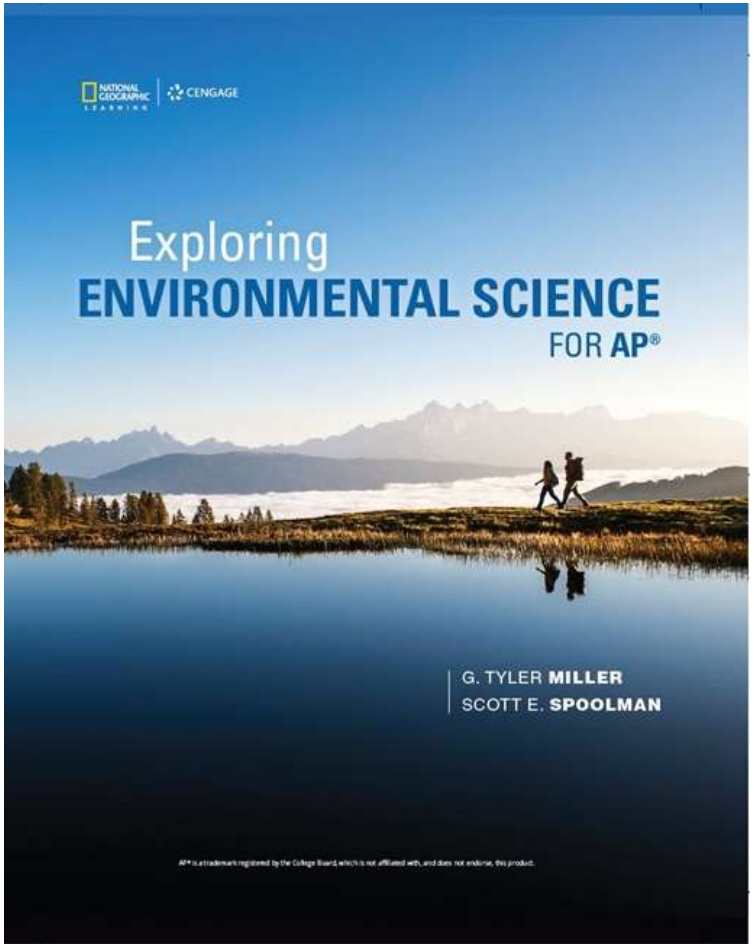
Exploring Environmental Science for AP®

1st Edition

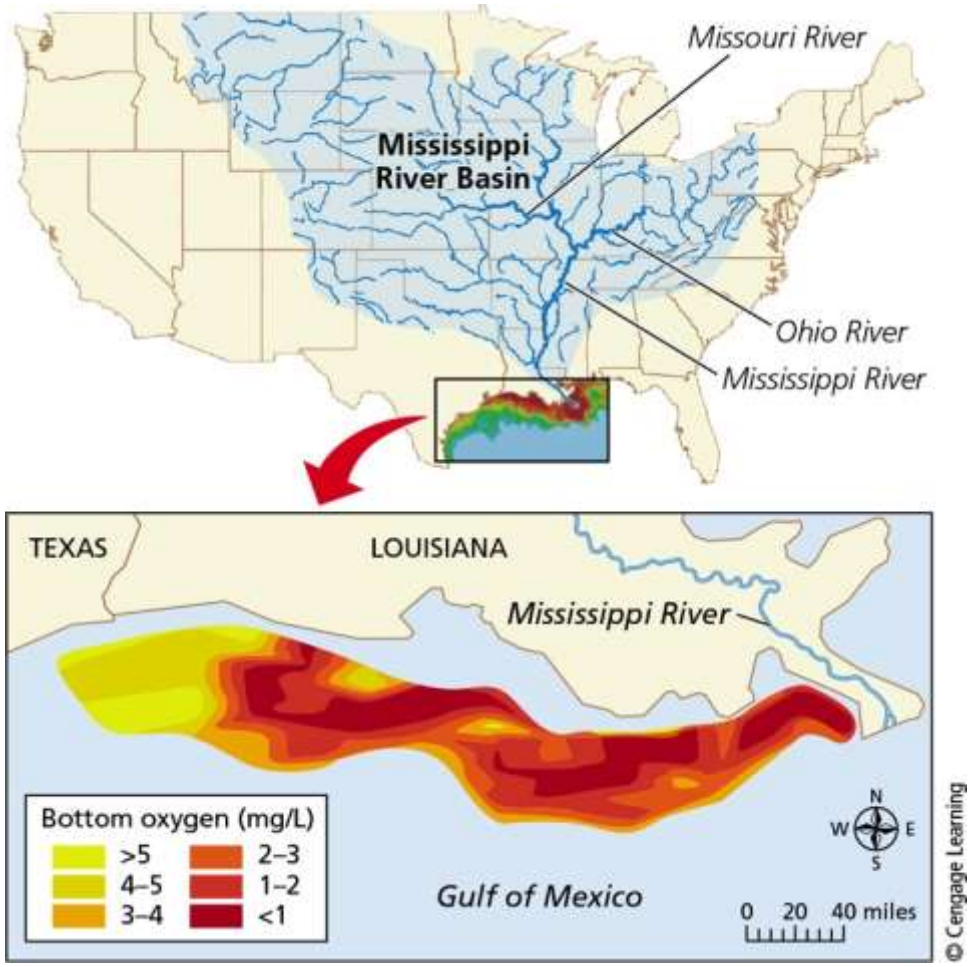


Chapter 17
Water Pollution

Core Case Study: The Gulf of Mexico's Annual Dead Zone (1 of 2)

