SECTION 3

Water Pollution

Objectives

- Compare point-source pollution and nonpoint-source pollution.
- Classify water pollutants by five types.
- Explain why groundwater pollution is difficult to clean.
- Describe the major sources of ocean pollution, and explain the effects of pollution on ecosystems.
- Describe six major laws designed to improve water quality in the United States.

Key Terms

water pollution
point-source pollution
nonpoint-source pollution
wastewater
artificial eutrophication
thermal pollution
biomagnification

You might think that you can tell if a body of water is polluted by the way that the water looks or smells, but sometimes you can't. There are many different forms of water pollution. **Water pollution** is the introduction of chemical, physical, or biological agents into water that degrade water quality and adversely affect the organisms that depend on the water. Almost all of the ways that we use water contribute to water pollution. However, the two underlying causes of water pollution are industrialization and rapid human population growth.

In the last 30 years, developed countries have made great strides in cleaning up many polluted water supplies. Despite this progress, some water is still dangerously polluted in the United States and in other countries. In developing parts of the world, water pollution is a big problem. Industry is usually not the major cause of water pollution in developing countries. Often, the only water available for drinking in these countries is polluted with sewage and agricultural runoff, which can spread waterborne diseases. To prevent water pollution, people must understand where pollutants come from. As you will learn, water pollution comes from two types of sources: point and nonpoint sources.

Figure 15 ▶ Point-source pollution comes from a single, easily identifiable source. In this photo, the waste from an iron mine is being stored in a pond.

Table 3 ▼

Sources of Point Pollution
• leaking septic-tank systems
• leaking storage lagoons for polluted waste
• unlined landfills
• leaking underground storage tanks that contain chemicals or fuels such as gasoline
• polluted water from abandoned and active mines
• water discharged by industries
• public and industrial wastewater treatment plants

Point-Source Pollution

When you think of water pollution, you probably think of a single source, such as a factory, a wastewater treatment plant, or a leaking oil tanker. These are all examples of **point-source pollution,** which is pollution discharged from a single source. **Table 3** lists some additional examples of point-source pollution. Point-source pollution can often be identified and traced to a source. But even when the source of pollution is known, enforcing cleanup is sometimes difficult.

Nonpoint-Source Pollution

Nonpoint-source pollution comes from many different sources that are often difficult to identify. For example, a river can be polluted by runoff from any of the land in its watershed. If a farm, a road, or any other land surface in a watershed is polluted, runoff from a rainstorm can carry the pollution into a nearby river, stream, or lake. **Figure 16** shows common sources of nonpoint pollutants. **Table 4** lists some additional causes of nonpoint pollution.

Because nonpoint pollutants can enter bodies of water in many different ways, they are extremely difficult to regulate and control. The accumulation of small amounts of water pollution from many sources is a major pollution problem—96 percent of the polluted bodies of water in the United States were contaminated by nonpoint sources. Controlling nonpoint-source pollution depends to a great extent on public awareness of the effects of activities such as spraying lawn chemicals and using storm drains to dispose of used motor oil.

FIELD ACTIVITY

Identifying Sources of Pollution Walk around your neighborhood, and record potential sources of nonpoint pollution. See Table 4 for examples. Count the number of potential sources of nonpoint pollution, and suggest ways to reduce each source of pollution in your ***EcoLog.***

Table 4 ▼

Nonpoint Sources of Pollution
• chemicals added to road surfaces (salt and other de-icing agents)
• water runoff from city and suburban streets that may contain oil, gasoline, animal feces, and litter
• pesticides, herbicides, and fertilizer from residential lawns, golf courses, and farmland
• feces and agricultural chemicals from livestock feedlots
• precipitation containing air pollutants
• soil runoff from farms and construction sites
• oil and gasoline from personal watercraft

Figure 16 ▶ Sources of Nonpoint Pollution Examples of nonpoint-source pollution include ❶ livestock polluting water holes that can flow into streams and reservoirs, ❷ oil on a street, which can wash into storm sewers and then drain into waterways, and ❸ thousands of watercraft, which can leak gasoline and oil.

