

Chapter 14

Water Pollution

Wastewater from humans and livestock poses multiple problems

- **Water pollution** The contamination of streams, rivers, lakes, oceans, or groundwater with substances produced through human activities. Wastewater Water produced by livestock operations and human activities, including human sewage from toilets and gray water from bathing and washing of clothes and dishes.
- **Point source** A distinct location from which pollution is directly produced.
- **Nonpoint source** A diffuse area that produces pollution.

Wastewater from humans and livestock poses multiple problems

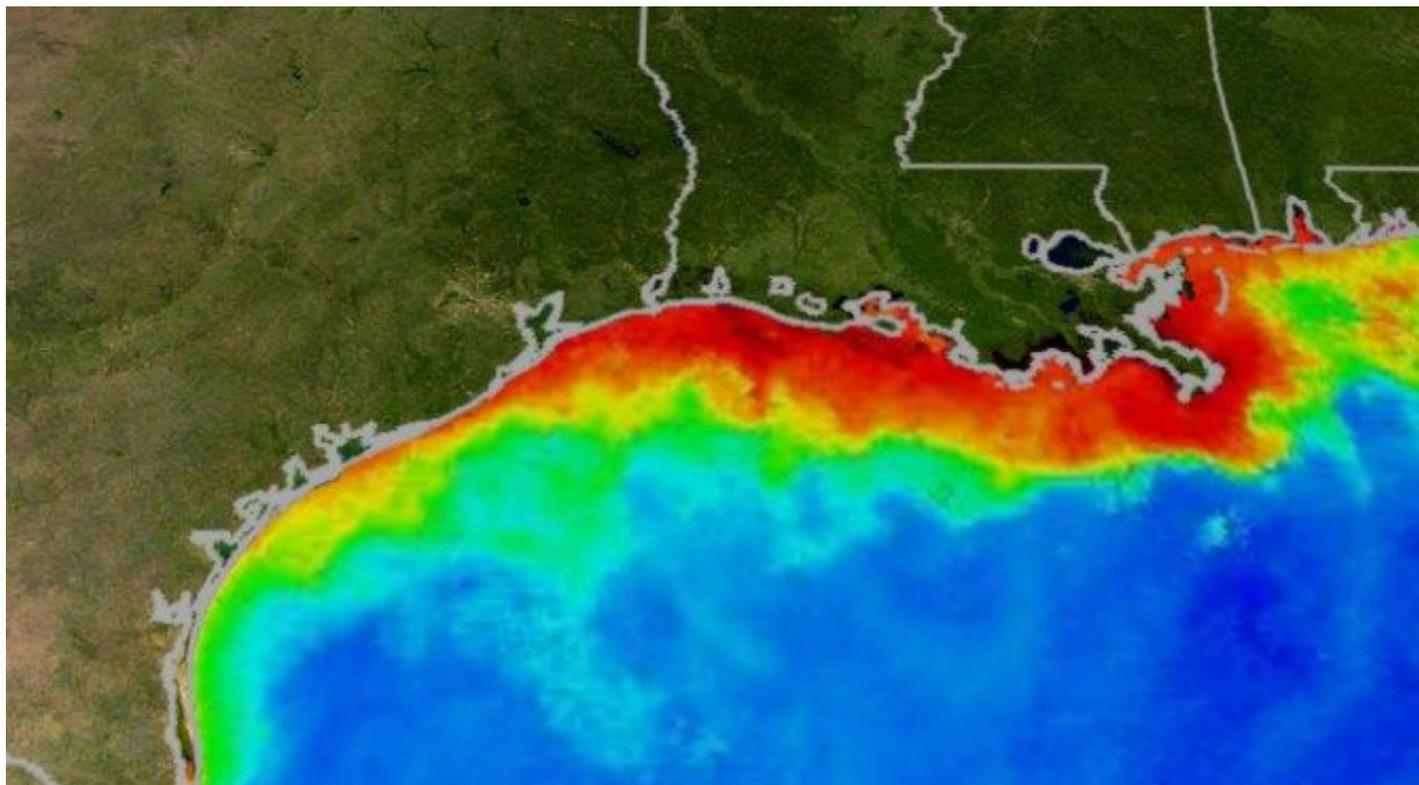
Problems from wastewater fall into three categories:

- Oxygen demand
- Nutrient release
- Disease-causing organisms

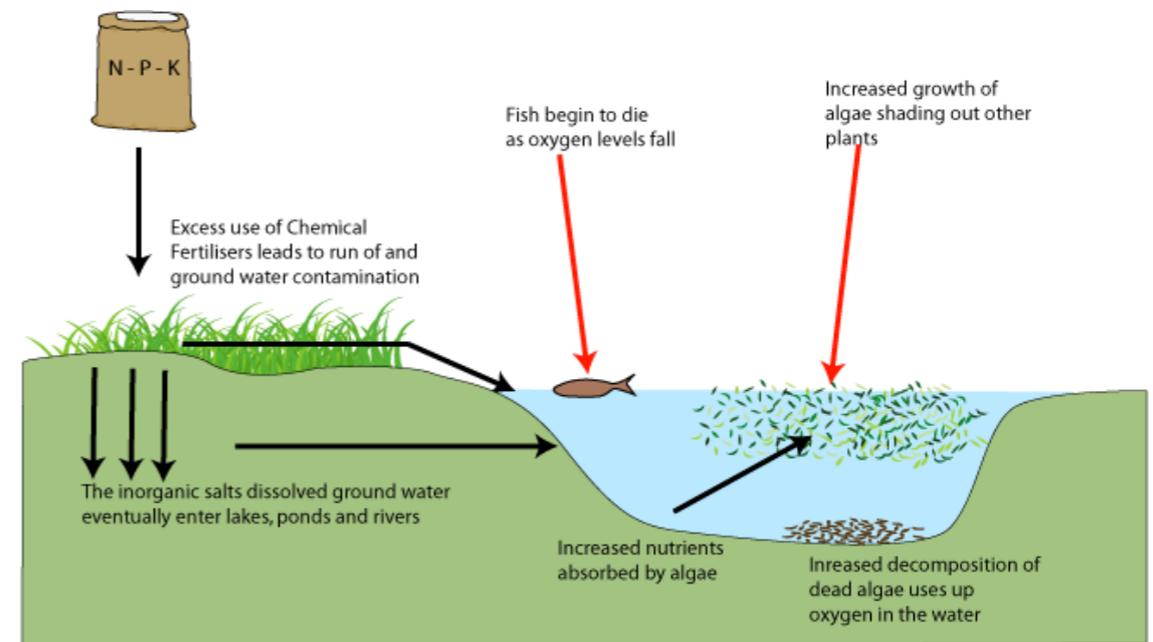


Oxygen Demand

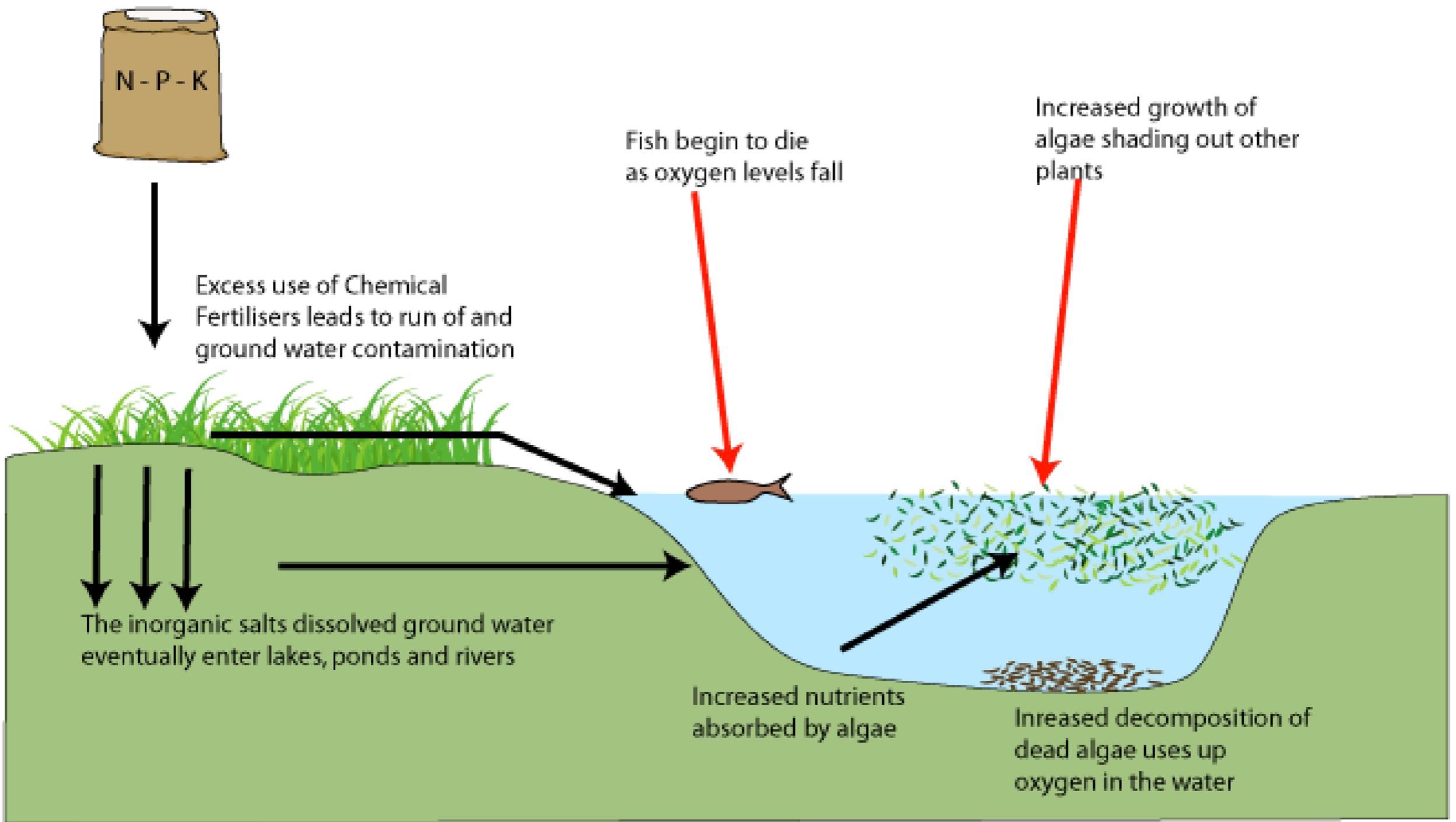
- **Biochemical oxygen demand (BOD)** The amount of oxygen a quantity of water uses over a period of time at specific temperatures.
- **Dead zone** In a body of water, an area with extremely low oxygen concentration and very little life.



Nutrient Release



- **Eutrophication** A phenomenon in which a body of water becomes rich in nutrients.
- **Cultural eutrophication** An increase in fertility in a body of water, the result of anthropogenic inputs of nutrients.
- Eutrophication is caused by an increase in nutrients, such as fertilizers
- Eutrophication can cause a rapid growth of algae which eventually dies, causing the microbes to increase the BOD.



N - P - K

Excess use of Chemical Fertilisers leads to run of and ground water contamination

The inorganic salts dissolved ground water eventually enter lakes, ponds and rivers

Fish begin to die as oxygen levels fall

Increased growth of algae shading out other plants

Increased nutrients absorbed by algae

Increased decomposition of dead algae uses up oxygen in the water

Disease-Causing Organisms

- Throughout the world people routinely use the same water source for drinking, bathing, and sewage.
- Wastewater can carry a variety of pathogens.

Diseases that can be contracted by coming into contact with contaminated water include:

- Cholera
- Typhoid fever
- Stomach flu
- Diarrhea
- Cholera
- Hepatitis



Disease-Causing Organisms

- Because of the risk that water-borne pathogens pose, we need a way to test for pathogens in our drinking water.
- **Indicator species** A species that indicates whether or not disease-causing pathogens are likely to be present.
- **Fecal coliform bacteria** A group of generally harmless microorganisms in human intestines that can serve as an indicator species for potentially harmful microorganisms associated with contaminated sewage.

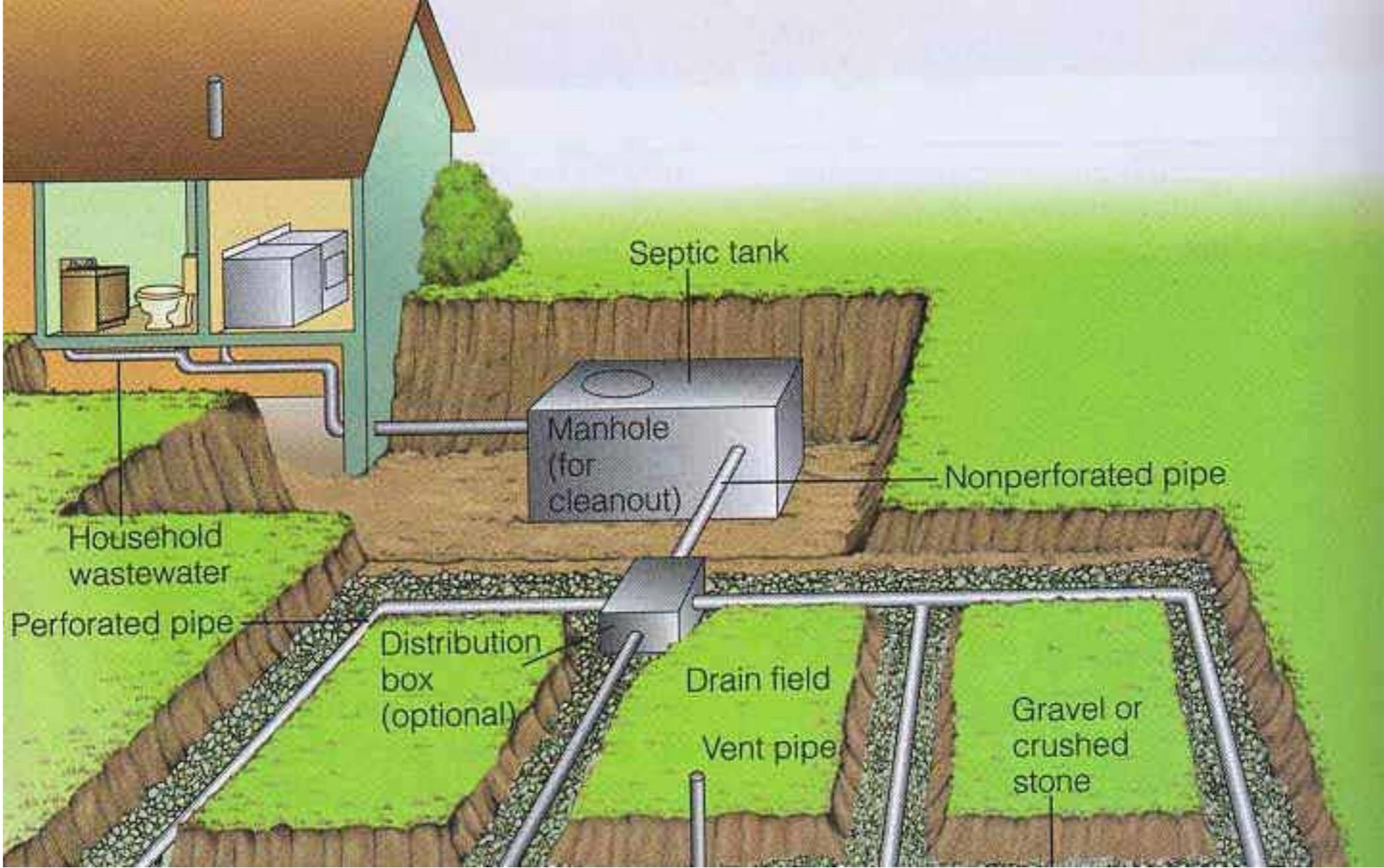
We have technologies to treat wastewater

- Treating wastewater properly reduces the risk of waterborne pathogens.