- Spring and summer bring huge inputs of nutrients from the Mississippi River basin
  - Explosive growth of phytoplankton that eventually die and are consumed by bacteria
  - Depletes oxygen in the Gulf's bottom layer of water
  - Resulting dead zone contains little marine life
  - Winter storms redistribute oxygen

Core Case Study: The Gulf of Mexico's Annual Dead Zone (2 of 2)



17.1 What Are the Causes and Effects of Water Pollution?

- The chief sources of water pollution are agriculture, industry, and untreated wastewater
- Water pollution causes illness and death in humans and other species, and disrupts ecosystems

Water Pollution Comes from Point and Nonpoint Sources (1 of 5)

- Water pollution
  - Change in water quality that can harm living organisms or make water unfit for human use
- Point sources
  - Discharge pollutants at specific locations
  - Examples: factories, animal feed lots, underground mines, oil wells, and oil tankers
- Nonpoint sources
  - Broad, diffuse areas
  - Rainfall or snowmelt washes pollutants from land into surface water
  - Examples: runoff of fertilizers and pesticides from croplands, logged forests, lawns, and golf courses

Water Pollution Comes from Point and Nonpoint Sources (2 of 5)

- Leading causes of water pollution
  - Agricultural activities
    - Sediment eroded from the lands
    - Fertilizers, pesticides, and bacteria from livestock and food-processing wastes
  - Industrial facilities
  - Mining
  - Untreated human wastewater
  - Plastic

Water Pollution Comes from Point and Nonpoint Sources (3 of 5)

Water Pollution Comes from Point and Nonpoint Sources (4 of 5)

Water Pollution Comes from Point and Nonpoint Sources (5 of 5)

Harmful Effects of Water Pollutants

- Most serious threats to stream and lake water quality
  - Mercury
  - Pathogens from broken sewer pipes
  - Sediment from land disturbance and erosion
  - Metals
  - Nutrients that cause oxygen depletion
- Infectious disease organisms
  - Contaminated drinking water
  - An estimated 1.6 million people die every year

TABLE 17.1 Major Water Pollutants and Their Sources (1 of 2)

Type/Effects	Examples	Major Sources
Infectious agents (pathogens) Cause diseases	Bacteria, viruses, protozoa, parasites	Human and animal wastes
Oxygen-demanding wastes Deplete dissolved oxygen needed by aquatic species	Biodegradable animal wastes and plant debris	Sewage, animal feedlots, food-processing facilities, paper mills
Plant nutrients Cause excessive growth of algae and other species	Nitrates (NO_3) and phosphates (PO_4^{3-})	Sewage, animal wastes, inorganic fertilizers
Organic chemicals Add toxins to aquatic systems	Oil, gasoline, plastics, pesticides, cleaning solvents	Industry, farms, households
Inorganic chemicals Add toxins to aquatic systems	Acids, bases, salts, metal compounds	Industry, households, surface runoff, mining sites

TABLE 17.1 Major Water Pollutants and Their Sources (2 of 2)

Sediments Disrupt photosynthesis, food webs, other processes	Soil, silt	Land erosion
Heavy metals Cause cancer, disrupt immune and endocrine systems	Lead, mercury, arsenic	Unlined landfills, household chemicals, mining refuse, industrial discharges
Thermal Make some species vulnerable to disease	Heat	Electric power and industrial plants

17.2 What Are the Major Pollution Problems in Streams and Lakes?

- Many streams and rivers around the world are polluted
  - Can cleanse themselves of biodegradable wastes if we do not overload them or reduce their flows
- Adding excessive nutrients to lakes from human activities can disrupt ecosystems
- Preventing pollution more effective and less costly than cleaning it up

Stream Pollution in More-Developed Countries

- 1970s: water pollution control laws
- Successful water clean-up
  - Ohio Cuyahoga River, U.S.
  - Driven by bottom-up pressure from citizens
- EPA estimate: mining wastes pollute 40 percent of headwaters of western watersheds
- Ohio River: most polluted river in the United States

Stream Pollution in Less-Developed Countries (1 of 2)

- Half of the world's 500 major rivers are polluted
  - Untreated sewage
  - Industrial waste
- Water often used for human activities
- Nearly half of China's rivers too toxic to touch or drink
  - Liver and stomach cancer linked to water pollution among leading causes of death

Stream Pollution in Less-Developed Countries (2 of 2)

Neale Cousland/Shutterstock.com

Critical Concept: Oxygen Sag Curves (1 of 2)

- Flowing rivers or streams can dilute organic pollutants and heated water unless overloaded
- Does not eliminate heavy metals or slowly degradable pollutants
- Oxygen sag curve is created when degradable pollutants are emitted and bacteria act to decompose the waste