Table 5 ▼

Pollutant Types and Sources		
Type of pollutant	**Agent**	**Major sources**
Pathogens	disease-causing organisms, such as bacteria, viruses, protozoa, and parasitic worms	mostly nonpoint sources; sewage or animal feces, livestock feedlots, and poultry farms; sewage from overburdened wastewater treatment plants
Organic matter	animal and plant matter remains, feces, food waste, and debris from food-processing plants	mostly nonpoint sources
Organic chemicals	pesticides, fertilizers, plastics, detergents, gasoline and oil, and other materials made from petroleum	mostly nonpoint sources; farms, lawns, golf courses, roads, wastewater, unlined landfills, and leaking underground storage tanks
Inorganic chemicals	acids, bases, salts, and industrial chemicals	point sources and nonpoint sources; industrial waste, road surfaces, wastewater, and polluted precipitation
Heavy metals	lead, mercury, cadmium, and arsenic	point sources and nonpoint sources; industrial discharge, unlined landfills, some household chemicals, and mining processes; heavy metals also occur naturally in some groundwater
Physical agents	heat and suspended solids	point sources and nonpoint sources; heat from industrial processes and suspended solids from soil erosion

Principal Water Pollutants

There are many different kinds of water pollutants. **Table 5** lists some common types of pollutants and some of the possible sources of each pollutant.

Wastewater

Do you know where water goes after it flows down the drain in a sink? The water usually flows through a series of sewage pipes that carry it—and all the other wastewater in your community—to a wastewater treatment plant. **Wastewater** is water that contains waste from homes or industry. At a wastewater treatment plant, water is filtered and treated to make the water clean enough to return to a river or lake.

Treating Wastewater A typical residential wastewater treatment process is illustrated in **Figure 17.** Most of the wastewater from homes contains biodegradable material that can be broken down by living organisms. For example, wastewater from toilets and kitchen sinks contains animal and plant wastes, paper, and soap, all of which

are biodegradable. But wastewater treatment plants may not remove all of the harmful substances in water. Some household and industrial wastewater and some storm-water runoff contains toxic substances that cannot be removed by the standard treatment.