Two common ways to handle human wastewater:

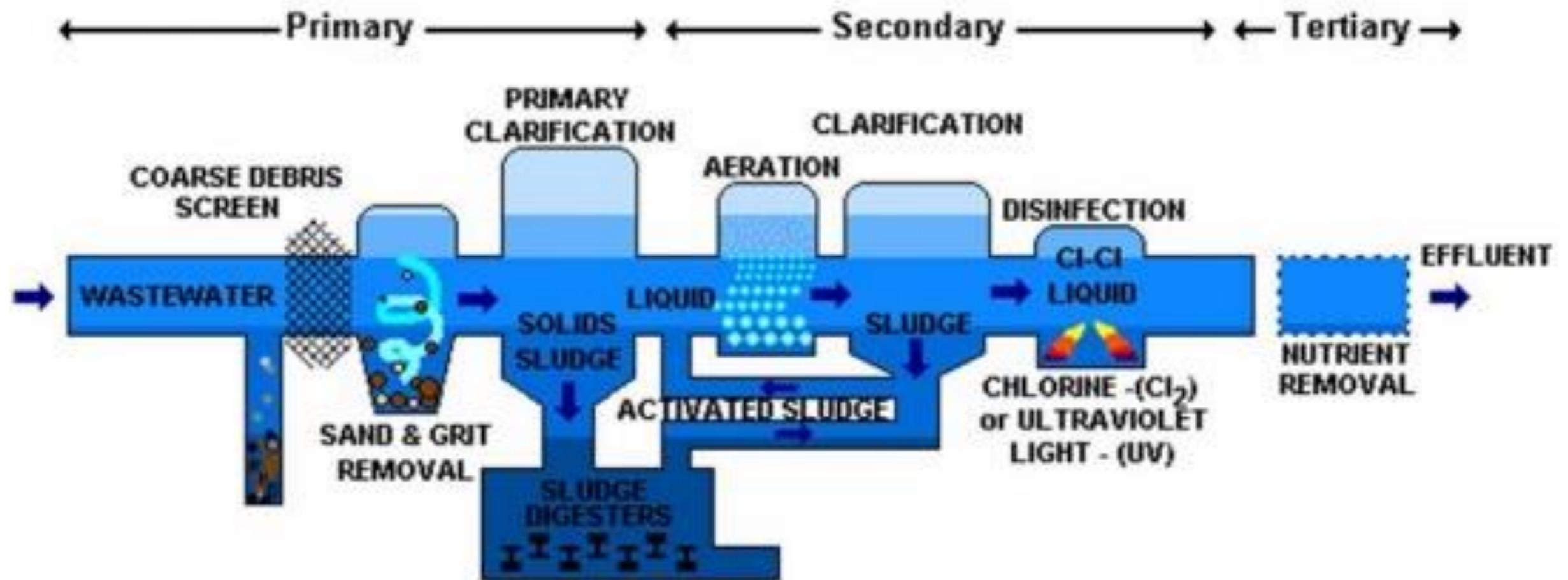
- Septic systems
- Sewage treatment plants

Septic System



Sewage Treatment

Wastewater Treatment Process



Septic Systems

- **Septic system** A relatively small and simple sewage treatment system, made up of a septic tank and a leach field, often used for homes in rural areas.
- **Septic tank** A large container that receives wastewater from a house as part of a septic system.
- **Sludge** Solid waste material from wastewater.
- **Septage** A layer of fairly clear water found in the middle of a septic tank.
- **Leach field** A component of a septic system, made up of underground pipes laid out below the surface of the ground.

Septic Systems

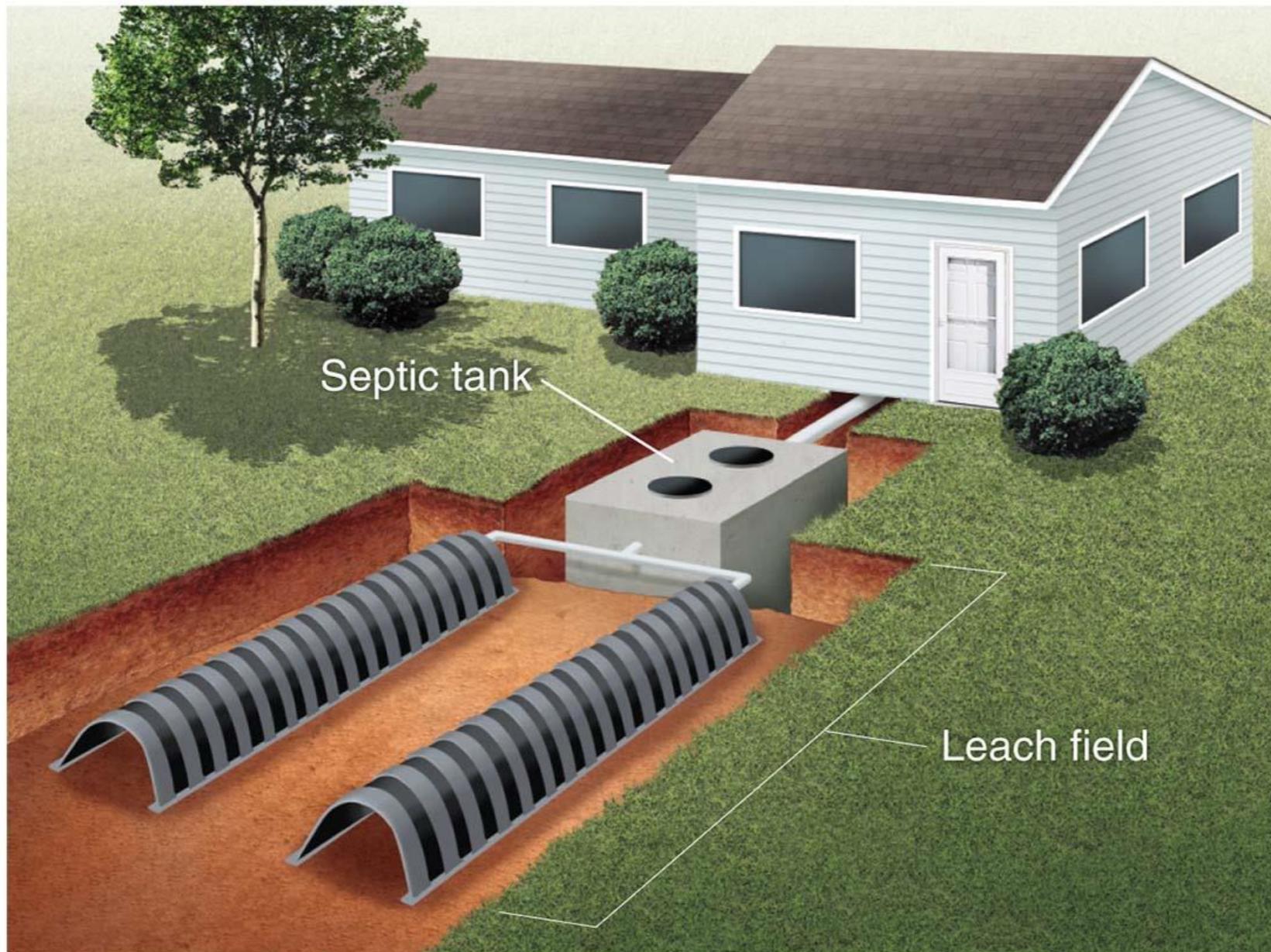


Figure 41.5
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A septic system. Wastewater from a house is held in a large septic tank where solids settle to the bottom and bacteria break down the sewage. The liquid moves through a pipe at the top of the tank and passes through perforated pipes that distribute the water through a leach field.