Pollution of Lakes and Reservoirs

- Lakes and reservoirs less effective at diluting pollutants than streams
  - Stratified layers with little vertical mixing
  - Little or no water flow
  - Can take up to 100 years to flush and change the water in a lake
  - Biological magnification of pollutants

Cultural Eutrophication: Too Much of a Good Thing (1 of 3)

- Eutrophication
  - Natural enrichment of a shallow lake, river mouth, or slow-moving stream
  - Caused by runoff of plant nutrients such as nitrates and phosphates
- Oligotrophic lake
  - Low nutrients
  - Clear water
- Cultural eutrophication
  - Nitrates and phosphates from human sources
    - Farms, feedlots, streets, parking lots, lawns, mining sites, and sewage plants

Cultural Eutrophication: Too Much of a Good Thing (2 of 3)

- During hot weather or drought
  - Dense growths of algae and cyanobacteria
  - Oxygen depleted by bacteria that decompose the algae
- Prevent or reduce cultural eutrophication
  - Remove nitrates and phosphates
  - Recycle nutrients into the soil
- Methods to clean up lakes
  - Remove excess weeds
  - Use herbicides and algaecides
  - Pump in air
  - Most lakes will recover if excessive input of nutrients is stopped

Cultural Eutrophication: Too Much of a Good Thing (3 of 3)

Yang Xiaoyuan/Xinhua Press/Corbis Wire/Corbis

Case Study: Pollution in the Great Lakes (1 of 4)

- 1960s: many areas with cultural eutrophication, fish kills, and contamination
- 1972: Great Lakes Water Quality Agreement
  - New or upgraded sewage treatment plants
  - Decreased algal blooms
  - Increased dissolved oxygen levels
  - Increased fishing catches

Case Study: Pollution in the Great Lakes (2 of 4)

Case Study: Pollution in the Great Lakes (3 of 4)

- Bans on phosphate-containing household cleaners
- Many problems remain
  - Increasing nonpoint runoff of pesticides and fertilizers greatest threat
  - Atmospheric deposition of pesticides, mercury, and other chemicals
    - From as far away as Mexico and Russia
  - 25% of fish had unsafe mercury content

Case Study: Pollution in the Great Lakes (4 of 4)

- Great Lakes Restoration Initiative
  - $1.3 billion provided between 2010 and 2015
  - Focused on reducing toxic pollution, cultural eutrophication, loss of wildlife habitat, invasive species, and soil erosion into lakes
  - Promotes wetlands restoration
- Prevention approach
  - Call for ban on toxic chlorine compounds used in pulp and paper industry

Gulf of Mexico Dead Zone: A Closer Look

- Level of nitrates discharged from Mississippi River into Gulf of Mexico tripled since 1950s
  - Causes severe depletion of dissolved oxygen
- Food web disruption
  - Many species cannot migrate away from area and die
    - Causes deaths of seabird and marine mammal species that depend on dying fish and shellfish
- Human factors
  - Dredging and straightening increases flow of nutrients
  - Removal of wetlands that act as filters for pollutants

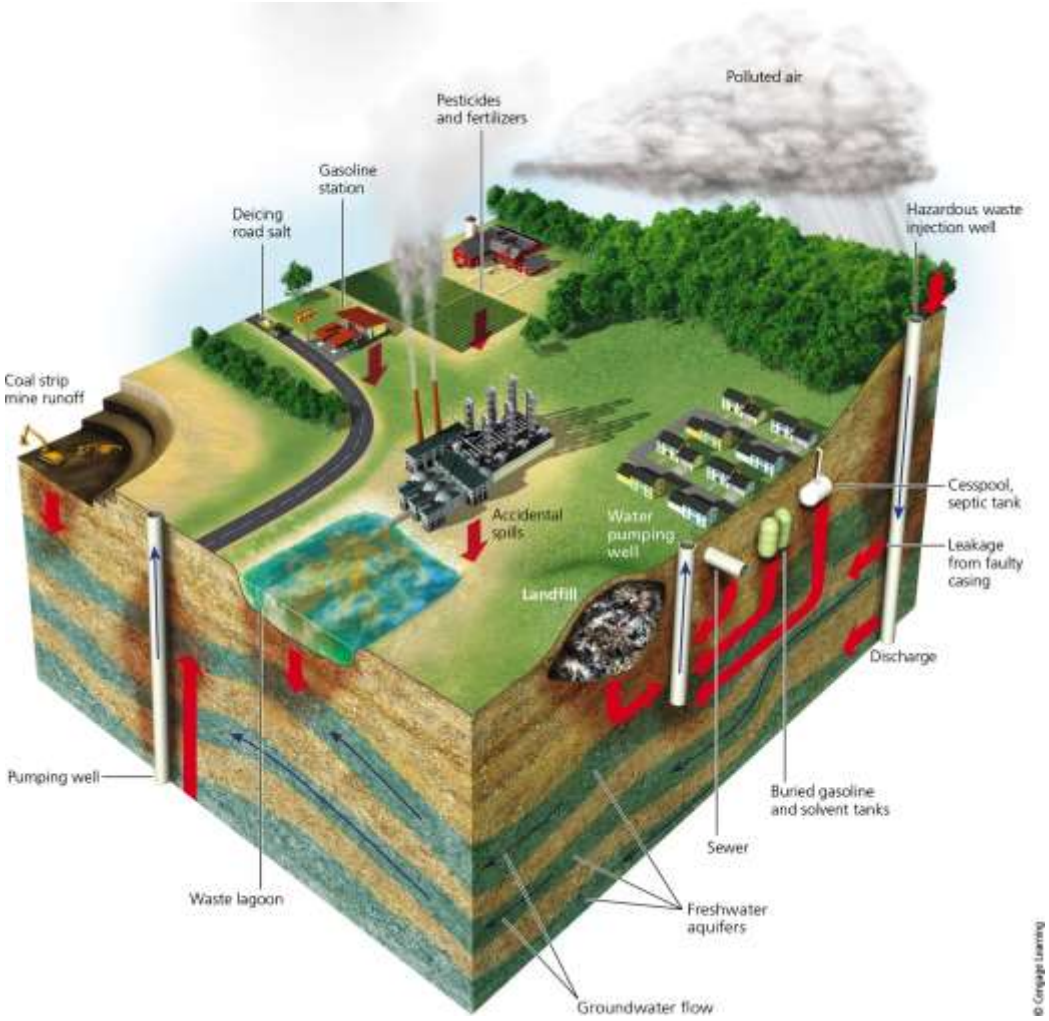
17.3 What Are the Major Groundwater Pollution Problems?