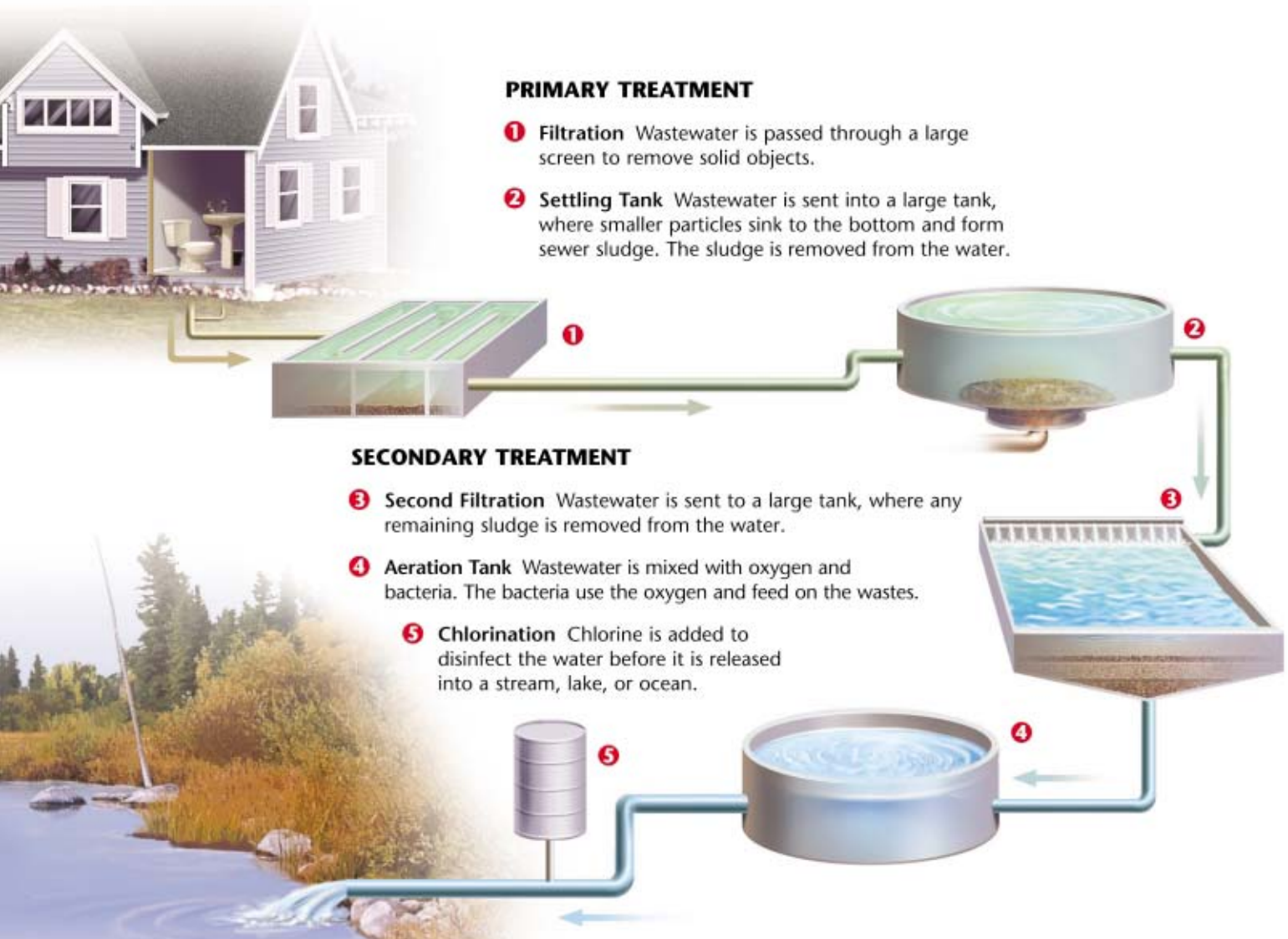
Sewage Sludge If you look again at **Figure 17,** you will see that one of the products of wastewater treatment is *sewage sludge,* the solid material that remains after treatment. When sludge contains dangerous concentrations of toxic chemicals, it must be disposed of as hazardous waste. The sludge is often incinerated, and then the ash is buried in a secure landfill. Sludge can be an expensive burden to towns and cities because the volume of sludge that has to be disposed of every year is enormous.

The problem of sludge disposal has prompted many communities to look for new uses for this waste. If the toxicity of sludge can be reduced to safe levels, sludge can be used as a fertilizer. In another process, sludge is combined with clay to make bricks that can be used in buildings. In the future, industries will probably find other creative ways to use sludge.

Connection to History

***Cryptosporidium* Outbreak** In 1993, a pathogen called *Cryptosporidium parvum* contaminated the municipal water supply of Milwaukee, Wisconsin. The waterborne parasite caused more than 100 deaths, and 400,000 people experienced a flulike illness. *Cryptosporidium* is found in animal feces, but the parasite usually occurs in low levels in water supplies. The outbreak in Milwaukee was probably caused by an unusual combination of heavy rainfall and agricultural runoff that overburdened the city's water treatment plants.

Figure 17 ▶ Wastewater Treatment Process



QuickLAB

Measuring Dissolved Oxygen

Procedure

1. Start with **three water samples,** each in a **plastic jar** that is ¾ full. Two water samples should be tap water from a faucet without an aerator. One sample should be water that has been boiled and allowed to cool.
2. Using a **dissolved-oxygen test kit,** test the boiled water and one other water sample.
3. Tighten the lid on the third sample, and then vigorously shake the sample for one minute. Unscrew the lid, and then recap the jar.
4. Repeat step 3 twice. Then, uncap the jar quickly, and test the sample.

