Region 5
Region 6	Arkansas, Louisiana, New Mexico, Oklahoma, Texas, and Indian lands within Region 6
Region 7	Iowa, Kansas, Missouri, Nebraska, and Indian lands within Region 7
Region 8	Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming, and Indian lands within Region 8
Region 9	Arizona, California, Hawaii, Nevada, Guam, Commonwealth of North Mariana Islands, and Indian lands within Region 9
Region 10	Alaska, Idaho, Oregon, Washington, and Indian lands within Region 10

Source: U.S. Environmental Protection Agency, www.epa.gov.

Industries using class II wells include salt, uranium, and sulfur mines.

- Class IV – shallow wells that inject hazardous or radioactive wastes above or into underground sources of drinking water. These wells are banned except under strict authorization by EPA and the relevant state authority to facilitate an emergent cleanup of radioactive waste or hazardous materials.
- Class V – mostly shallow, low-tech wells that inject nonhazardous fluids not specified in classes I through IV and provide little or no protection against ground water contamination. These wells include septic systems, cesspools, and leach fields. Industries using class V wells include agricultural, food processing, and municipal storm water systems (EPA 2002b).

Private well systems

Households relying on private wells as their source of drinking water must take special precautions to ensure the safety of their water supply, particularly if the wells are near UIC Program injection wells. Private well systems are not subject to EPA standards and regulations, so private well owners are primarily responsible for the safety of the water drawn from their wells. Nevertheless, EPA offers guidelines for safe water from private wells: For possible sources of water contamination, EPA recommends maintaining the following distances between the source and the private well (EPA 2002a):

1. Livestock yards, silos, and septic leach fields – 50 feet
2. Septic tanks – 50 feet
3. Petroleum tanks, liquid-tight manure storage, and fertilizer storage/handling – 100 feet
4. Manure stacks – 250 feet

Bottled Water

People across America have nearly free access to safe drinking water through municipal taps. Despite the easy access of tap water, drinking water is also packaged in plastic and glass bottles and sold at a much higher price. Americans spend billions of dollars each year on bottled water; as a result, bottled water has become the second largest commercial beverage category, surpassing coffee and milk (Marsh 2007). Produced and distributed as a food product, bottled water is defined by the U.S. Food and Drug Administration (FDA) as water intended for human consumption that is enclosed in a sanitary container, contains no added ingredients (except for optional antimicrobial agents or FDA-specified amounts of fluoride), and meets all applicable federal and state standards (Posnick and Kim 2002; IBWA 2004; EPA 2005). More specifically, bottled water companies must adhere to FDA's standards of quality, standards of identity (including labeling requirements), and current good manufacturing practices (Posnick and Kim 2002; IBWA 2004).

FDA's standards of quality (21 CFR § 165.110[b]) establish maximum allowable levels of contaminants—chemical, physical, microbiological, and radiological—in bottled water. All bottled water sold in interstate commerce in the United States, including products from other countries, must adhere to FDA standards for physical, chemical, microbial, and radiological contaminants. In fact, the federal Food, Drug, and Cosmetic Act (FDCA) provides that FDA's standards for bottled water must be at least as stringent and qualitative as EPA's standards for public water systems; thus, the maximum contaminant levels for bottled water are very similar to those for tap water (Bullers 2002; Posnick and Kim 2002; EPA 2005). Moreover, the FDCA requires that when EPA implements a new standard for tap-derived drinking water, FDA must either adopt that standard for bottled water or determine that the standard does not apply to bottled water and is therefore unnecessary (Bullers 2002).

FDA's standards of identity define the different classifications of bottled water. Consequently, bottled water labels must indicate the type of water and its source as well as the name of the product; the name and address of the manufacturer, packer, or distributor; and the net content (Posnick and Kim 2002; IBWA 2003). For instance, bottled water originates from 2 sources: natural ground water and public water systems. By far, most bottled water brands (approximately 75%) obtain their water from natural underground sources such as springs or artesian wells (IBWA 2003, 2004). However, some bottled water brands use municipal water systems as their sources for water. Many companies that rely on public water supplies as their source for bottled water treat the water to processing methods that further enhance water quality. FDA's designated standard definitions for various types of bottled water are as follows:

- Artesian Water – water from an underground confined aquifer in which the water level stands at a height above the top of the aquifer.
- Mineral Water – ground water that naturally contains at least 250 ppm of total dissolved solids.
- Purified Water – water treated to meet the U.S. Pharmacopeia definition of purified water (this designation may also appear as demineralized water, deionized water, distilled water, and reverse osmosis water).
- Sparkling Bottled Water – after undergoing treatment and possible carbon dioxide replacement, water containing the same amount of carbon dioxide that it had when it emerged from its source.
- Spring Water – water from an underground aquifer that flows naturally to the earth's surface.