Sewage Treatment Plants

- In developed countries, municipalities use centralized sewage treatment plant that receive wastewater from hundreds or even thousands of households.
- In traditional waste treatment plants, there are two phases of treatment: primary and secondary.

Sewage Treatment Plants

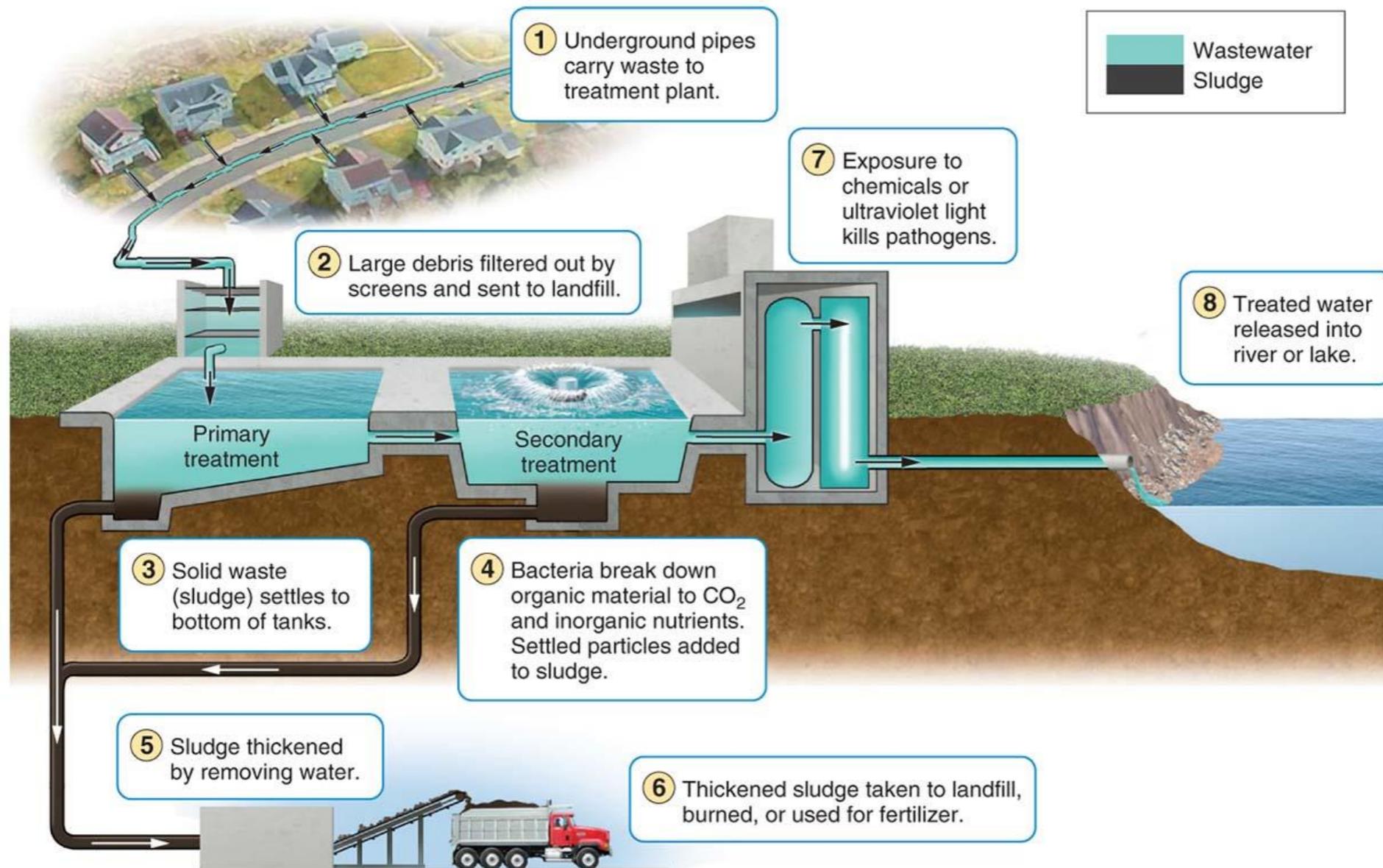


Figure 41.6
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A sewage treatment plant. In large municipalities, great volumes of wastewater are handled by separating the sludge from the water and then using bacteria to break down both components.

Animal Feed Lots and Manure Lagoons

- Manure from concentrated animal feeding operations is a problem because of volume. It can also contain hormones and antibiotics that are given to the animals.
- **Manure lagoon** Human-made pond lined with rubber built to handle large quantities of manure produced by livestock.
- After the manure is broken down by bacteria, it is spread onto fields as fertilizers.

Manure Lagoons



Heavy metals are highly toxic to organisms

Three heavy metals are of particular concern:

- Lead: found in pipes and other materials in older construction.
- Arsenic: occurs naturally and through human activity such as mining and industry.
- Mercury: occurs naturally and through human activity, primarily burning coal.