Analysis

1. Which sample had the highest dissolved oxygen level? Which sample had the lowest level?
2. What effects do rapids and waterfalls have on the levels of dissolved oxygen in a stream? What effect does thermal pollution have?

Artificial Eutrophication

Most nutrients in water come from organic matter, such as leaves and animal waste, that is broken down into mineral nutrients by decomposers such as bacteria and fungi. Nutrients are an essential part of any aquatic ecosystem, but an overabundance of nutrients can disrupt an ecosystem. When lakes and slow-moving streams contain an abundance of nutrients, they are eutrophic (yoo TROH fik).

Eutrophication is a natural process. When organic matter builds up in a body of water, it will begin to decay and decompose. The process of decomposition uses up oxygen. As oxygen levels decrease, the types of organisms that live in the water change over time. For example, as a body of water becomes eutrophic, plants take root in the nutrient-rich sediment at the bottom. As more plants grow, the shallow waters begin to fill in. Eventually, the body of water becomes a swamp or marsh.

The natural process of eutrophication is accelerated when inorganic plant nutrients, such as phosphorus and nitrogen, enter the water from sewage and fertilizer runoff. Eutrophication caused by humans is called **artificial eutrophication.** Fertilizer from farms, lawns, and gardens is the largest source of nutrients that cause artificial eutrophication. Phosphates in some laundry and dishwashing detergents are another major cause of eutrophication. Phosphorus is a plant nutrient that can cause the excessive growth of algae. In bodies of water polluted by phosphorus, algae can form large floating mats, called *algal blooms,* as shown in **Figure 18.** As the algae die and decompose, most of the dissolved oxygen is used and fish and other organisms suffocate in the oxygen-depleted water.

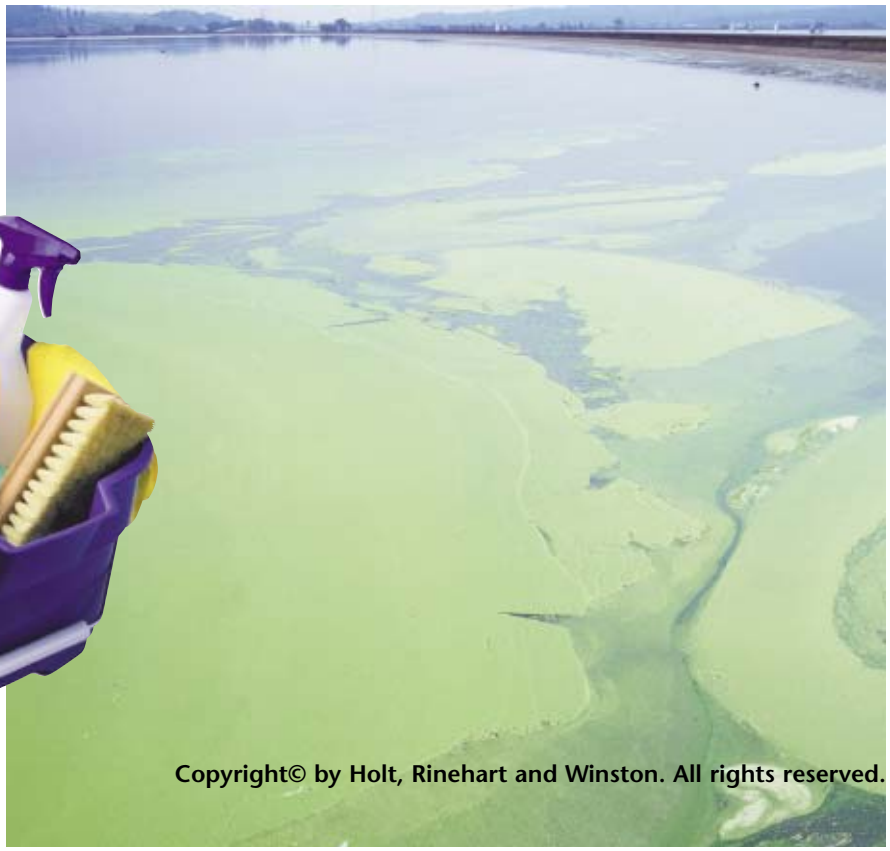


Figure 18 ▶ In an effort to limit artificial eutrophication, some states have either banned phosphate detergents or limited the amount of phosphates in detergents.

