LESSON 3

Water Pollution

Guiding Question: How does water pollution affect humans and ecosystems?

Knowledge and Skills

- Discuss the main categories of water pollution.
- Explain why groundwater pollution is difficult to clean up.
- Discuss the sources and effects of major pollutants found in the ocean.
- Describe how water is regulated and treated.

Reading Strategy and Vocabulary

Reading Strategy As you read, make a cluster diagram for each category of water pollution.

Vocabulary point-source pollution, nonpoint-source pollution, cultural eutrophication, wastewater, algal bloom, pathogen, red tide, septic system

IT'S A BIG CHALLENGE making sure everyone has the fresh water he or she needs. Ensuring that the quality of that water is good enough for human use makes the challenge even greater. To be safe for humans and other organisms, water must be relatively free of disease-causing organisms and toxic substances. All too often, this is not the case. The United Nations estimates that, around the world, 3800 children (mostly under the age of 5) die every day from diseases associated with unsafe drinking water. What is making these children so sick, and what can be done about it?

Types of Water Pollution

There are many different kinds of water pollution, each with its own sources and effects.

Every type of water pollution comes from either a point or a nonpoint source, as shown in **Figure 16.** **Point-source pollution** comes from distinct locations, such as a factory or sewer pipe. In contrast, **nonpoint-source pollution** comes from many places spread over a large area. As runoff produced by rain and snowmelt makes its way across farms, lawns, and streets, it picks up accumulated fertilizers, pesticides, salt, oil, and other pollutants. The runoff eventually carries all of this nonpoint-source pollution to bodies of water such as streams, lakes, or the ocean.

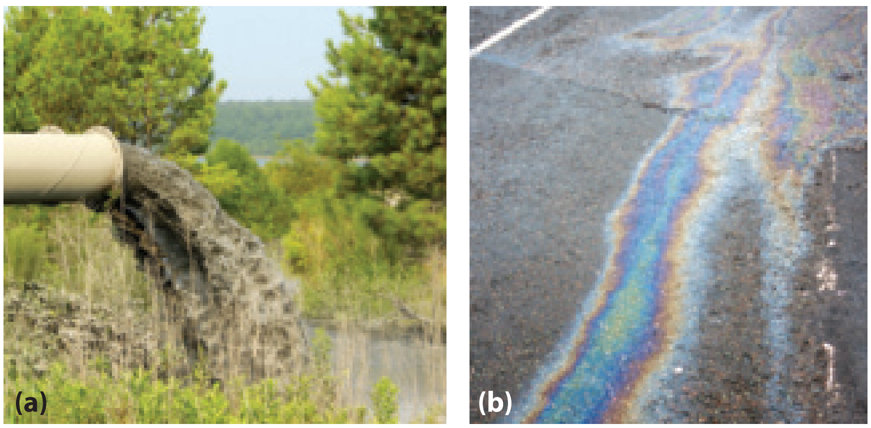

FIGURE 16 Point and Nonpoint Sources (a) Point-source pollution comes from distinct facilities or locations, usually from single outflow pipes. **(b)** Nonpoint-source pollution originates from numerous sources, such as oil-covered city streets, spread over large areas.

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14.3 LESSON PLAN PREVIEW

Real World Have students identify possible local sources of pollution.

Differentiated Instruction Have struggling readers re-phrase headings into question-and-answer format.

Inquiry Use a teacher demon-stration to model filtration.

14.3 RESOURCES

In Your Neighborhood Activity, *The Water You Drink* • Scientific Method Lab, *Testing Water Quality* • Lesson 14.3 Worksheets and Assessment • Chapter 14 Overview Presentation

GUIDING QUESTION

FOCUS Have students write contin-uously for five minutes about how they think water pollution affects humans and ecosystems. Once you have completed the lesson, have students repeat the activity and compare their responses.

BIG QUESTION

Why are we running out of water?

Application Have students write a short paragraph that applies what they learned in Lesson 2 about Earth's limited supply of fresh water to justify the following statement: Water pollution is a serious problem made more serious by the size of Earth's freshwater supply.

