

Chapter 18

Lecture Outline*

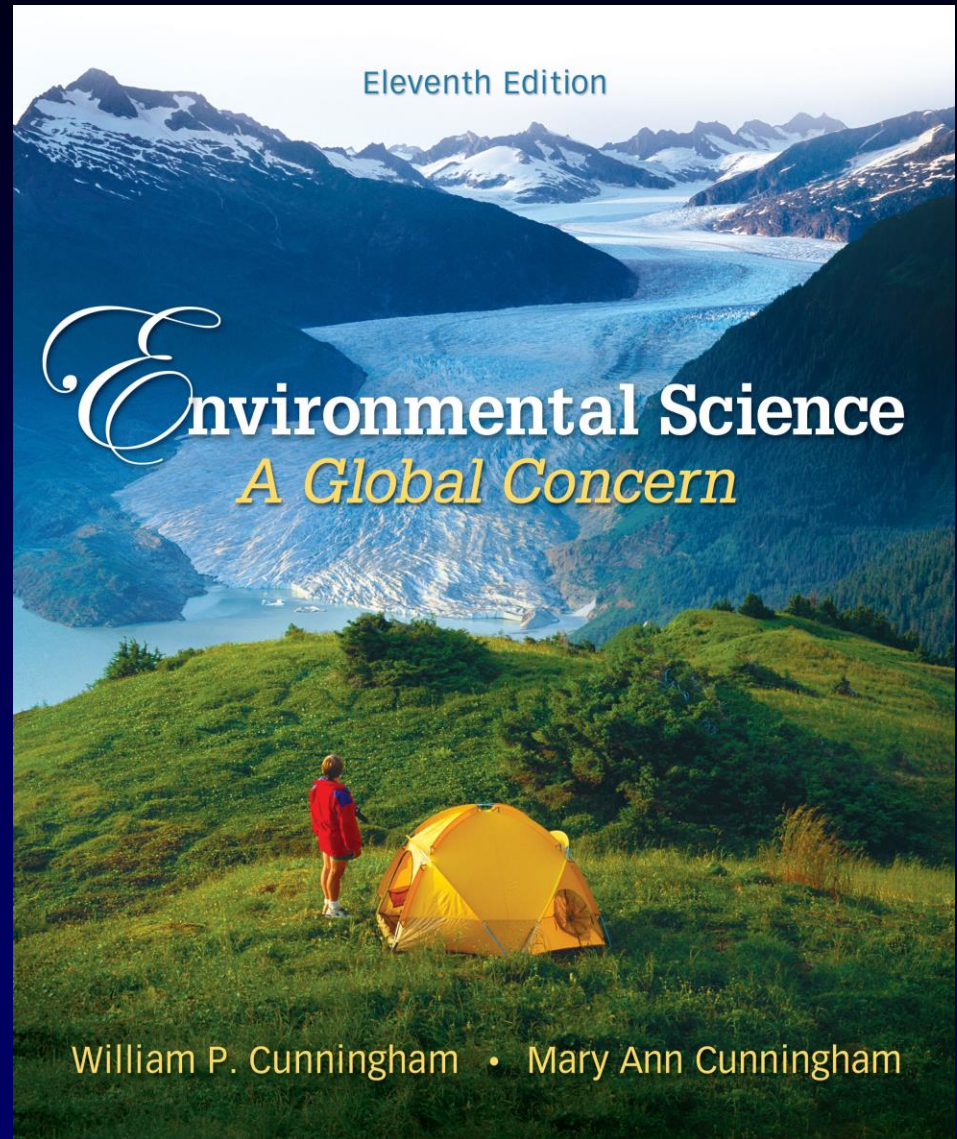
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Water Pollution

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Outline

- Types and Effects of Water Pollution
 - ❖ Point vs. Non-Point Sources
- Water Quality Today
 - ❖ Surface Water
 - ❖ Groundwater
 - ❖ Ocean Water
- Water Pollution Control
 - ❖ Source Reduction
 - ❖ Municipal Sewage Treatment
- Water Legislation
 - ❖ Clean Water Act (1972)