Seltzer, soda, tonic, and certain sparkling waters are considered soft drinks, not bottled water.

As with all the food items FDA regulates, bottled water must be processed, packaged, shipped, and stored in a safe and sanitary manner. Current good manufacturing practices for bottled water (21 CFR part 129) specify ground and plant construction, design, and maintenance; appropriate plumbing and sewage disposal; sanitation of buildings and fixtures; a safe, sanitary water supply; and sanitary transport. Any new source for bottled water must be approved by state or local jurisdictions. In addition, bottled water manufacturers must test their sources at least once a week for microbiological contaminants and once a year for chemical contaminants. Moreover, bottled water manufacturers must test their finished bottled water products at least once a week for microbiological contaminants and once a year for physical, chemical, and radiological contaminants. All U.S. bottled water manufacturers producing bottled water products for interstate commerce must operate their plants according to FDA's current good manufacturing practices (IBWA 2003, 2004; EPA 2005). In addition, bottled water imported from other countries and sold in the United States must adhere to the same federal and state regulations that apply to domestic bottled water brands (IBWA 2004).

Besides adhering to federal and state standards, many companies in the bottled water industry follow the guidelines of the International Bottled Water Association (IBWA). Founded in 1958, IBWA is the trade association that represents the bottled water industry. The association's membership includes bottlers, distributors, and suppliers from the United States and other countries. IBWA has collaborated with FDA, state legislatures, and international governments to establish regulations aimed at ensuring high-quality bottled waters. In fact, IBWA created a model code that many states use as guidelines to develop bottled water regulations: the Bottled Water Code of Practice. IBWA's model code contains protective standards to ensure the safety of bottled water from source through packaging, supplements FDA's current good manufacturing practices, and provides the basis for the Hazard Analysis and Critical Control Point (HACCP) system in the bottled water industry (IBWA 2005). To that end, all member bottlers must undergo an annual, unannounced inspection conducted by an independent internationally recognized organization. Unannounced inspections ensure that all IBWA member bottlers meet federal, state, and IBWA requirements for the production and sale of bottled water.

Potable Water on Airplanes, Cruise Ships, Trains, and Buses

EPA is responsible for public water systems that provide tap water, and it is responsible for parent water systems that provide potable water to aircraft. Consequently, EPA has the objective of ensuring that the drinking water on aircraft is as safe as the drinking water from a tap. In October 2005, EPA finalized agreements with 24 U.S. passenger airlines to implement new aircraft water testing and disinfection protocols to protect the traveling public (EPA 2006d). The agreements stipulate that airlines will quarterly disinfect water delivery systems aboard passenger aircraft, increase monitoring, and notify the public when water is found not to meet EPA standards. However, EPA plans to offer further guidance by issuing proposed regulations sometime in 2007 (at the time of this printing, the proposed regulations had not been issued), and final regulations should be complete by 2009. In the meantime, the 24 U.S. airlines must adhere to the following protocols:

1. regular monitoring of aircraft water systems,
2. regular disinfecting of aircraft water systems and water transfer equipment,
3. undertaking corrective action when testing reveals a positive total coliform sample,
4. providing public notice or suspending water service when a positive total coliform result occurs,
5. conducting studies of possible sources of contamination that exist outside the aircraft, and
6. supplying information on various aspects of their domestic and foreign water practices (EPA 2006d).

While EPA regulates the public water systems that supply water to airports and aircraft, FDA regulates culinary water (for example, ice, bottled water, and water serving as an ingredient in food and beverages) and the points where aircraft obtain water from the airport, such as pipes and tankers. In addition, the Federal Aviation Administration (FAA) requires airline companies to submit operation and maintenance plans for all aircraft parts, including potable water systems. The safety of drinking water on aircraft thus requires a collaborative effort between EPA, FDA, and FAA (EPA 2006e).