ANSWERS

Quick Lab

1. Students should observe algal growth, with a greater amount of growth in jar *A*.
2. It increased the rate of algal growth.
3. Jar *B* is a control.
4. Cultural eutrophication occurs when humans add excess nutrients to water. In this experiment, cultural eutrophication was modeled by adding fertilizer to one jar.
5. Sample answer: I predict that there would be more algal growth with the high-phosphorus fertilizer since eutrophication is often associated with the buildup of phosphorus.

Point and nonpoint water pollution comes in many forms and can have diverse effects. Major categories of pollution include nutrient pollution, toxic chemical pollution, sediment pollution, thermal pollution, and biological pollution.

Nutrient Pollution Bodies of water that have a high nutrient content and low oxygen content are called eutrophic. The word *eutrophic* comes from the Greek for "good food." Indeed, many healthy aquatic ecosystems are eutrophic. However, nutrient pollution by humans can speed up the eutrophication process with negative effects.

▶ ***The Process of Eutrophication*** Eutrophication occurs naturally when nutrients build up in a body of water. In fresh water, eutrophication usually involves a buildup of phosphorus. This can happen for a number of reasons, and is often part of the normal aging process of a lake or pond. When nutrients build up, the growth rate of algae and aquatic plants increases. More growth means more decomposition as the algae and plants die. Decomposition requires oxygen, so the levels of dissolved oxygen in the water decrease. The result is a body of water that is high in nutrients and low in oxygen. When it occurs naturally, eutrophication takes a long time, sometimes centuries.

▶ ***Cultural Eutrophication*** Nutrient pollution by humans can dramatically increase the rate at which eutrophication occurs, a situation called **cultural eutrophication,** or artificial eutrophication. **Figure 17** shows a lake in Ontario, Canada, that suffers from cultural eutrophication. Excess phosphorus is the most common cause of cultural eutrophication in fresh water. Phosphorus pollution mostly comes from nonpoint sources such as phosphorus-rich fertilizers and detergents carried in runoff or wastewater. **Wastewater** is water that has been used by people in some way. Individuals can help reduce nutrient pollution by using less fertilizer and purchasing phosphate-free detergents.

Cultural eutrophication can severely harm aquatic ecosystems. Excess nutrients cause sudden explosions of algal growth called **algal blooms.** Although algae are a source of food and oxygen for other organisms, algal blooms can be so thick that they cover the water's surface. When this happens, sunlight can't reach the plants below and they die off. Further, as nutrient levels climb, decomposition increases and overall oxygen levels in the water drop. Eventually, there may not be enough oxygen to support aquatic organisms such as fish and shellfish.

FIGURE 17 Nutrient Pollution Algal blooms, like this one in Lake Simon in Ontario, Canada, are caused by nutrient pollution. Phosphorus-rich runoff and wastewater result in foul-smelling blooms in Lake Simon every summer.

Quick Lab

Cultural Eutrophication

1. Label one jar *A* and a second jar *B*. Pour tap water into each jar until it is half full.
2. Add water from a pond or freshwater aquarium to each jar until it is three-quarters full.
3. Add 5 mL of liquid fertilizer to jar *A* only.
4. Cover both jars tightly and place them on a windowsill in the sunlight. Wash your hands with soap and warm water.
5. Observe the two jars every day for a week.

Analyze and Conclude

1. **Observe** Describe the changes you observed in both jars over the week.
2. **Relate Cause and Effect** How did the fertilizer affect the growth of algae in jar *A*?
3. **Control Variables** What was the purpose of jar *B* in this experiment?
4. **Use Models** What is cultural eutrophication? How did this experiment model the process?
5. **Predict** Describe the result you would expect if you were comparing the effects of a high-phosphorus fertilizer to a low-phosphorus fertilizer. Explain your answer.