Figure 19 ▶ Fish kills, such as this one in Brazil, can result from thermal pollution.

Thermal Pollution

If you look at **Figure 19,** you might assume that a toxic chemical caused the massive fish kill in the photo. But the fish were not killed by a chemical spill—they died because of thermal pollution. When the temperature of a body of water, such as a lake or stream, increases, **thermal pollution** can result. Thermal pollution can occur when power plants and other industries use water in their cooling systems and then discharge the warm water into a lake or river.

Thermal pollution can cause large fish kills if the discharged water is too warm for the fish to survive. But most thermal pollution is more subtle. If the temperature of a body of water rises even a few degrees, the amount of oxygen the water can hold decreases significantly. As oxygen levels drop, aquatic organisms may suffocate and die. If the flow of warm water into a lake or stream is constant, it may cause the total disruption of an aquatic ecosystem.

Groundwater Pollution

Pollutants usually enter groundwater when polluted surface water percolates down from the Earth's surface. Any pollution of the surface water in an area can affect the groundwater. Pesticides, herbicides, chemical fertilizers, and petroleum products are common groundwater pollutants. Leaking underground storage tanks are another major source of groundwater pollution. It is estimated that there are millions of underground storage tanks in the United States. Most of the tanks—located beneath gas stations, farms, and homes—hold petroleum products, such as gasoline and heating fuel. As underground storage tanks age, they may develop leaks, which allow pollutants to seep into the groundwater.

Connection to Chemistry

Dissolved Oxygen One of the most important measures of the health of a body of water is the amount of dissolved oxygen in the water. Gaseous oxygen enters water by diffusion from the surrounding air, as a byproduct of photosynthesis, and as a result of the rapid movement (aeration) of water. The amount of oxygen that water can hold is determined by the water's temperature, pressure, and salinity. Slow-moving waters tend to have low levels of dissolved oxygen, while rapidly flowing streams have higher levels. Artificial eutrophication and thermal pollution also reduce levels of dissolved oxygen. When dissolved oxygen levels remain below 1 to 2 mg/L for several hours, fish and other organisms suffocate, and massive fish kills can result.

MATH PRACTICE

Parts per Million Water contamination is often measured in parts per million (ppm). If the concentration of a pollutant is 5 ppm, there are 5 parts of the pollutant in 1 million parts of water. If the concentration of gasoline is 3 ppm in 650,000 L of water, how many liters of gasoline are in the water?

The location of aging underground storage tanks is not always known, so the tanks often cannot be repaired or replaced until after they have leaked enough pollutants to be located. Modern underground storage tanks are contained in concrete and have many features to prevent leaks. Other sources of groundwater pollution include septic tanks, unlined landfills, and industrial wastewater lagoons, as shown in **Figure 20.**

Cleaning Up Groundwater Pollution Groundwater pollution is one of the most challenging environmental problems that the world faces. Even if groundwater pollution could be stopped tomorrow, some groundwater would remain polluted for generations to come. As you have learned, groundwater recharges very slowly. The process for some aquifers to recycle water and purge contaminants can take hundreds or thousands of years. Groundwater is also difficult to decontaminate because the water is dispersed throughout large areas of rock and sand. Pollution can cling to the materials that make up an aquifer, so even if all of the water in an aquifer were pumped out and replaced with clean water, the groundwater could still become polluted.

Figure 20 ▶ This diagram shows some of the major sources of groundwater pollution. Runoff and percolation transport contaminants to the groundwater.