The World Health Organization estimates that since 1970 more than 100 disease epidemics have occurred on ships. Of those epidemics, most gastrointestinal illnesses that occurred on cruise ships—such as *Salmonella*, hepatitis A, *Escherichia coli* O157:H7, and Norwalk-like virus—were the result of contaminated food and drinking water (WHO 2002). As a consequence, the oversight of potable water systems on cruise ships with international itineraries falls under the jurisdiction of the U.S. Centers for Disease Control and Prevention (CDC). In the 1970s, CDC developed the Vessel Sanitation Program (VSP) as a way to protect the health of passengers and crews by reducing the risk of gastrointestinal ailment aboard cruise ships. Through VSP, CDC ensures that the cruise ship industry maintains sanitary vessels and provides safe drinking water on ships. Twice a year, VSP assessors conduct unannounced inspections of every cruise ship carrying 13 or more passengers that navigates through international waters and visits U.S. ports. The inspections are based on the VSP Operations Manual and include assessments of food, water supply, spas and pools, employee hygiene practices, general cleanliness of the ship (including pest control), and surveillance of illnesses (CDC 2005).

Potable water on domestic cruise ships that never navigate beyond U.S. waters and on all other travel vessels that engage solely in interstate travel, such as trains and buses, is subject to FDA's Interstate Travel Sanitation Program and to EPA regulations. Prior to passage of the SDWA, EPA had authority over public water systems servicing interstate carrier conveyances, and FDA regulated the watering points from which interstate carriers obtained potable water. After enactment of the SDWA, EPA expanded its authority to include regulating the quality of potable water on board interstate carriers. To address the unique characteristics of interstate carriers, EPA customized the requirements of the SDWA by issuing Water Supply Guidance 29. In general, Water Supply Guidance 29 provides that all interstate travel vessels supplying drinking water to passengers must meet the standards of the NPDWRs (EPA 1986, 21 CFR §1250.82).

The Clean Water Act

Adopted by Congress in 1972 and amended in 1977, the Clean Water Act (CWA) is the federal law governing the control of water pollution. With the objective of maintaining and restoring the chemical, physical, and biological integrity of the nation's waters, the CWA requires state and local jurisdictions to monitor the quality of waters within their regions. In addition to determining whether their water meets quality and health standards, states must prepare and submit to EPA biennial reports on their findings. Even though the CWA allows state and local officials to develop their own water quality standards, the standards must be at a level that renders all publicly accessible waters safe for fishing and swimming (EPA 2002c).

Fostering the safety and protection of all U.S. waters, water quality standards contain 3 elements: state-designated uses, state water-quality criteria, and antidegradation policies. One element, state water-quality criteria, establishes descriptors and numeric thresholds for contaminants and/or pollutants. Another element, antidegradation policies, establishes protocols to maintain the level of quality in bodies of water. For the third element, state-designated uses, EPA has defined 6 general uses for water quality assessment (EPA 2002c). These general-use categories are as follows:

1. Drinking water supply – with standard treatments, water must be safe for drinking.
2. Agricultural uses – water must be safe to use for irrigating crops and watering livestock.
3. Aquatic life support – water must be of a good enough quality to support healthy aquatic organisms, including fish, plants, insects, and algae.
4. Fish consumption – people must be able to safely consume fish caught in waters such as rivers, lakes, and streams.
5. Primary contact recreation – people must be able to make full body contact with the waters without risking their health.
6. Secondary contact recreation – risks to public health must not occur from recreational activities—such as boating—that minimally expose people to water (EPA 2002c).

Besides establishing standards and methods for discharging pollutants into U.S. waters, the CWA authorizes EPA to execute other pollution control programs and reinforces quality standards for contaminants in surface waters. Because of the CWA, it is unlawful for anyone to discharge a pollutant from a point source into navigable waters without a permit. As provided by the CWA, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by establishing point sources through which pollutants may be discharged into U.S. waters. Point sources consist of isolated conveyances such as pipes or man-made ditches (Table 4). Structures that do not directly discharge wastewater into surface water—such as individual homes that are connected to a municipal system or that use a septic system—need not obtain NPDES permits. However, industrial, municipal, and other facilities must have NPDES permits if their wastewater is discharged directly into surface waters (EPA 2003b, 2007a).