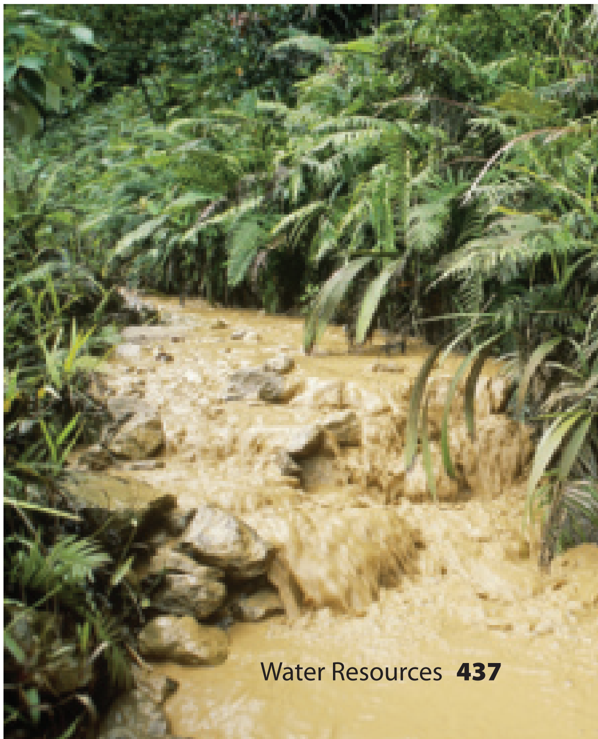
Toxic-Chemical Pollution Many freshwater supplies have become polluted with toxic chemicals. Toxic chemicals can be organic or inorganic. Petroleum and petroleum products, such as plastics, contain organic chemicals such as Bisphenol-A. Organic chemicals are also found in many pesticides and detergents. Inorganic chemicals include heavy metals such as mercury, arsenic, and lead. Toxic chemicals are released during many industrial and manufacturing processes.

All of these substances can make their way into fresh water through point or nonpoint sources. Toxic chemicals can poison aquatic animals and plants as well as cause a wide array of human health problems, including cancer. Regulating industrial, manufacturing, and agricultural processes to control the amount of toxic chemicals they use and release into the environment will help decrease toxic chemical pollution.

Sediment Pollution Sediment transported by rivers and runoff can harm aquatic ecosystems. Some rivers, like the Colorado River and China's Yellow River, are naturally sediment rich, but many others are not. When a large amount of sediment enters a river, it can cause the aquatic environment to change. Rates of photosynthesis may decline as the water clouds up, causing food webs to collapse. Sediment also degrades water quality, making it less suitable to humans and other organisms.

Sediment pollution is the result of erosion. So, steps taken to decrease erosion, such as avoiding large-scale land clearing, also help decrease sediment pollution. Mining, clear-cutting, clearing land to build for houses, and careless farming practices all expose soil to wind and water erosion. **Figure 18** shows a river polluted with sediment runoff from a heavy metal mine in Papua New Guinea. Mine operators have been heavily criticized by international organizations and have been sued for environmental damage by downstream residents.

FIGURE 18 Sediment Pollution Millions of tons of sediment from the Ok Tedi Mine in Papua New Guinea is deposited into the Ok Tedi River each year. The pollution affects about 50,000 people downstream who rely on the river's water.



Thermal Pollution The warmer water is, the less oxygen it can hold. So, some aquatic organisms may not survive when human activities raise water temperatures. Recall that one of the most common uses of water is for cooling industrial processes and power plants. Water used in this way absorbs a lot of heat. When the water is returned to its source, the temperature of the water will be higher than when it was withdrawn, resulting in thermal pollution. Thermal pollution can also occur when trees and plants that shade bodies of water are removed. Thermal pollution harms fish and other aquatic organisms that cannot tolerate increased water temperatures or decreased oxygen.