- Chemicals used in agriculture, industry, transportation, and homes spill and leak into groundwater
- Protecting groundwater through pollution prevention
  - Least expensive and most effective strategy

Groundwater Cannot Cleanse Itself Very Well (1 of 2)

- Aquifers: drinking water source for about half the U.S. population
- Common pollutants
  - Fertilizers and pesticides
  - Gasoline
  - Organic solvents
  - Fracking
- Slower chemical reactions in groundwater due to:
  - Slow flow–contaminants not diluted
  - Less dissolved oxygen
  - Fewer decomposing bacteria
  - Cold temperatures

Groundwater Cannot Cleanse Itself Very Well (2 of 2)



Groundwater Pollution Is a Hidden Threat (1 of 2)

- China: 90% of shallow groundwater is polluted
  - About 37% so polluted it cannot be treated for use as drinking water
- Liquid hazardous wastes are injected into ground in disposal wells in the United States
- EPA cleaning up leaking underground storage tanks
- Slowly degradable wastes
  - Can take decades to thousands of years to clear
- Non-biodegradable wastes
  - Remain in the water permanently
- Prevention is the most effective solution

Groundwater Pollution Is a Hidden Threat (2 of 2)

Solutions

Groundwater Pollution

Prevention

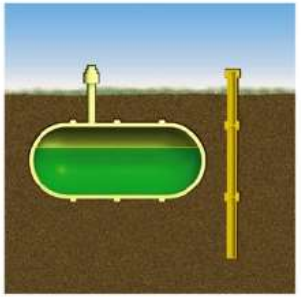
Find substitutes for toxic chemicals

Keep toxic chemicals out of the environment

Require leak detectors on underground tanks

Ban hazardous waste disposal in landfills and injection wells

Store harmful liquids in aboveground tanks with leak detection and collection systems



Cleanup

Pump to surface, clean, and return to aquifer (very expensive)

Inject microorganisms to clean up contamination (less expensive but still costly)

Pump nanoparticles of inorganic compounds to remove pollutants (still being developed)

Case Study: Arsenic in Drinking Water

- Arsenic-rich rocks can contaminate wells
  - Long-term exposure likely to cause skin, lung, and bladder cancer
  - Levels especially high in Bangladesh, China, India's state of West Bengal, and parts of northern Chile
- Treatment approach: rust nanoparticles removed with magnet

Purifying Drinking Water

- Reservoirs and purification plants
- Process sewer water to drinking water
- Expose clear plastic containers to intense sunlight (UV) to kill infectious microbes
- The LifeStraw filters viruses and parasites

Case Study: Is Bottled Water a Good Option?

- Bottled water can be useful but expensive
- The United States has some of the world's cleanest drinking water
- Bottled water takes huge energy inputs and creates environmental problems
  - 67 million plastic water bottles discarded daily in the United States
  - Most end up in landfills

Using Laws to Protect Drinking Water Quality

- 1975: U.S. Safe Drinking Water Act
  - Sets maximum contaminant levels for any pollutants that affect human health
  - Health scientists recommend strengthening the law
  - Various industries have lobbied to weaken the law
- Less-developed countries: laws do not exist or are not enforced

Case Study: Lead in Drinking Water

- 2014: residents of Flint, Michigan were exposed to dangerous levels of lead in tap water
  - Officials began withdrawing water from Flint River instead of Lake Huron
  - Failed to add chemicals to reduce leaching from lead pipes
  - Public outcry resulted in water source switched back to Lake Huron