Water Pollution and Wastewater Management

On the earth, water is constantly changing and moving, traversing over hills and through tributaries, freezing, thawing, and then moving again. Because of its constant movement, water is affected by everything with which it comes in contact within a watershed, including land, soil, and waste. Defined by geologic high points and low points, a watershed is an area of land from which all of the water shed from the area after rain and snow drains into a particular brook, marsh, stream, river, or lake. Polluted source waters threaten public health through the consumption of contaminated seafood and through exposure to contaminants in bathing or recreational waters. Some toxic chemicals in polluted water have been linked to human birth defects, neurological disorders, kidney ailments, and cancer. Furthermore, acute respiratory illness, gastrointestinal problems, jaundice, dehydration, brain inflammation, and heart problems are all symptoms of encounters with waterborne pathogens (EPA 2002c).

EPA's Office of Wastewater Management (OWM) oversees the safe operation of waters and watersheds in the United States and promotes compliance with the CWA. In addition, OWM implements the CWA in collaboration with regions, states, and tribes to regulate discharges into surface waters such as bays, rivers, lakes, and oceans. Because source water usually encounters some sort of pollution, it must go through drinking water treatment plants before it can flow through pipes to taps. Polluted source waters dramatically increase the cost and amount of treatment needed to provide safe drinking water to consumers (EPA 2002c). Water that comes in contact with pollutants such as human and animal waste, food scraps, chemicals, oils, and so on is called wastewater. There are 3 categories of wastewater: storm water runoff, domestic wastewater, and industrial wastewater.

Storm water runoff

Automobile fluids and roadway grease, road salt and other deicing agents, lawn pesticides, construction-site sediment, and trash are common pollutants that are released by storm water runoff into local surface waters. Another considerable source of U.S. water pollution is storm water runoff from industrial facilities: Precipitation from rain- and snow-covered industrial projects can transport pollutants to storm sewer systems, rivers, lakes, and oceans, wreaking havoc in aquatic habitats. In fact, states report that urban runoff and storm sewers—along with municipal sewage treatment plants—pollute nearly 3 million lake acres (EPA 2002c). Consequently, the NPDES program issues permits for storm water discharge associated with industrial activities that fall in the following 11 categories (EPA 2007b):

1. Facilities with effluent limitations
2. Manufacturing
3. Mineral, metal, oil, and gas
4. Hazardous waste, treatment, or disposal facilities
5. Landfills
6. Recycling facilities
7. Steam electric plants
8. Transportation facilities
9. Treatment works
10. Construction activity
11. Light industrial activity

Typically, storm water runoff travels through municipal storm sewer systems and discharges into nearby surface waters without being treated. For this reason, the CWA provides 2 phases of regulations for the discharge of industrial and municipal storm water into U.S. waters. Adopted in 1990, phase 1 regulations apply to storm water releases from municipal separate storm sewer systems that serve populations of more than 100,000 people, industrial activities, and construction activities taking place on 5 or more acres of land. Municipal separate storm sewer systems serving more than 100,000 must obtain NPDES permits from either EPA or designated state authorities. All phase 1 permits prohibit the discharge of nonstorm water into storm sewers. In addition, such permits specify strategies and techniques to reduce the release of pollutants as much as possible (McElfish and Casey-Lefkowitz 2001).

Phase 2 regulations, which were adopted in 1999, extend the NPDES permit program to discharges from municipal separate storm sewer systems in urbanized areas with populations of fewer than 100,000 people and to construction activities occurring on 1 to 5 acres (McElfish and Casey-Lefkowitz 2001). Rather than mandating specific conditions, phase 2 regulations rely on best management practices that permit-seekers either choose from an EPA-derived list of recommendations or develop themselves according to what conditions are most appropriate for their programs (EPA 2000; McElfish and Casey-Lefkowitz 2001).

Domestic wastewater

Unlike storm water runoff, which can flow directly into surface waters without treatment, domestic wastewater from U.S. residences and businesses is treated before it is released back to

Table 4—Point source pollution versus nonpoint source pollution.