Water Pollution

- Any physical, biological, or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired uses can be considered pollution.
 - ❖ **Point Sources** - discharge pollution from specific locations
 - Factories, power plants, drain pipes
 - ❖ **Non-Point Sources** - scattered or diffuse, having no specific location of discharge
 - Agricultural fields, feedlots

Water Pollution

❖ Non point sources continued

- **Atmospheric Deposition** - contaminants carried by air currents and precipitated into watersheds or directly onto surface waters as rain, snow or dry particles
- Estimated 600,000 kg of the herbicide atrazine in the Great Lakes
 - Most thought to have been deposited from the atmosphere
- Contaminants can also evaporate from lakes.

Types and Effects of Water Pollution

- **Infectious Agents**

- ❖ Main source of waterborne pathogens is improperly treated human waste
 - Animal waste from feedlots and fields is also important source of pathogens.
 - At least 2.5 billion people in less developed countries lack adequate sanitation, and about half of these lack access to clean drinking water.

Infectious Agents

- In developed countries, sewage treatment plants and pollution-control devices have greatly reduced pathogens.
 - ❖ **Coliform bacteria** - intestinal bacteria; used to detect water contamination
 - ❖ Drinking water generally disinfected via chlorination



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Oxygen-Demanding Wastes

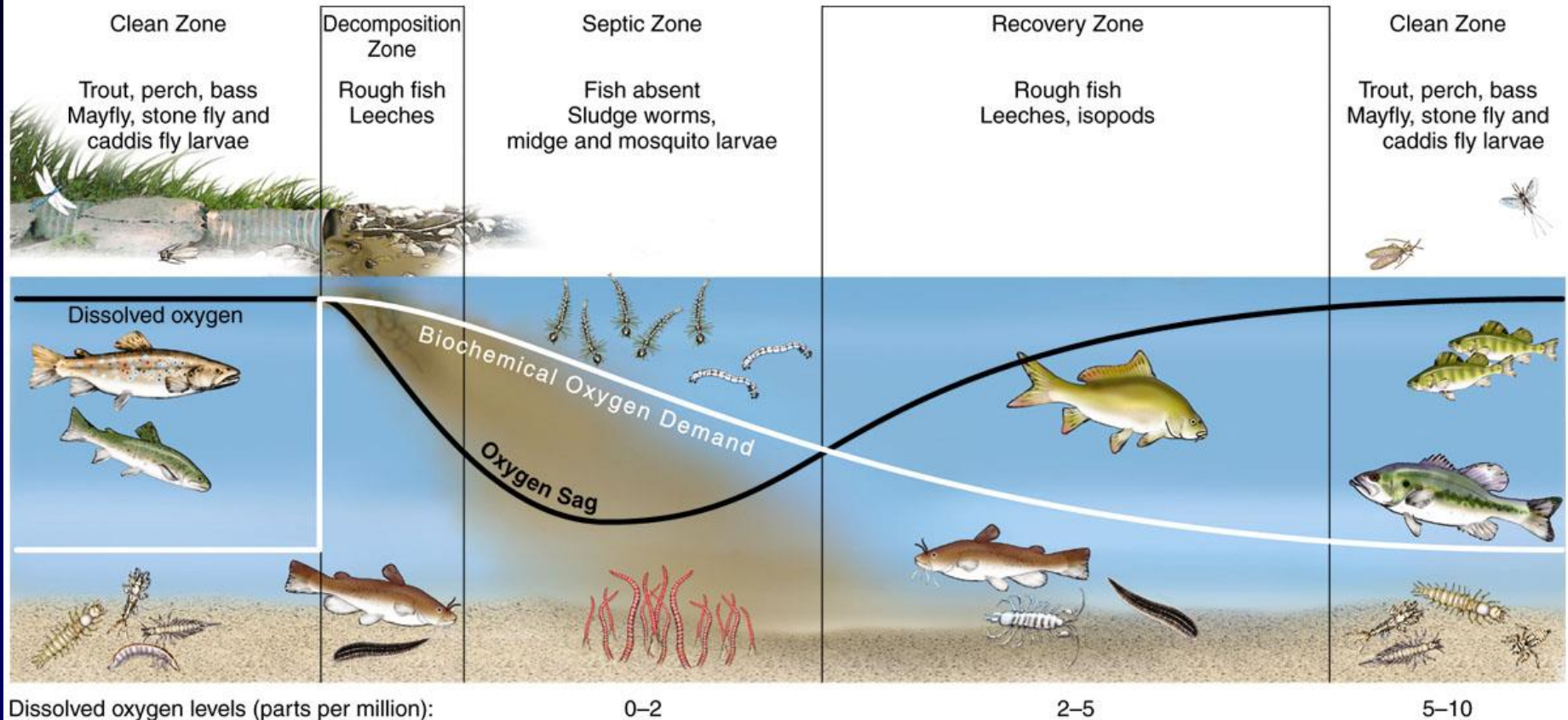
- Water with an oxygen content > 6 ppm will support desirable aquatic life.
 - ❖ Water with < 2 ppm oxygen will support mainly detritivores and decomposers.
- Oxygen is added to water by diffusion from wind and waves, and by photosynthesis from green plants, algae, and cyanobacteria.
 - ❖ Oxygen is removed from water by respiration and oxygen-consuming processes.