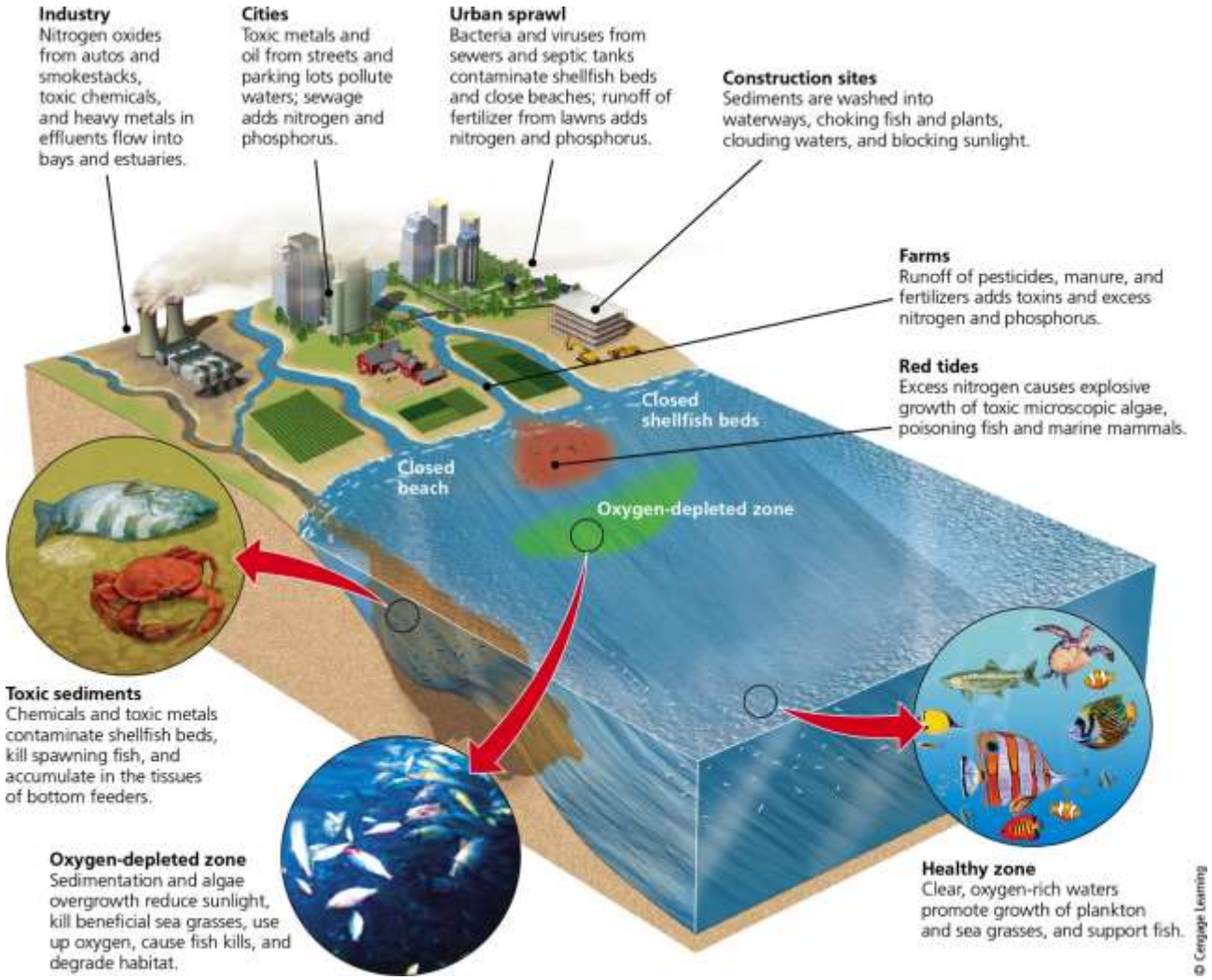
17.4 What Are the Major Ocean Pollution Problems?

- Most ocean pollution originates on land
  - Oil and other toxic chemicals
  - Solid waste
  - Threats to fish and wildlife
    - Disrupt marine ecosystems
- Key to protecting the oceans
  - Reduce pollution flow from land and air and from streams emptying into ocean waters

Ocean Pollution Is a Growing Problem (1 of 2)

- Municipal sewage from less-developed countries often dumped into oceans without treatment
  - Overwhelms coastal waters' ability to degrade wastes
- Deeper ocean waters
  - Dilution
  - Dispersion
  - Degradation
- U.S. coastal waters
  - Raw sewage–viruses
  - Sewage and agricultural runoff: NO_3^- and PO_4^{3-}
  - Harmful algal blooms
  - Oxygen-depleted zones