ANSWERS

Reading Checkpoint Four: cholera, dysentery, *E. coli* infection, typhoid fever

Biological Pollution When disease-causing organisms and viruses, called **pathogens,** make their way into our air, soil, and water, it is called *biological pollution*. Drinking water supplies can become contaminated with biological pollution when they are exposed to human or animal waste. Biological pollution causes more human health problems than any other type of water pollution. **Figure 19** lists some of the most common diseases that result from freshwater biological pollution.

The best way of decreasing biological water pollution is to treat water and waste with chemicals or other substances that kill the disease-causing organisms. This already happens in many parts of the world. However, more than 3.4 million people die worldwide each year because of diseases carried in water. Most of these deaths occur in young children living in South Asia and sub-Saharan Africa. Two thirds of people living in these areas do not have access to clean water and waste treatment.

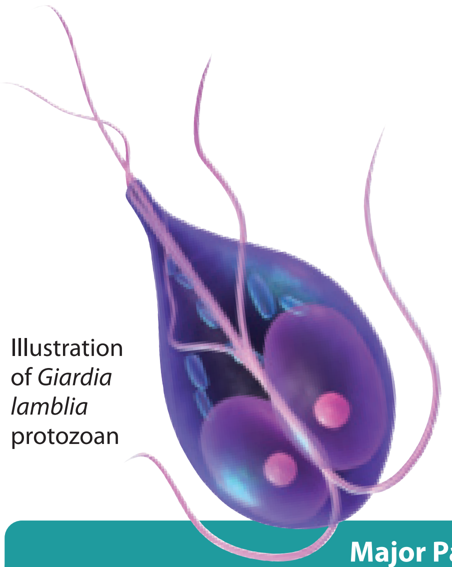


Illustration of *Giardia lamblia* protozoan

Reading Checkpoint *How many of the diseases listed in* **Figure 19** *are caused by bacteria?*

Major Pathogens Found in Water and Their Effects

Pollutant	Disease	Symptoms	Important Facts
Vibrio cholerae (bacteria)	Cholera	Diarrhea, nausea, and vomiting	87% of cholera cases reported to the World Health Organization in 2000 were in African nations.
Shigella dysenteriae (bacteria) or *Entamoeba histolytica* (amoeba)	Dysentery	Diarrhea (sometimes bloody), fever, and nausea	*Shigella* bacteria infections can be treated with antibiotics. *Entamoeba* infections tend to occur in tropical areas and are more difficult to treat.
Escherichia coli (bacteria)	*E. coli* infection	Severe, often bloody diarrhea	*E. coli* is more often food borne than waterborne. However, epidemics from contaminated water have occurred.
Giardia lamblia (protozoa)	Giardiasis	Diarrhea, gas, cramping, and nausea	Giardiasis is the most common form of waterborne disease in the United States.
Schistosoma haematobium, S. japonicum, and *S. mansoni* (flatworms)	Schistosomiasis	Rash and itchy skin followed by fever, chills, muscle aches, and cough	According to the World Health Organization, 200 million people are infected worldwide, 80% in sub-Saharan Africa. Reservoirs made by dams provide breeding grounds for the parasites.
Salmonella typhi (bacteria)	Typhoid fever	Fever, headache, and rose-colored spots on the chest	About 17 million people are infected every year. The disease is treatable with antibiotics.

Data from World Health Organization and Centers for Disease Control and Prevention.

FIGURE 19 Biological Pollution More people are affected by biological pollution than any other kind of water pollution. This table lists some common pathogens spread through contaminated water.

Groundwater Pollution

It can take decades to clean up groundwater pollution, so every effort should be made to prevent it from occurring.

Groundwater sources have become contaminated by pollution from industrial and agricultural practices. Groundwater pollution is largely hidden from view and is extremely difficult to monitor. Often, groundwater contamination is not discovered until drinking water is affected.

Sources of Groundwater Pollution Some chemicals that are toxic at high concentrations, such as aluminum, fluoride, nitrates, and sulfates, occur naturally in groundwater. However, groundwater pollution from human activity is widespread. Because many pollutants enter groundwater from the surface, any of the pollutants already discussed can become groundwater pollutants. Chemicals in fertilizers and pesticides leach through soil and seep into aquifers. Improperly designed wells and leaky storage tanks provide entry for industrial chemicals, raw sewage, gasoline, and other dangerous pollutants.