Arsenic

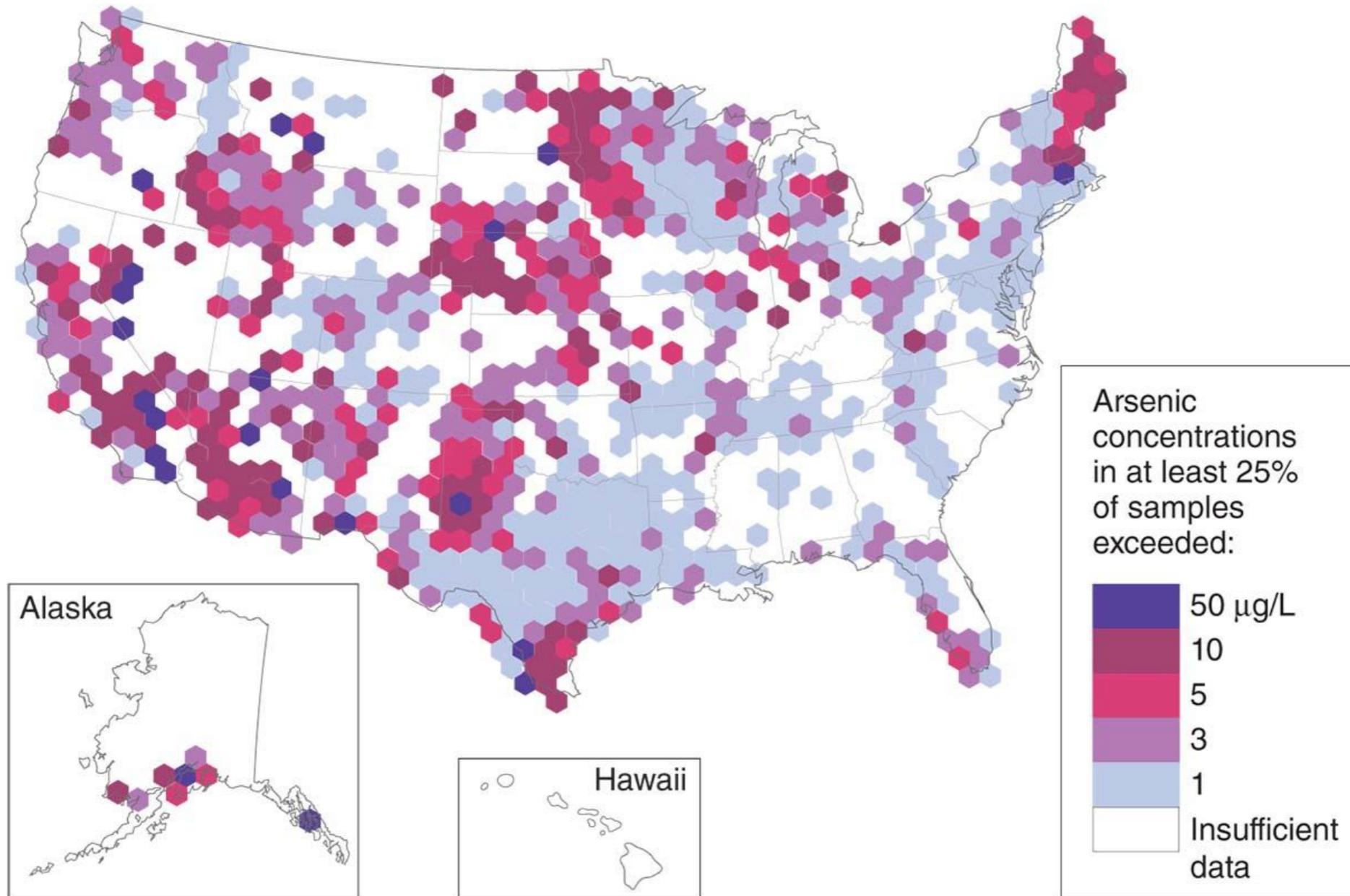


Figure 42.1
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Source: http://water.usgs.gov/nawqa/trace/pubs/geo_v46n11/fig3.html

Arsenic in U.S. well water. The highest concentrations of arsenic are generally found in the upper Midwest and the West.

Mercury

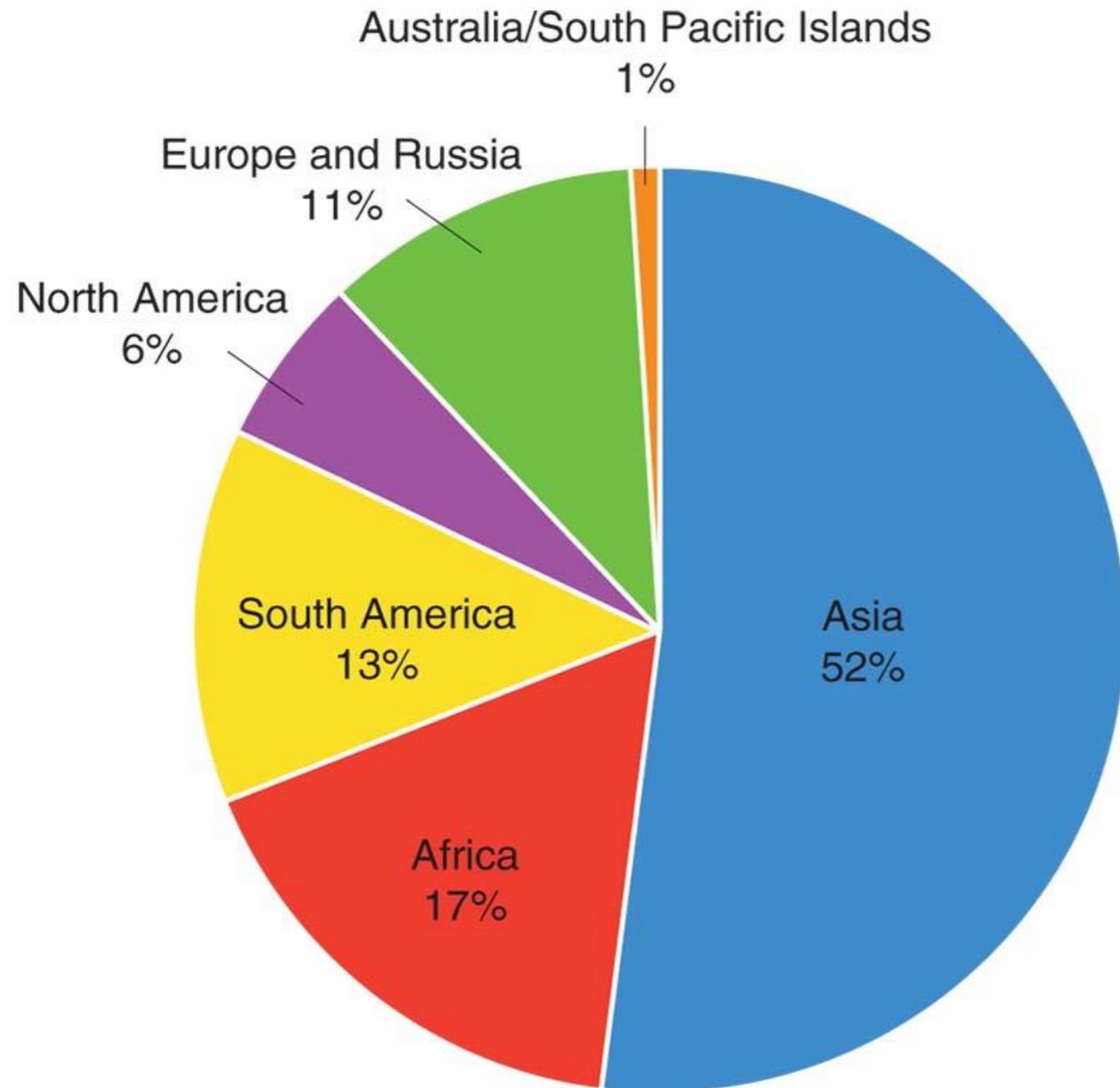


Figure 42.2

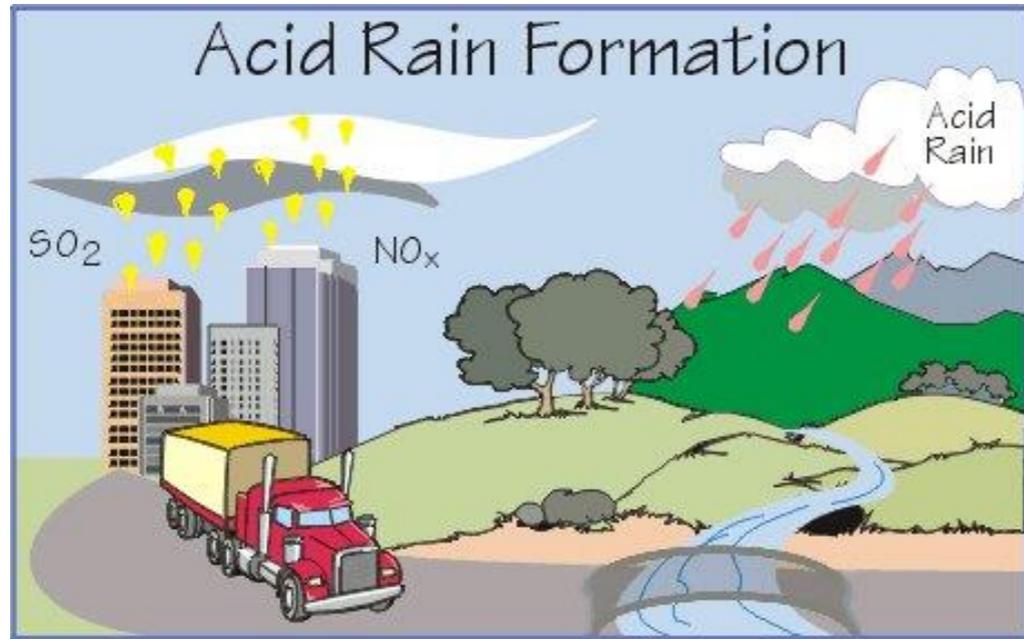
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Data from AMAP/UNEP, 2013. Technical Background Report for the Global Mercury Assessment 2013. Arctic Monitoring and Assessment Programme, Oslo, Norway/UNEP Chemicals Branch, Geneva, Switzerland. vi + 263 pp

World mercury emissions. Mercury emissions from human activities vary greatly among regions of the world.