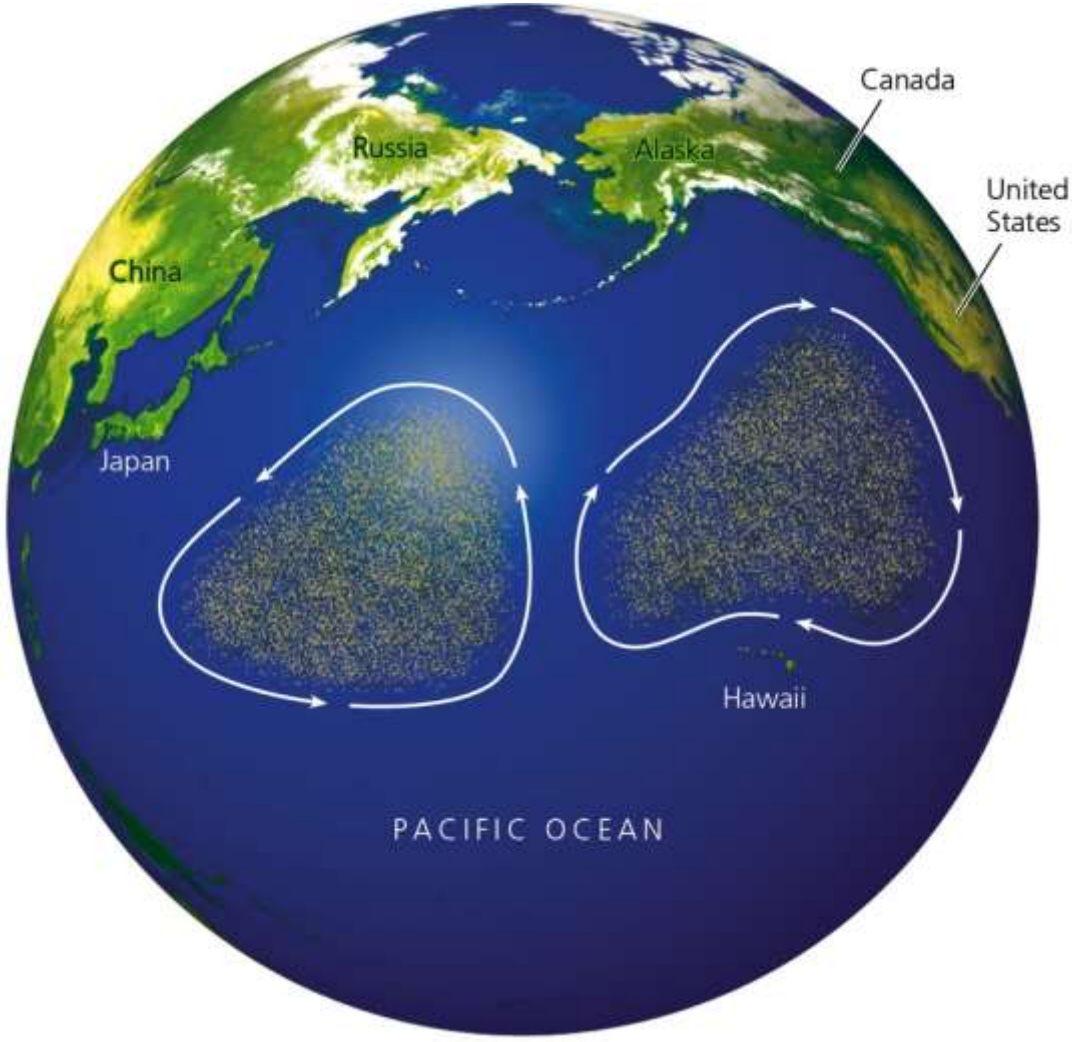
Ocean Pollution Is a Growing Problem (2 of 2)



Case Study: Ocean Garbage Patches: There Is No Away (1 of 2)

- North Pacific Garbage Patch
  - Two rotating gyres
    - Particles float on or just beneath the water surface
  - 80% of this trash comes from the land
- Tiny plastic pieces harmful to wildlife
  - Hazardous chemicals move through the food chain
- No practical way to clean up
  - Best approach: prevent growth by reducing production of solid wastes

Case Study: Ocean Garbage Patches: There Is No Away (2 of 2)



Ocean Pollution from Oil (1 of 3)

- Crude and refined petroleum
  - From natural sources and human activities
- Urban and industrial runoff from land
  - Largest source of ocean oil pollution from human activities
- Prominent pollution accidents
  - 1989: Exxon Valdez, oil tanker
  - 2010: BP Deepwater Horizon in the Gulf of Mexico
- Volatile organic hydrocarbons
  - Kill many aquatic organisms

Ocean Pollution from Oil (2 of 3)

- Tar-like globs on the ocean's surface
  - Coat animals' fur and feathers
    - Animals drown or die from loss of body heat
- Heavy oil components sink
  - Smother bottom-dwelling organisms
- Faster recovery in warm water with rapid currents
  - In cold, calm waters recovery can take decades
- Current cleanup methods
  - Recover up to only 15% of oil from a major spill
- Methods of preventing oil spills
  - Double-hulled tankers

Ocean Pollution from Oil (3 of 3)

U.S. Coast Guard

Case Study: The BP Deepwater Horizon Oil-Rig Spill

- Spill from deep-sea oil drilling
  - Released 3.1 million barrels of crude oil before well was capped
  - Contaminated vast areas of coastline
  - Caused by equipment failure and poor decisions
- Government developed new standards for offshore drilling procedures