Cleaning Up Groundwater In general, rivers can flush away pollutants quickly. However, it can take years or even decades for groundwater to get rid of contaminants. The long-lived pesticide DDT, for instance, is still found widely in aquifers in the United States, even though it was banned by the government in 1972. Chemicals break down much more slowly in aquifers than they do in surface water. Groundwater generally contains less dissolved oxygen, microbes, minerals, and organic matter, so decomposition is slower than it is in surface water or soils. For example, concentrations of a certain herbicide called alachlor decline by 50% after 20 days in soil, but in groundwater, a 50% reduction takes four years. Making matters even worse, groundwater moves slowly and takes a long time to recharge.

Most efforts to reduce groundwater pollution focus on preventing it from happening. For example, the U.S. Environmental Protection Agency (EPA) has been working on a nationwide cleanup program to locate and repair leaky gasoline tanks, as shown in **Figure 20.** Over the past 25 years, the agency has closed more than 1.7 million tanks, and has cleaned up more than 380,000 other sites that were exposed to tank leaks. To help prevent future leaks, new sewage and gas tanks are built with strong materials such as fiberglass that don't break down as easily as the plain steel used in older tanks.

Reading Checkpoint *Where do groundwater pollutants come from?*

ANSWERS

Reading Checkpoint Some pollutants occur naturally in groundwater. Other pollutants can enter groundwater when chemicals on the surface leach down through the soil, and when wells and underground storage tanks leak.

FIGURE 20 Groundwater Pollution Leaky underground storage tanks are a major source of groundwater pollution. Under an EPA program, hundreds of thousands of tanks, such as these in Sunnyvale, California, are being unearthed and repaired or replaced.

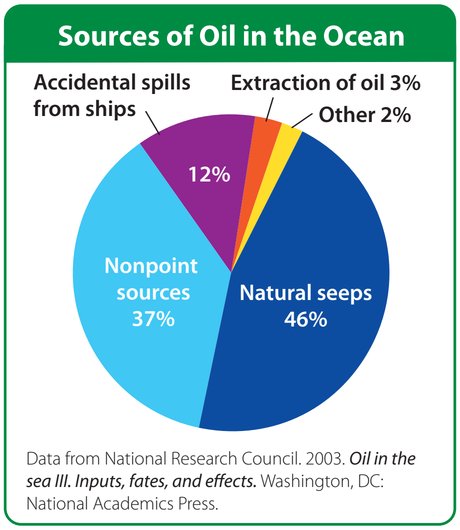


FIGURE 21 Sources of Oil Pollution The National Research Council estimates that on average, 1.3 million tons of oil are released into the oceans every year. Of that, nearly half comes from natural oil seepage. Nonpoint sources, including runoff from land, account for more than three times as much oil as tanker spills.

FIGURE 22 Nutrient Pollution in the Ocean In 2000, a harmful red tide occurred in the Sea of Cortez, east of Baja California, Mexico.

Ocean Water Pollution

Oceans are polluted with oil, toxic chemicals, and nutrients that run off from land.

People have been dumping wastes and pollution into the ocean for centuries. Even into the mid-twentieth century, it was common for coastal U.S. cities to dump trash and untreated sewage into the ocean. Oil, mercury, and excess nutrients can all eventually make their way from land into the oceans through runoff.