	Point Source Pollution	Nonpoint Source Pollution
What is it?	An identifiable source of pollution from which pollutants can be measured and discharged, such as pipes, ditches, smokestacks, and wells	An indeterminate source of pollution from which pollutants cannot be measured
Where does it come from?	Sewage treatment plants Oil refineries Manufacturers of chemicals, electronics, and automobiles Animal feeding operations Ships and other watercraft Septic tanks Landfills	Excess fertilizers and pesticides from agricultural lands and residential areas Paint, oil, grease, and toxic chemicals from urban runoff Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks Salt from irrigation practices and acid drainage from abandoned mines Bacteria and nutrients from livestock, pet wastes, and faulty septic systems

Source: U.S. Environmental Protection Agency, www.epa.gov.

the environment. Even though nature has the capacity to accommodate limited amounts of water pollution, freshwater sources would be overwhelmed with the amount of pollutants in domestic wastewater. Stemming from showers and baths, toilets, kitchen sinks, and washing machines, domestic wastewater can contain substances such as food scraps, hair, human waste, soaps, and grease. It can also contain excessive amounts of phosphorus, a common ingredient in cleaning agents used in homes and business. Despite findings that it degrades water quality, phosphorus may be contained in cleaning agents such as automatic dishwasher detergents, household cleansers, degreasing compounds, and industrial cleansers (Litke 1999). Domestic wastewater is thus purposely routed into either a municipal sanitary sewer system, which routes wastewater to a wastewater treatment plant, or a septic system.

Even though municipal wastewater treatment systems use modern technology to clean water before returning it to the environment, the process has remained virtually the same for decades (EPA 2002d). Meanwhile, steady advances in health care have led to the presence of compounds in domestic wastewater that treatment plants are simply not equipped to handle. For example, the drug-dependent lifestyle that many individuals have adopted is quickly becoming a concern for environmentalists and engineers: traces of prescription and nonprescription drugs—antibiotics, antidepressants, birth control pills, anticancer drugs, painkillers, and so on—have been detected in American, Canadian, and European waters (Raloff 2000). Presumably, the chief source of this type of contamination is human and livestock waste; however, another possibility is emerging: when consumers dispose of their prescription and nonprescription drugs, many flush them down the toilet or rinse them down the drain. Regardless of the method of transmission, prescription drugs eventually end up dissolving in water sources that either house aquatic ecosystems or serve as drinking water supplies. Sewage treatment plants do not have the capacity to remove prescription drugs from water, and virtually no studies have determined whether chronic exposure to diluted drugs poses a threat to humans. On the other hand, diluted-drug exposure does pose a threat to aquatic wildlife: evidence suggests that trace amounts of prescription drugs in rivers, lakes, and streams have caused the feminization of male fish, delayed reproduction in female fish, and impaired kidneys and livers in both sexes (Nagler and others 2001; Barber and others 2007).

Industrial wastewater: agriculture

Economic stability in the United States is dependent on a strong agricultural industry. Crop production and livestock propagation ensure a wholesome, high-quality food supply for U.S. residents and the sustainability of rural communities. On the other hand, agricultural activities also constitute the most predominant source of pollution for U.S. lakes, rivers, and streams (EPA 2002c). Agricultural wastewater comes from a variety of farm activities and sources, such as animal waste, milking center wash water, feedlot runoff, egg washing and processing, and animal slaughter. For example, in typical animal feeding operations, the raising of animals occurs in confined situations: animals are kept on a small parcel of land which they share with their feed, their manure, production operations, and any dead livestock. Leaks or spills from waste storage structures (such as manure lagoons, holding ponds, or class V injection wells) can enter water sources, causing adverse effects on aquatic ecosystems (EPA 2007c). Specifically, manure contains nitrogen, phosphorus, organic solids, inorganic salts, and microorganisms, most of which make for a nutrient-rich substance when applied to soil. On the other hand, intermittent fish-kill events result from spills, runoff, and other discharges of manure from animal feeding operations. Another result is increased algae growth, which may eventually lead to fish kills, reduced biodiversity, unpleasant tastes and odors, and elevated costs for drinking water treatment (EPA 2003a). Unquestionably, certain agricultural practices introduce pollutants that adversely affect aquatic animals or otherwise hamper public use of millions of gallons of surface water (EPA 2002c). For this reason, discharges from animal feeding operations and aquatic animal production facilities are subject to NPDES regulations, but runoff from agriculture irrigation and agricultural storm water are not (EPA 2003a).