17.5 How Can We Deal with Water Pollution?

- Reducing water pollution
  - Prevent it
  - Work with nature to treat sewage
  - Use natural resources more efficiently

Reducing Ocean Water Pollution (1 of 2)

- Reduce flow of pollution from land
  - Land-use
  - Air pollution
  - Linked to energy and climate policy

Reducing Ocean Water Pollution (2 of 2)

Solutions

Coastal Water Pollution

Prevention

Separate sewage and storm water lines

Ban dumping of wastes and sewage by ships in coastal waters

Require secondary treatment of coastal sewage

Strictly regulate coastal development, oil drilling, and oil shipping

Use wetlands and other natural methods to treat sewage

Require double hulls for oil tankers

Cleanup

Improve oil-spill cleanup capabilities

Use nanoparticles on sewage and oil spills to dissolve the oil or sewage (still under development)

Reducing Water Pollution from Nonpoint Sources

- Methods to reduce pollution
  - Use soil conservation methods
  - Use fertilizers that release nutrients slowly
    - Do not use on steeply sloped land
  - Reduce use and runoff of plant nutrients and pesticides
  - Plant buffer zones of vegetation
  - Set discharge standards for nitrate chemicals from sewage treatment and industrial plants

Case Study: Reducing Water Pollution in the United States

- 1972/1977: Clean Water Act
- 1972: Marine Protection, Research, and Sanctuaries Act
- 1975/1996: Clean Drinking Water Act
- 1976: Toxic substances Control Act
- 1980: Comprehensive Environmental Response Compensation and Liability Act (CERCLA)
- 1987: Water Quality Act
- 1990: Oil Pollution Act
- Experimenting with a discharge trading policy that uses market forces
- What are some achievements of the Clean Water Act?

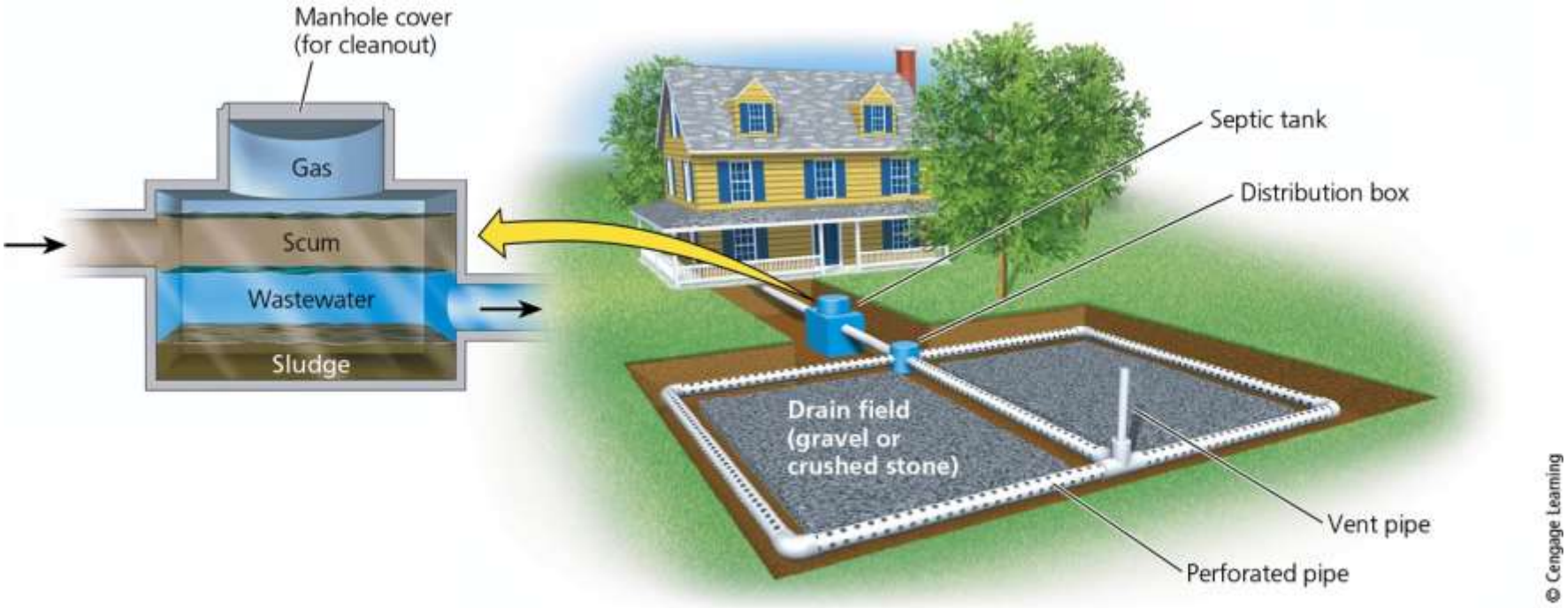
Sewage Treatment Reduces Water Pollution (1 of 4)