Oil Pollution Major oil spills, such as the 1989 *Exxon Valdez* spill in Prince William Sound, Alaska, make headlines and cause serious environmental problems. Yet it is important to put such accidents into perspective. A lot of oil pollution in the oceans comes from many widely spread small sources, not large tanker spills. Small, nonpoint sources include leakage from small boats and runoff from human activities on land. Surprisingly, the largest single source of oil in the oceans may be naturally occurring deposits on the sea floor. This "natural pollution" is called *oil seepage* and, according to one study published in 2003, it accounts for 46 percent of all oil in the ocean, as shown in **Figure 21.**

Minimizing the amount of oil released into coastal waters is important because petroleum pollution harms marine life. Oil can physically coat and kill marine organisms and can poison them when ingested. In 1990, the Oil Pollution Act created a $1 billion prevention and cleanup fund. It also required that by 2015, all oil tankers in U.S. waters have double hulls to help prevent oil leaks.

Mercury Pollution in the Ocean Marine pollution can make some fish and shellfish unsafe for people to eat. A primary concern today is mercury contamination. Mercury is a toxic heavy metal that collects in the tissues of animals. Mercury makes its way up the food chain by biomagnification. As a result, some organisms at high trophic levels, such as swordfish, shark, and albacore tuna, can contain high levels of mercury. Eating a lot of seafood with high levels of mercury can affect humans. Mercury can cause neurological damage, especially in fetuses, babies, and children.

Nutrient Pollution in the Ocean Recall that phosphorus-rich nutrient pollution can cause harmful algal blooms in fresh water. Nutrient pollution is also a problem in the ocean, though it is nitrogen, not phosphorus, that does the most damage. One type of algal bloom is nicknamed **red tide** because the algae produce reddish pigments, as shown in **Figure 22.** Some red tides and other harmful algal blooms release powerful toxins that make their way through the food chain, causing illness and death among zooplankton, fish, marine mammals, birds, and humans. Harmful algal blooms also hurt the economy. When one occurs, beaches are closed and fishing must stop. Reducing nutrient runoff into coastal waters can lessen the frequency of algal blooms.

FIGURE 23 Successful Cleanup Great strides have been made in reducing the pollution in Lake Erie over the last 30 years. **(a)** A sign warns against swimming in August 1973. **(b)** Today, thousands enjoy swimming in Lake Erie. Regulations set by the governments of the United States and Canada have helped to reduce pollution in all the Great Lakes.

Controlling Water Pollution

Government regulation and water treatment are two ways of decreasing the effects of water pollution.

As numerous as our water pollution problems may seem, it is important to remember that many of them were worse a few decades ago. Today, legislation, technology, and citizen action are helping to control the harm done by water pollution.

The Clean Water Act The Federal Water Pollution Control Act, which was later amended and renamed the Clean Water Act in 1977, remains the single most important law to prevent water pollution in the United States. The Clean Water Act made it illegal to release pollution from a point source without a permit. It also set standards for pollution levels in surface waters and industrial wastewater, and funded construction of sewage treatment plants. Thanks to this law and others, point-source pollution in the United States has been reduced, and rivers and lakes are cleaner than they have been in decades.

The Great Lakes of Canada and the United States represent a success story in fighting water pollution. In the 1970s these lakes, which hold 18 percent of the world's surface fresh water, were badly polluted. Nutrient and chemical pollution were such a huge problem that Lake Erie was pronounced "dead." Today, efforts by the Canadian and U.S. governments to reduce pollution and increase water treatment have paid off. Nutrient and toxic-chemical pollution have dropped significantly. Bird populations are rebounding, and Lake Erie is now home to the world's largest walleye fishery. **Figure 23** shows just how far Lake Erie has come. The Great Lakes' troubles are by no means over, but the progress shows how conditions can improve when citizens and their governments take action.

Reading Checkpoint *What did the Clean Water Act do?*

ANSWERS

Reading Checkpoint The Clean Water Act made it illegal to release pollution from point sources without a permit, set standards for pollution levels in surface water and industrial wastewater, and funded sewage treatment plant construction.

Water Treatment Technological advances have also improved our ability to control water pollution. The treatment of drinking water and wastewater are mainstream practices in developed nations today.

▶ ***Drinking Water Treatment*** The EPA sets standards for more than 80 drinking water contaminants, which local governments and private water suppliers must meet. Unless your water comes from a well on your property, it is usually treated with chemicals and run through filters before being sent to your tap. Pathogens are killed, sediment is filtered out, and chemical pollutants are removed, making the water safe to drink. **Figure 24** shows the steps in a typical public drinking water treatment process.