Acid deposition and acid mine drainage affect terrestrial and aquatic ecosystems

- **Acid deposition** Acids deposited on Earth as rain and snow or as gases and particles that attach to the surfaces of plants, soil, and water.
- Acid deposition occurs when burning coal releases sulfur dioxide and nitrogen dioxide into the air.
- In the atmosphere, these chemicals are converted to sulfuric acid and nitric acid, which fall back to Earth as acid deposition.
- Acid deposition reduces the pH of water bodies to levels that are lethal to many organisms.
- Many coal-burning facilities have installed coal scrubbers to combat this problem.



Synthetic organic compounds are human-produced chemicals

- Synthetic compounds can enter the water supply from industrial point sources or from nonpoint sources when they are applied over large areas.
- These compounds include pesticides, pharmaceuticals, military compounds, and industrial compounds.
- Synthetic organic compounds can be toxic, cause genetic defects, and interfere with growth and sexual development.

Pesticides and Inert Ingredients

- Pesticides serve an important role in helping to control pest organisms that pose a threat to crop production and human health.
- However pesticides can have unintended impacts on other pests as well as on many nonpest species.
- For example, DDT—designed to kill mosquitoes—can move up an aquatic food chain to birds that consume fish. Eagles that consumed DDT-contaminated fish produced eggs with thinner shells that broke too easily. After the United States DDT in 1972, the bald eagle and other birds of prey increased in numbers.



Pharmaceuticals and Hormones

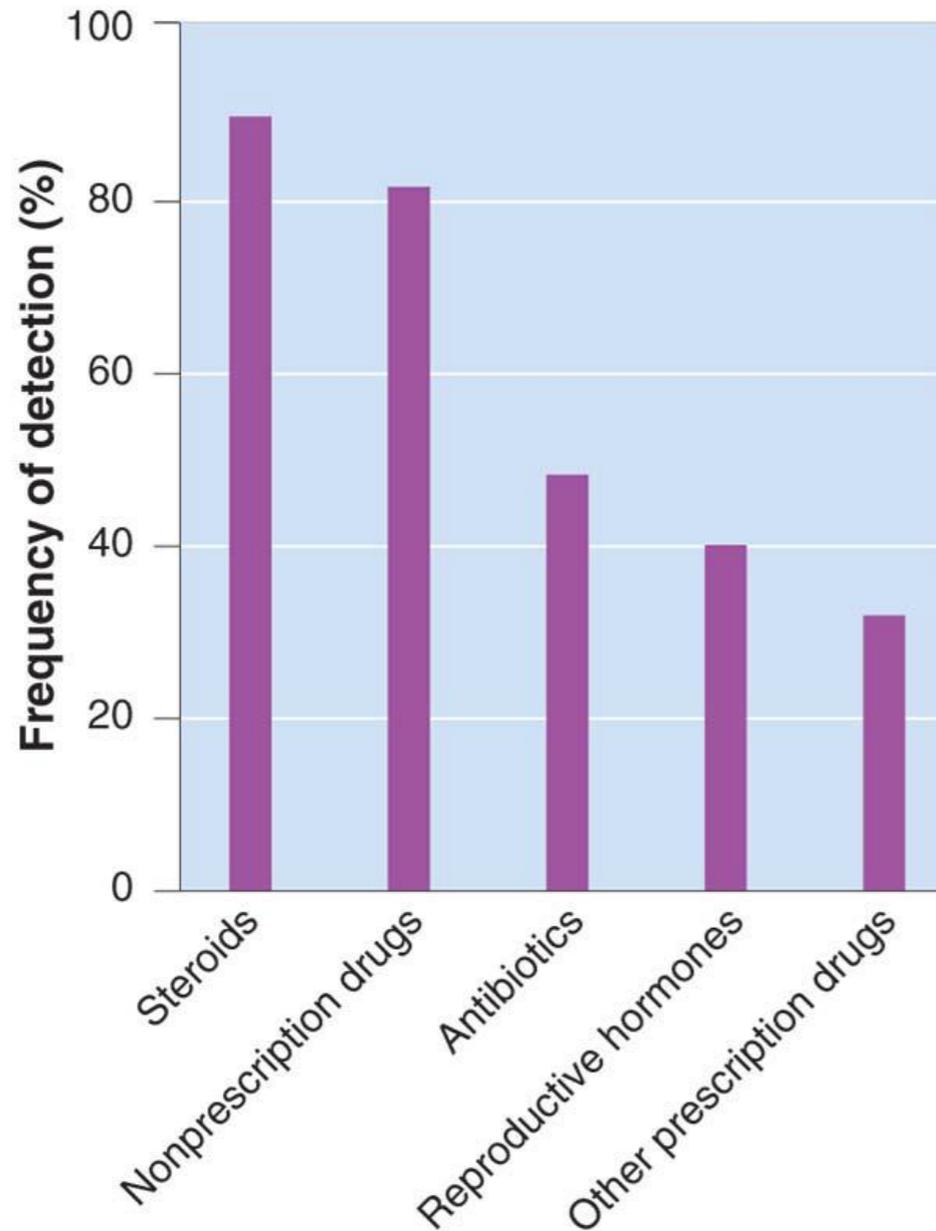


Figure 42.5

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After D. W. Kolpin et al. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999–2000: A national reconnaissance. *Environmental Science & Technology* 36: 1202–1211

Contaminants in streams. Streams contain a wide variety of chemicals including pharmaceutical drugs and hormones. These come from a combination of wastewater inputs, agriculture, forestry, and industry.

Military Compounds

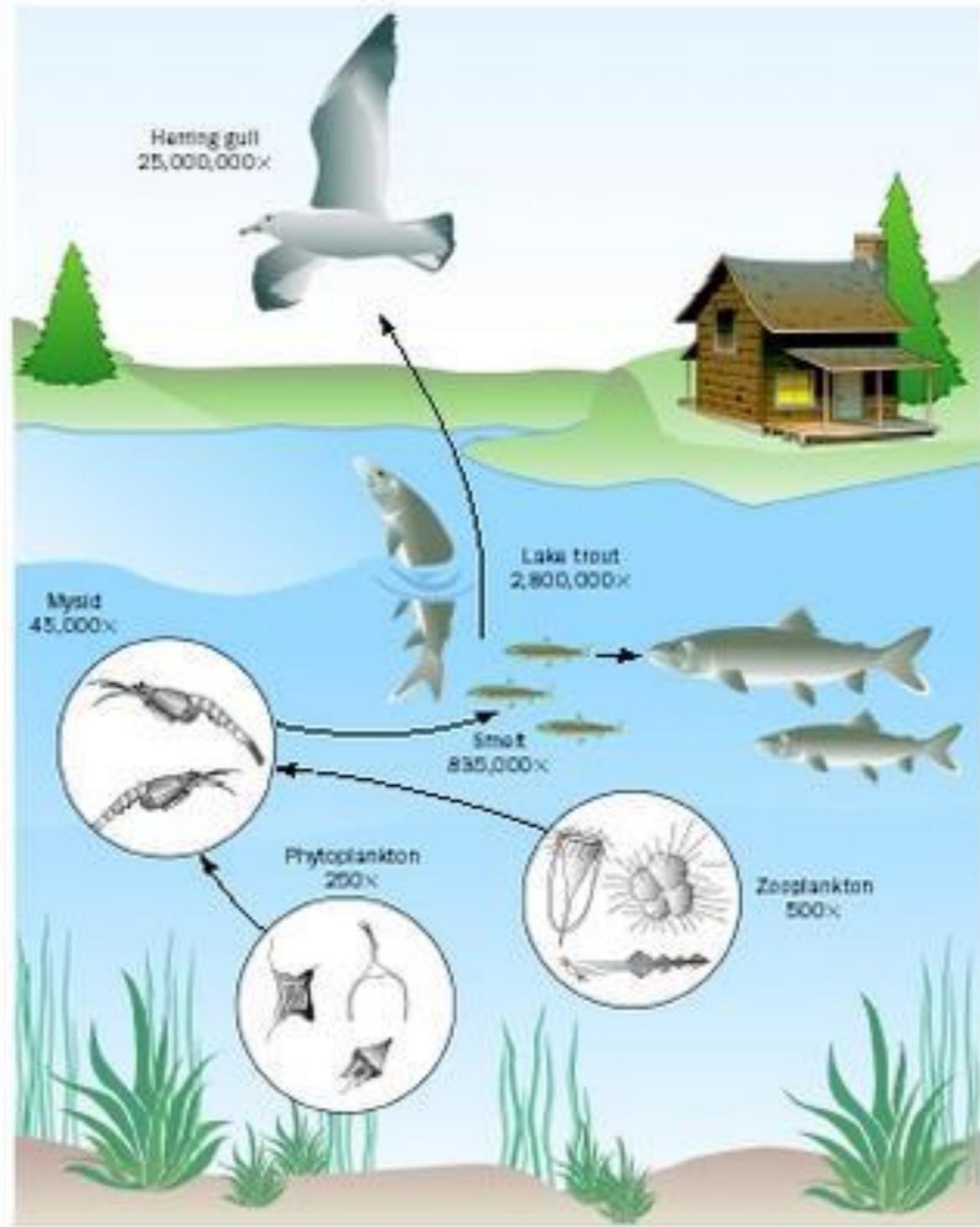
- **Perchlorates** A group of harmful chemicals used for rocket fuel.
- Perchlorates sometimes contaminate the soil in regions of the world where military rockets are manufactured, tested, or dismantled.