- Septic tanks used in rural areas
- Wastewater or sewage treatment plants
  - Primary sewage treatment
    - Physical process
  - Secondary sewage treatment
    - Biological process using bacteria
  - Tertiary or advance sewage treatment
    - Special filtering processes
    - Bleaching and disinfection

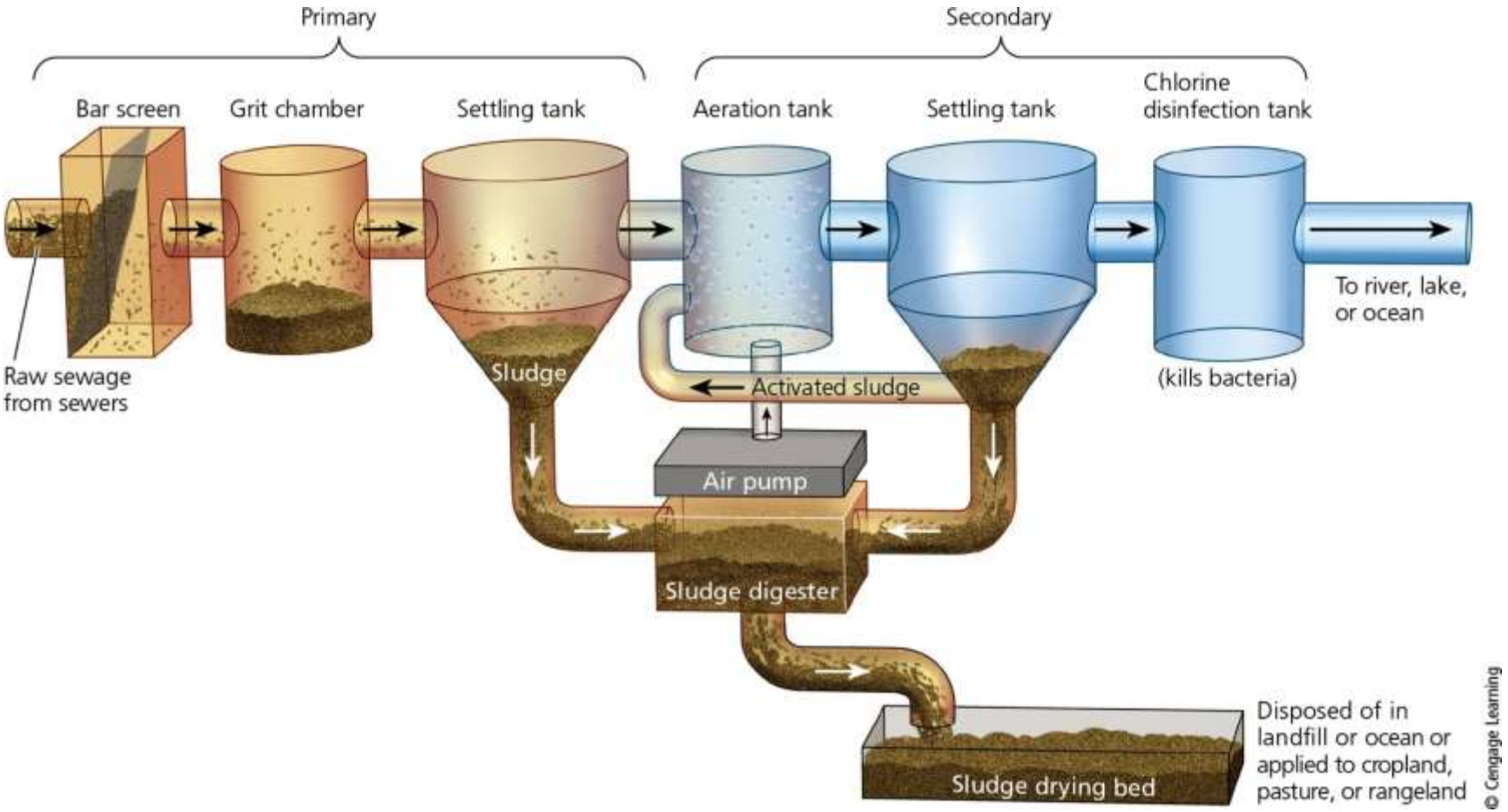
Sewage Treatment Reduces Water Pollution (2 of 4)

- Many cities violate federal standards for sewage treatment plants
  - Federal law requires primary and secondary treatment
    - Exemptions from secondary treatment
- Health risks result from swimming in water with blended sewage wastes

Sewage Treatment Reduces Water Pollution (3 of 4)



Sewage Treatment Reduces Water Pollution (4 of 4)



Improving Conventional Sewage Treatment

- Remove toxic wastes before water goes to municipal sewage treatment plants
- Reduce or eliminate use and waste of toxic chemicals
- Use composting toilet systems
- Wetland-based sewage treatment systems
  - Work with nature

Sustainable Ways to Reduce and Prevent Water Pollution (1 of 3)

- Developed countries
  - Bottom-up political pressure to pass laws
- Less-developed countries
  - Little has been done to reduce water pollution
  - China has plans for small sewage treatment plants
- How can we avoid producing water pollutants in the first place?