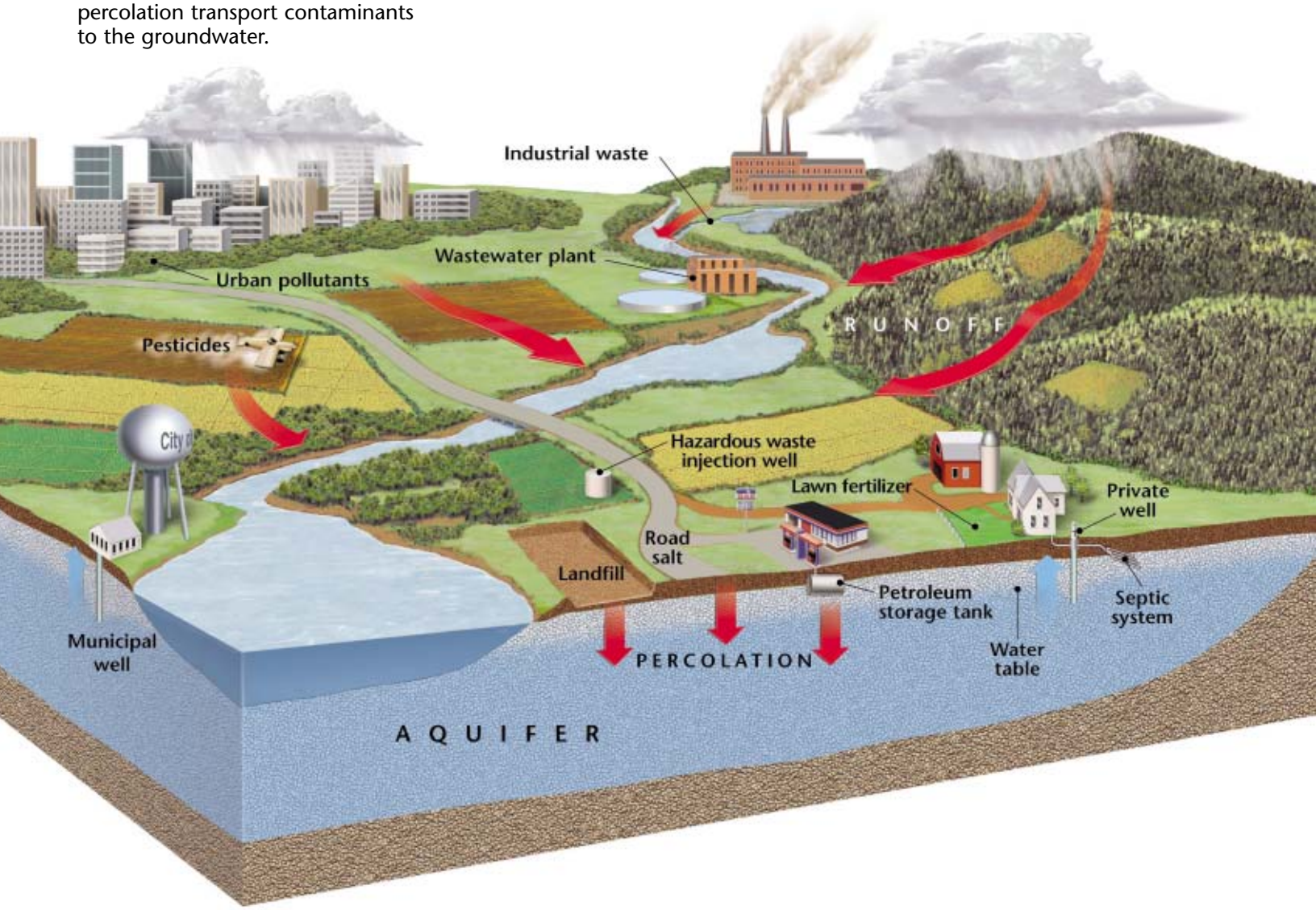
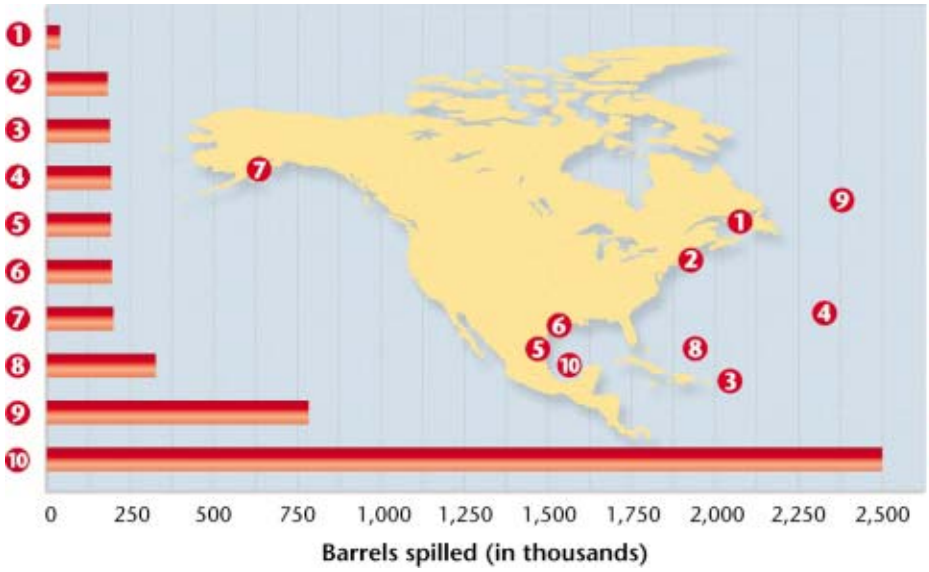