Industrial Compounds

- Industrial compounds: chemicals used in manufacturing.
- It used to be common for manufacturers in the United States to dump industrial compounds directly into bodies of water.
- **Polychlorinated biphenyls (PCBs)** A group of industrial compounds used to manufacture plastics and insulate electrical transformers, and responsible for many environmental problems.

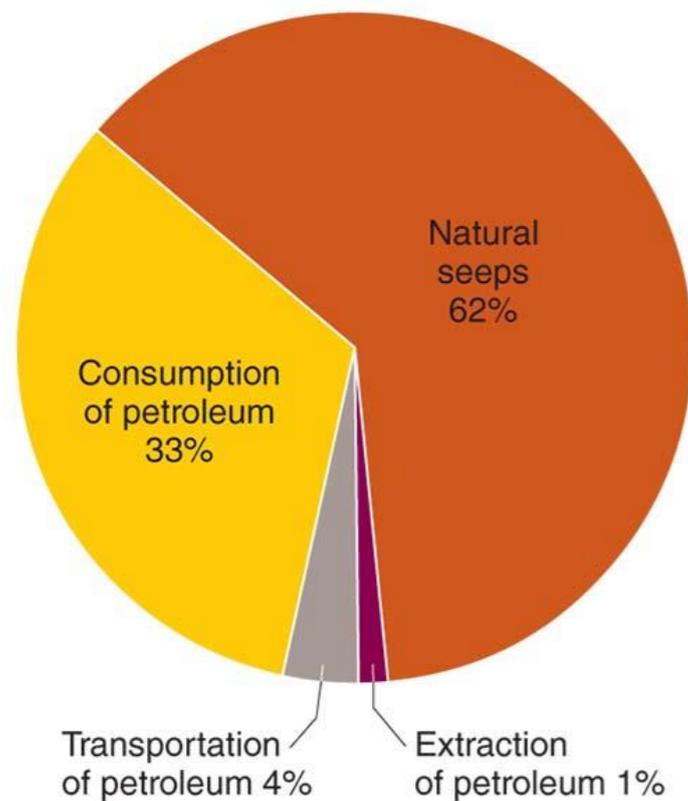
LAKE ONTARIO BIOMAGNIFICATION OF PCBs



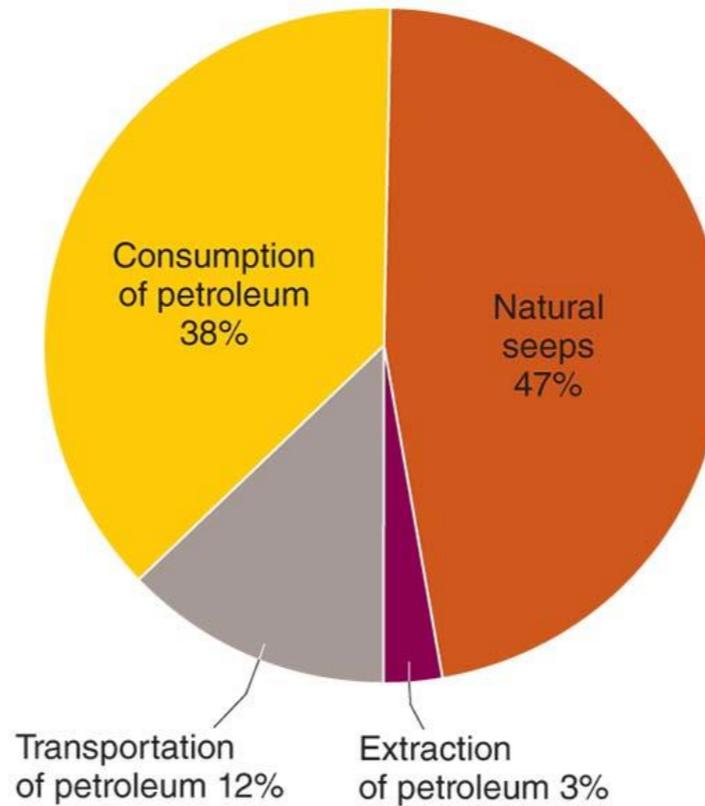
There are several sources of oil pollution

- Petroleum products are highly toxic to many marine organisms, including birds, mammals, and fish, as well as to the algae and microorganisms that form the base of the aquatic food chain.
- One source of oil in the water comes from drilling for undersea oil using offshore platforms.
- Oil and other petroleum products can also enter the oceans as spills from oil tankers.
- Oil pollution in the ocean also occurs naturally.

Oil Pollution



(a)



(b)

Figure 43.2
Environmental Science for AP[®], Second Edition
After <http://oceanworld.tamu.edu/resources/oceanography-book/contents.htm>

Sources of oil in the ocean. Oil contamination in the ocean, both (a) in North America and (b) worldwide, comes from a variety of sources including natural seeps, extraction of oil from underneath the ocean, transport of oil by tanker or pipeline, and consumption of petroleum-based products.

The are ways to remediate oil pollution

- Containment: Booms keep the floating oil from spreading, then boats equipped with giant oil vacuums suck up as much oil as possible.
- Chemicals: Chemicals break up the oil on the surface, making it disperse before it hits the shoreline.
- Bacteria: A particular bacterium consumes oil; scientists are currently trying to genetically engineer the bacterium to consume oil even faster.



The Oil Spill Diet

Oil-consuming bacteria offer one of the least destructive ways to clean oil from marshlands, where mechanical cleaning can destroy fragile habitats. But microbes are not a perfect solution.



Cleanup rarely requires adding new bacteria to the environment. Instead, local species are fertilized with nitrogen and phosphorous to speed up their appetites.

Fertilizers can be added directly to the oil slick, or in the form of other decaying organic matter, such as dead shrimp. But overfertilization can result in algal blooms, deplete oxygen, and create "dead zones," uninhabitable for fish.



Sunlight and oxygen at the ocean's surface encourage bacteria growth and provide the best environment for oil breakdown.

Wave motion and exposure can transform thin oil slicks into tarballs and a thick slurry often called "chocolate mousse." Research has shown that oil-eating bacteria has a difficult time penetrating these forms of oil contamination, resulting in a much slower breakdown.