▶ ***Wastewater Treatment*** Water from showers, sinks, dishwashers, washing machines, and toilets are all examples of wastewater. Runoff from farm fields and water used by industry to cool power plants are too. Concentrated amounts of wastewater can harm ecosystems and pose threats to human health. Thus, attempts are now being made to treat wastewater before releasing it into the environment.

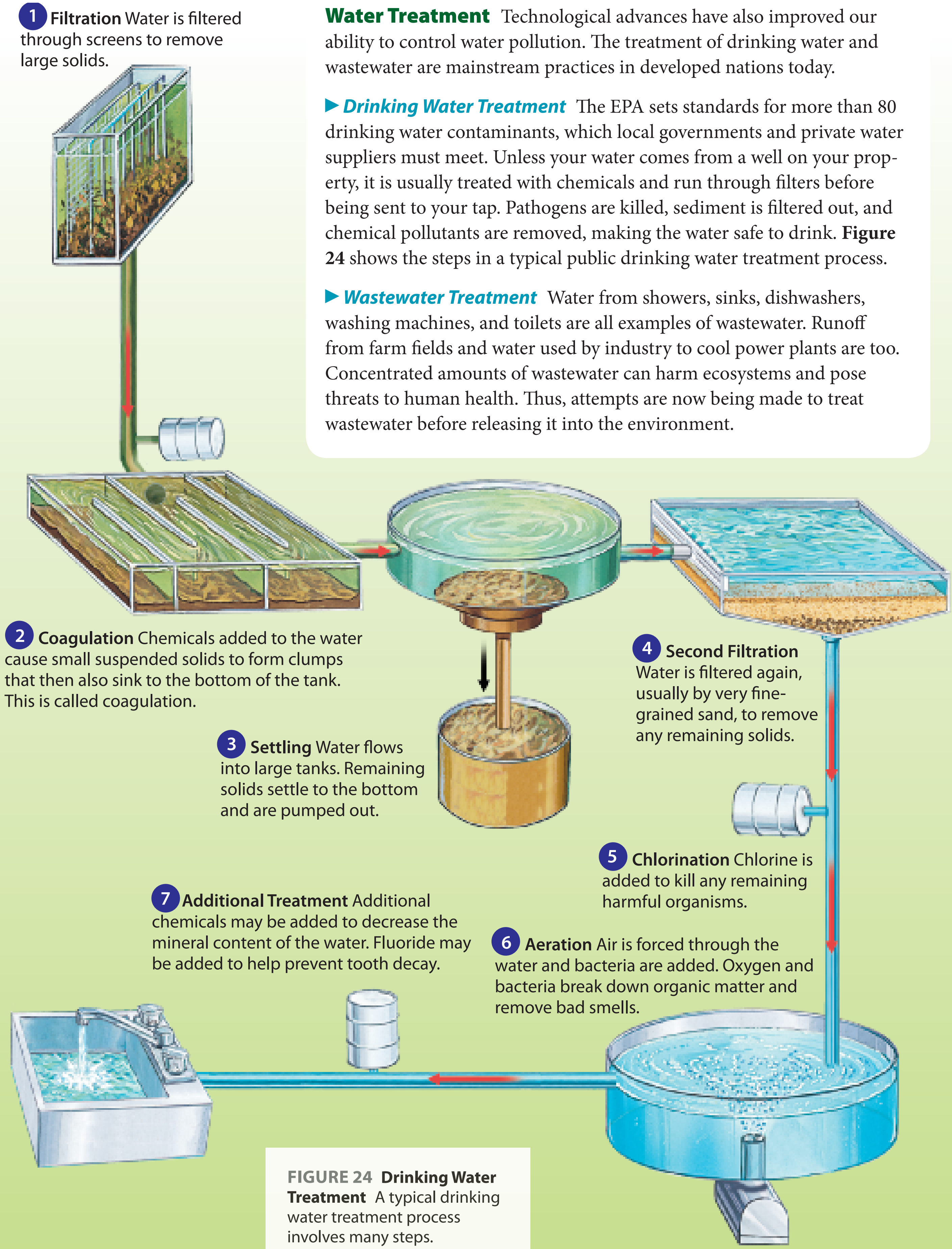


FIGURE 24 Drinking Water Treatment A typical drinking water treatment process involves many steps.