To clarify, certain animal feeding operations that purposefully discharge wastewater to surface waters must apply for an NPDES permit. However, animal feeding operations whose discharge is solely from agricultural storm water need not apply for an NPDES permit. All concentrated animal feeding operations—that is, a lot or facility where land-based animals are confined and fed for at least 45 days during a 12-month period but crops are not sustained—must apply for NPDES permits and develop plans to implement proper and effective manure and wastewater management (EPA 2003a). Because most crop-producing operations do not produce point-source wastewater, they are not subject to NPDES permits. In addition, EPA has issued a final rule addressing the release of pesticides in or around water: NPDES permits are not required to apply pesticides directly to or around water when a pesticide is being used to control pests in the water or pests that are above or near water. This clarification allows public health officials to respond adequately to infestations of mosquitoes carrying West Nile virus or invasive pests that could damage natural resources (EPA 2006f).

Of course, animal husbandry is not the sole origin of agricultural wastewater. Crop production can also generate runoff that can adversely affect water quality. For example, cover crops add organic matter to soil and protect it from erosion. In the absence of such protection, the byproduct of soil erosion, soil sediment, becomes a significant nonpoint source of pollution for surface waters (Burkart and Jha 2007; Helmers and others 2007). It reduces the clarity of water, thereby creating a less than ideal environment for aquatic organisms. Similarly, fertilizer applications, though beneficial for crop soil, create a runoff of nutrients that also impairs water sources. As mentioned previously, nitrate contamination of ground water poses potential health risks to the youngest of humans. Moreover, excessive levels of nitrogen and, in particular, phosphorus cause surface water quality problems by serving as food for algae and other aquatic plants. Expensive water purification technologies can remove nitrogen and phosphorus from water to prepare it for human consumption, but aquatic residents are less fortunate (Burkart and Jha 2007): When the overgrown aquatic vegetation dies, the process of decay usurps a disproportionate amount of oxygen in the water, which may subsequently lead to the death of fish and other aquatic organisms.

Industrial wastewater: food processing

Instant pancake mixes, canned fruits and vegetables, frozen yogurt, fish sticks, and chicken pot pies are just a few examples of processed food items that have become staples of American meals. A significant portion of the American diet, processed food either contains water or requires consumers to add water, but being an ingredient is not the only role water plays in food processing. Water is also used in the food processing industry as an initial and intermediate cleaning source for produce, meat, seafood, and poultry and as the principal agent for cleaning and sanitizing plant machinery and surrounding areas (USAEP 1997). In fact, washing and rinsing make up 50% of the water used in the fruit and vegetable sector, and the U.S. Dept. of Agriculture has established minimum requirements for the amount of water used to clean poultry products (USAEP 1997). As a result, the food processing industry uses a significant amount of water and generates turbid wastewater that contains high concentrations of nutrients, organic matter, and residual chemicals. For example, the slaughtering of meat and poultry and the skinning and eviscerating of fish create wastewater that contains blood byproducts; fats, oils, and greases; loose flesh and tissue; and pathogenic organisms such as *E. coli* and *Salmonella*. Wastewater from the produce sector may contain sugars and starches, other organic matter such as seeds and rinds, and residual pesticides. And in the dairy sector, wastewater pollutants typically include milk waste and sanitary cleansers (USAEP 1997).

The excessive amount of organic suspended solids, oily substances, and nutrients in food-processing wastewater creates high biochemical oxygen demands (BODs). Biochemical contaminants usurp oxygen in water, so higher BODs greatly reduce the oxygen content of water, which impairs aquatic ecosystems (EPA 2004c). For some municipality-based food processors, this translates into costly sewage surcharges levied by municipal wastewater treatment plants for the supplemental treatment this type of wastewater demands. For other food processors, wastewater with high BODs translates into investment in either pretreatment systems that reduce BODs before discharging wastewater into publicly owned wastewater systems or full-treatment systems that completely treat wastewater before reusing it or discharging it directly into receiving waters (EPA 2004c; Colic 2007). Regardless of the route to treatment, wastewater from food processing contains a load of contaminants that would render surface and ground waters unsuitable for drinking, recreational use, or aquatic habitats without undergoing wastewater treatment.