Shallow Marshes



Samples of water and existing bacteria are taken from marshlands to determine how the oil, fertilizers and oil-eating bacteria might affect the local environment.

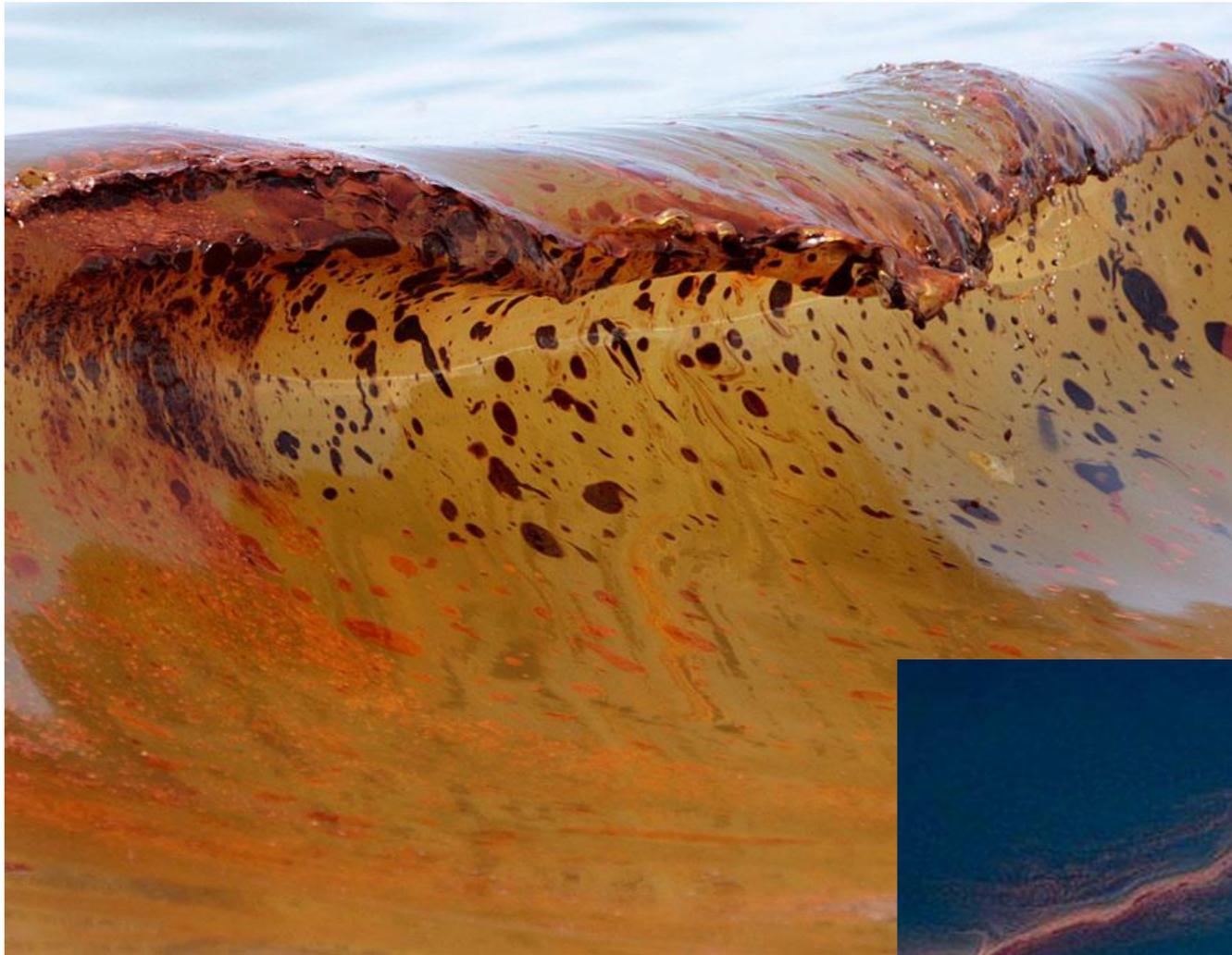
Deep Ocean

Oxygen, a key ingredient in the oil breakdown process, is scarce in the deep ocean and under sediments and in the marshes. Oil can be digested in these areas, but the process can take decades.



Once the bacteria have fully broken down the oil, all that remains is carbon dioxide and water, but that process can take days, months or even years depending on the conditions.





Solid waste includes garbage and sludge

- Much solid waste is what we call garbage and the sludge produced by sewage treatment plants.
- Garbage on beaches and in the ocean is dangerous to both marine organisms and people.
- In the United States the practice of dumping garbage in the ocean was curtailed in the early 1980s.
- The problem remains in many developing countries.



Sediment pollution consists of soil particles that are carried downstream

- 30 percent of all sediments in our waterways comes from natural sources while 70 percent comes from human activities.
- Problems with sedimentation:
- Suspension of soil particles cause waterways to become brown and cloudy.
- Reduced infiltration of sunlight lowers productivity of aquatic plants and algae.
- Sediments clog gills and prevent aquatic organisms from obtaining oxygen.



Thermal pollution causes change in water temperatures

- **Thermal pollution** Nonchemical water pollution that occurs when human activities cause a substantial change in the temperature of water.
- **Thermal shock** A dramatic change in water temperature that can kill organisms.
- One common solution is cooling towers that release the excess heat into the atmosphere instead of into the water.

Brayton Point, Somerset, MA



Noise pollution may interfere with animal communication

- Sounds emitted by ships and submarines can interfere with animal communication.
- Especially loud sonar can negatively affect species such as whales that rely on low-frequency, long-distance communication.
- An increased awareness of noise pollution in the ocean has inspired some ship builders to design ships equipped with quieter propellers.



The Clean Water Act protects water bodies

- **Clean Water Act** Legislation that supports the “protection and propagation of fish, shellfish, and wildlife and recreation in and on the water” by maintaining and, when necessary, restoring the chemical, physical, and biological properties of surface waters.
- The Clean water Act issued water quality standards that defined acceptable limits of various pollutants in U.S. waterways.



The Safe Drinking Water Act protects sources of drinking water

- **Safe Drinking Water Act** Legislation that sets the national standards for safe drinking water.
- The Safe Water Drinking Act establishes maximum contaminant levels (MCL) for 77 different elements or substances in both surface water and groundwater.
- **Maximum contaminant level (MCL)** The standard for safe drinking water established by the EPA under the Safe Drinking Water Act.



Safe Drinking Water Act

TABLE 45.1

The maximum contaminant levels (MCL) for a variety of contaminants in drinking water as determined by the U.S. Environmental Protection Agency, in parts per billion (ppb)

Contaminant category	Contaminant	Maximum contaminant level (ppb)
Microorganism	Giardia	0
Microorganism	Fecal coliform	0
Inorganic chemical	Arsenic	10
Inorganic chemical	Mercury	2
Organic chemical	Benzene	5
Organic chemical	Atrazine	3

Table 45.1

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Safe Drinking Water Act

TABLE 45.2		The current leading causes and sources of impaired waterways in the United States	
	Causes of impairment	Sources of impairment	
Streams and rivers	Bacterial pathogens, habitat alteration, oxygen depletion	Agriculture, water diversions, dam construction	
Lakes, ponds, and reservoirs	Mercury, PCBs, nutrients	Atmospheric deposition, agriculture	
Bays and estuaries	Bacterial pathogens, oxygen depletion, mercury	Atmospheric deposition, municipal discharges including sewage	

Table 45.2
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Water pollution legislation is becoming more common in the developing world

- Developed countries have addressed the problems of pollution by cleaning up polluted areas and by passing legislation to prevent pollution in the future.
- Developing countries are still in the process of industrializing and are less able to afford water-quality improvements
- Developing countries suffer from the additional pollution, but also benefit economically from the additional jobs and industrial spending.
- As a nation becomes more affluent, it has more resources available to address environmental issues.