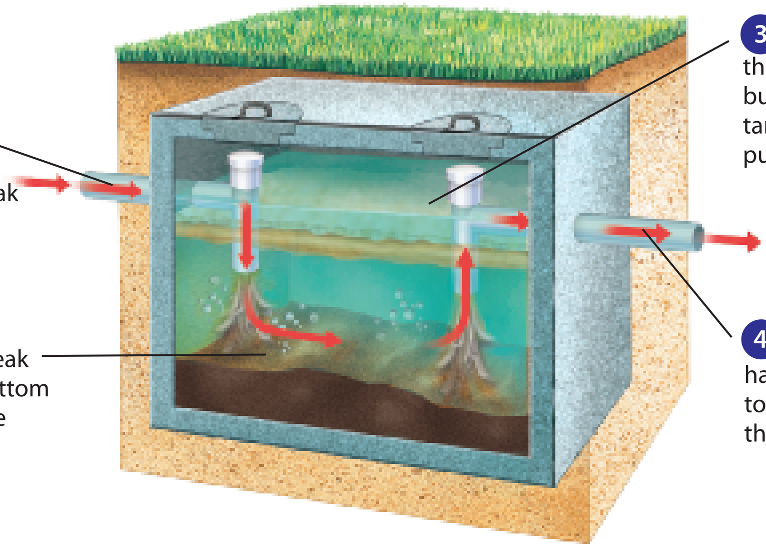
In more densely populated areas, sewer systems carry wastewater from homes and businesses to centralized treatment locations. There, pollutants in wastewater are removed by physical, chemical, and biological means (see **A Closer Look,** on the next page). Most often the treated water, called *effluent*, is piped into rivers, reservoirs, or the ocean following primary, secondary, and tertiary treatment. Water that is not released to a body of surface water is called *reclaimed water.* This water might not be treated to drinking water standards, but instead used for irrigation or to cool power plants.

In rural areas, **septic systems** are the most popular method of wastewater disposal. In a septic system, shown in **Figure 25,** wastewater runs through a pipe from the house to an underground septic tank. Inside the tank, solids and oils separate from water. The water moves downhill to an underground field of gravel where microbes decompose the remaining organic material in the wastewater. The cleansed water eventually makes its way into aquifers. Periodically, solid waste, called *sludge*, is pumped from the septic tank and taken to a landfill or dried and sold as fertilizer.

ANSWERS

Lesson 3 Assessment For answers to the Lesson 3 Assessment, see page A–22 at the back of the book.

FIGURE 25 **Septic Systems** In many rural areas, wastewater flows into a septic tank. In the tank, wastes separate out and bacteria break down organic material.



LESSON 3 Assessment

1. **Compare and Contrast** What is the difference between point and nonpoint sources of water pollution? Give an example of each.
2. **Explain** Why is groundwater pollution so hard to clean up?
3. **Relate Cause and Effect** Explain how using nitrogen-rich fertilizers can affect algal blooms in the oceans.
4. **Sequence** Describe the steps involved in a typical public drinking water treatment process.
5. **THINK IT *THROUGH*** You run a large farm that is considering using sludge from wastewater treatment plants as fertilizer. You have been told that the sludge can increase the growth rate of your crops, and you know that using the sludge will prevent it from making its way into landfills. However, you have also heard that sludge can contain pollutants such as heavy metals and pathogens. What questions would you want to ask before deciding to use the sludge? Do you feel that the benefits outweigh the costs?