Wastewater Treatment

Around the world, thirst quenching, shower taking, toilet flushing, crop watering, and food processing occur on a daily basis, relying heavily on freshwater supply. Because freshwater is a limited resource, aquifers, lakes, rivers, and streams would run dry if water were not reclaimed and recycled. Water reclamation and reuse, through the treating of wastewater, helps prevent freshwater from depleting. For urban and suburban areas, wastewater treatment involves the use of sewer systems to collect wastewater and cleaning used water (including sewage) so that it can be returned safely to the environment. In most publicly owned wastewater treatment plants, wastewater undergoes 2 or 3 different stages of treatment (EPA 2004c): In the first stage, water flows through a screen that removes large solids such as sticks, diapers, dead animals, and so on. After screening, water flows into a grit chamber so that smaller particles such as sand, rocks, and gravel settle to the bottom, and grease, oils, and fats rise to the top. Mechanical arms skim oils, grease, and fats from the top and scrape the grit from the bottom. In the second stage, water flows into aerated or oxidized tanks that contain naturally occurring bacteria and other microorganisms. Under the influence of filtered air, the microbes ravenously consume organic matter and other pollutants in the water. After the microbes are stabilized, the water flows into a second settling chamber where they clump together and sink to the bottom. The third stage of wastewater treatment involves further filtration of the water and disinfection to remove or destroy nutrients (such as nitrogen and phosphorus) and bacteria that could be harmful to humans or aquatic life (EPA 2004c). The entire process usually takes 12 to 48 hours (MWRDGC 1995). With direct and indirect assistance from EPA, wastewater treatment systems in urbanized areas make use of complex sewer plans and expensive technologies that could effectively treat wastewater stemming from both domestic and industrial sources (EPA 2002c). The same cannot be said of rural areas.

In areas where houses and buildings are not part of a municipal sewer system, wastewater goes through a less sophisticated treatment process: septic systems. A septic system uses a septic tank and a drain field to dispose of and treat wastewater. Usually composed of concrete, a septic tank is a watertight chamber below ground that receives untreated wastewater from residences and businesses. Wastewater enters the septic tank at 1 end and separates into 3 layers: Heavier solid wastes settle to the bottom and form sludge, lighter wastes such as oil and grease rise to the top and form scum, and liquid wastewater forms a layer between the sludge and the scum. While naturally occurring bacteria in the septic tank break down solid materials, the liquid wastewater slowly flows from the opposite end of the tank into the drain field, which is a collection of perforated pipes in gravel-filled trenches. The drain field allows soil to absorb the water and serve as a filter. Clearly, septic systems have neither the capacity nor the technology to treat storm water or agricultural runoff in addition to domestic wastewater. The combination of an improperly maintained septic system and polluted runoff in the form of automobile fluids, roadway grease, or chemical pesticides and fertilizers could thus seriously contaminate ground water and surface water.

Water Security

The term *water security* has different meanings in various parts of the world. In Australia, water security refers to a wide-reaching management strategy to ensure continued availability of water resources to large rural areas suffering from severe drought. For Africa and Asia, water security refers to uncomplicated access to safe, clean water for daily activities that others take for granted, such as drinking, food preparation, and personal hygiene. And in low-income countries spread across 3 continents, water security often translates to the reduction of poverty and food scarcity (UN-Water 2006). But for the United States, in addition to efforts aimed at conserving water and expanding water reclamation, water security has another meaning: protecting drinking water systems and wastewater facilities from potential threats and attacks.

After September 11, 2001, America became acutely aware of opportunities for water-related bioterrorism threats—especially since U.S. public water systems and wastewater facilities are often housed in large, remote facilities that are difficult to monitor. As a result, in September 2002, EPA developed the Strategic Plan for Homeland Security and updated the plan with the 2004 Homeland Security Strategy. EPA based its water security strategies on Homeland Security Presidential Directives (HSPDs), which constitute 20 specific responsibilities necessary to increase the security of the nation. Four of the 20 directives are specifically relevant to water security:

HSPD 7: Critical Infrastructure Identification, Prioritization, and Protection
HSPD 8: National Preparedness
HSPD 9: Defense of United States Agriculture and Food
HSPD 10: Biodefense for the 21st Century

With 4 HSPDs serving as guidance, EPA developed water security strategic plans that not only include measures for physical security and cyber security but also outline the risks associated with the intentional release of biological, chemical, and radiological contaminants into U.S. water systems. One result of the strategic plan is EPA's collaboration with the Water Environment Research Foundation to develop tactics to improve wastewater security.