Figure 21 ▶ Major North American Oil Spills



1. *Kurdistan* Gulf of St. Lawrence, Canada, 1979
2. *Argo Merchant* Nantucket, MA, 1976
3. Storage Tank Benuelan, Puerto Rico, 1978
4. *Athenian Venture* Atlantic Ocean, 1988
5. *Unnamed Tanker* Tuxpan, Mexico, 1996
6. *Burmah Agate* Galveston Bay, TX, 1979
7. *Exxon Valdez* Prince William Sound, AK, 1989
8. *Epic Colocotronis* Caribbean Sea, 1975
9. *Odyssey* North Atlantic Ocean, 1988
10. Exploratory Well Bay of Campeche, 1979

Ocean Pollution

Although oceans are the largest bodies of water on Earth, they are still vulnerable to pollution. Pollutants are often dumped directly into the oceans. For example, ships can legally dump wastewater and garbage overboard in some parts of the ocean. But at least 85 percent of ocean pollution—including pollutants such as oil, toxic wastes, and medical wastes—comes from activities on land. If polluted runoff enters rivers, for example, the rivers may carry the polluted water to the ocean. Most activities that pollute oceans occur near the coasts, where much of the world's human population lives. As you might imagine, sensitive coastal ecosystems, such as coral reefs, estuaries, and coastal marshes, are the most affected by pollution.

Oil Spills Ocean water is also polluted by accidental oil spills. Disasters such as the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska, make front-page news around the world. In 2001, a fuel-oil spill off the coast of the Galápagos Islands captured public attention. Each year, approximately 37 million gallons of oil from tanker accidents are spilled into the oceans. **Figure 21** shows some of the major oil spills that occurred off the coast of North America in the last 30 years.

Such oil spills have dramatic effects, but they are responsible for only about 5 percent of oil pollution in the oceans. Most of the oil that pollutes the oceans comes from cities and towns. Every year, as many as 200 million to 300 million gallons of oil enter the ocean from nonpoint sources on land. That's almost 10 times the amount of oil spilled by tankers. In fact, in one year, the road runoff from a coastal city of 5 million people could contain as much oil as a tanker spill does. Limiting these nonpoint sources of oil pollution would go a long way toward keeping the oceans clean.

Ecofact

Cruise Ship Discharges In one year, ships dump almost 7 billion kilograms of trash into the ocean. About 75 percent of all ship waste comes from cruise ships. According to most international law, cruise ships are allowed to dump nonplastic waste—including untreated sewage—into the ocean. Increasing public pressure has begun to cause the cruise-ship industry to change this practice, however.

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