Another result of EPA's strategic plan is the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (Bioterrorism Act), which requires EPA to sponsor research that identifies (1) the most likely physical and cyber threats that would be used against drinking water systems, (2) the consequences of such threats if used in an attack, and (3) any countermeasures to either prevent or respond to such attacks. State and local officials obtain this information from EPA and use it to assess their vulnerability to attacks and implement strategies to counter these possibilities. Consequently, the Bioterrorism Act requires all community drinking water systems serving more than 3300 people to evaluate their vulnerability to potential threats and pinpoint remedial measures (EPA 2003c). Although water systems serving fewer than 3300 people are not required to conduct vulnerability assessments, such facilities receive from EPA information on the types of threats they could encounter (EPA 2004a, 2004d).

In most scenarios, the intentional release of biological, chemical, or radiological contaminants into a drinking water system would not be immediately evident. Some contaminants are not detectable by mere observation, tasting, or conventional testing. Therefore, it is paramount that a method be in place to accurately distinguish toxins introduced in drinking water. Moreover, drinking water systems must be capable of restoration after an intentional contamination occurs. The Bioterrorism Act also requires that community drinking water systems have analytical measures and detection techniques in place to provide accurate information on contaminants. Such measures include singling out field and laboratory capabilities for collecting and analyzing samples and establishing early warning systems (EPA 2004a).

Conclusion

In the United States as well as other developed countries, water safe for human consumption and use is a life-sustaining necessity that businesses and individuals often take for granted. Few consider that this privilege is the result of federal, state, and local entities enforcing laws aimed at maintaining safe, clean water. However, maintaining an abundant supply of safe drinking water—whether from ground water sources or surface waters—requires more than just the passing and enforcing of laws by federal, state, and local officials. It requires the diligence of the nation's residents and businesses to abide by the laws and follow safe practices that conserve water and minimize water pollution: for the average household, perhaps this means completely shutting off water taps when not in use; refraining from pouring oil, paint, or other hazardous chemicals directly into city sewers or nearby streams; scheduling regular maintenance of septic systems; and not discarding unused drugs in sinks or toilets. For agricultural operations, minimizing water pollution may mean investigating ways to reduce fertilizer and pesticide applications to crops, improving irrigation and drainage techniques for optimal performance, promptly cleaning spills and sealing leaks from waste storage structures, and applying for NPDES permits as necessary. And for food processors, investigating and utilizing methods to reduce the amount of organic suspended solids in wastewater, using more robust wastewater pretreatment systems, and increasing efforts to reclaim and reuse water may be effective ways to minimize water pollution.

Besides setting standards to prevent ground water and surface waters from becoming polluted by the daily habits and activities of U.S. businesses and residents, federal, state, and local officials also have the responsibility of securing the nation's water utilities from deliberate threats and purposeful attacks. To that end, EPA, drinking water systems, and wastewater management facilities recognize that increased security of U.S. drinking water and wastewater infrastructures requires enhanced measures to prevent, detect, respond to, and recover from intentional or unintentional breaches in water security. Unquestionably, such measures will require the collaboration of national, state, and local water sector stakeholders to reduce the risk to public health and the environment. Although additional tools and resources are necessary to determine and address vulnerabilities, some issues have already been identified and are being addressed.

Ultimately, clean water is not merely a necessity for providing water that is safe for the consumption of humans and land-based animals. Unpolluted water is vital for the habitats of countless aquatic organisms—many of which have recurring roles on the menus of restaurants and as staples in the fresh- or frozen-food offerings of markets around the world. And of course, clean water is essential for the producing, processing, and preparing of food. In short, the fact that water is essential for food, industry, and life may make it more than just the most common ingredient; perhaps it is the most important. Even though modern water treatment facilities remove a sizable amount of impurities from water, there are still aspects of water quality monitoring that are beyond the control of water utilities and governing authorities. It is thus everyone's responsibility to follow good-sense practices for improving the quality of water.

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