Oxygen-Demanding Wastes

- **Biochemical Oxygen Demand** - amount of dissolved oxygen consumed by aquatic microorganisms. Used as a test for organic waste contamination.
- **Dissolved Oxygen Content** - measure of dissolved oxygen in the water
- Effects of oxygen-demanding wastes on rivers depend on volume, flow, and temperature of river water.
 - ❖ **Oxygen Sag** - oxygen levels decline downstream from a pollution source as decomposers metabolize waste materials

Oxygen Sag

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Plant Nutrients and Cultural Eutrophication

- **Oligotrophic** - bodies of water that have clear water and low biological productivity
- **Eutrophic** - bodies of water that are rich in organisms and organic material
 - ❖ **Eutrophication** - process of increasing nutrient levels and biological productivity
 - **Cultural Eutrophication** - increase in biological productivity and ecosystem succession caused by human activities
 - Algal blooms often result. Decomposing algae rob water of oxygen.

Toxic Tides

- Red tides - dinoflagellate blooms - have become increasingly common in slow-moving and shallow waters.
 - ❖ Dinoflagellates are single-celled organisms that swim with 2 whiplike flagella.
 - *Pfiesteria piscicida* is a poisonous dinoflagellate recently recognized.
 - ❖ Found in marine zones that are hypoxic due to eutrophication e.g. dead zone at mouth of Mississippi River

Inorganic Pollutants

- Metals

- ❖ Many metals such as mercury, lead, cadmium, and nickel are highly toxic.
 - Highly persistent and tend to bioaccumulate in food chains
 - Most widespread toxic metal contaminant in North America is mercury (found in fish)
 - 600,000 American children have mercury levels high enough to cause mental deterioration and 1 woman in 6 has levels high enough to harm fetus.

Other Metal Contaminants in Water

- Mine drainage and leaching are serious sources of environmental contamination.
 - In a Tennessee study, 43% of streams and 50% of groundwater contaminated by metals and acid from mine drainage

Inorganic Pollutants

- Nonmetallic Salts

- ❖ Many salts that are non-toxic at low concentrations can be mobilized by irrigation and concentrated by evaporation, reaching levels toxic to plants and animals.
 - Leaching of road salts has had detrimental effect on many ecosystems.
 - Arsenic in India and Bangladesh

Acids and Bases

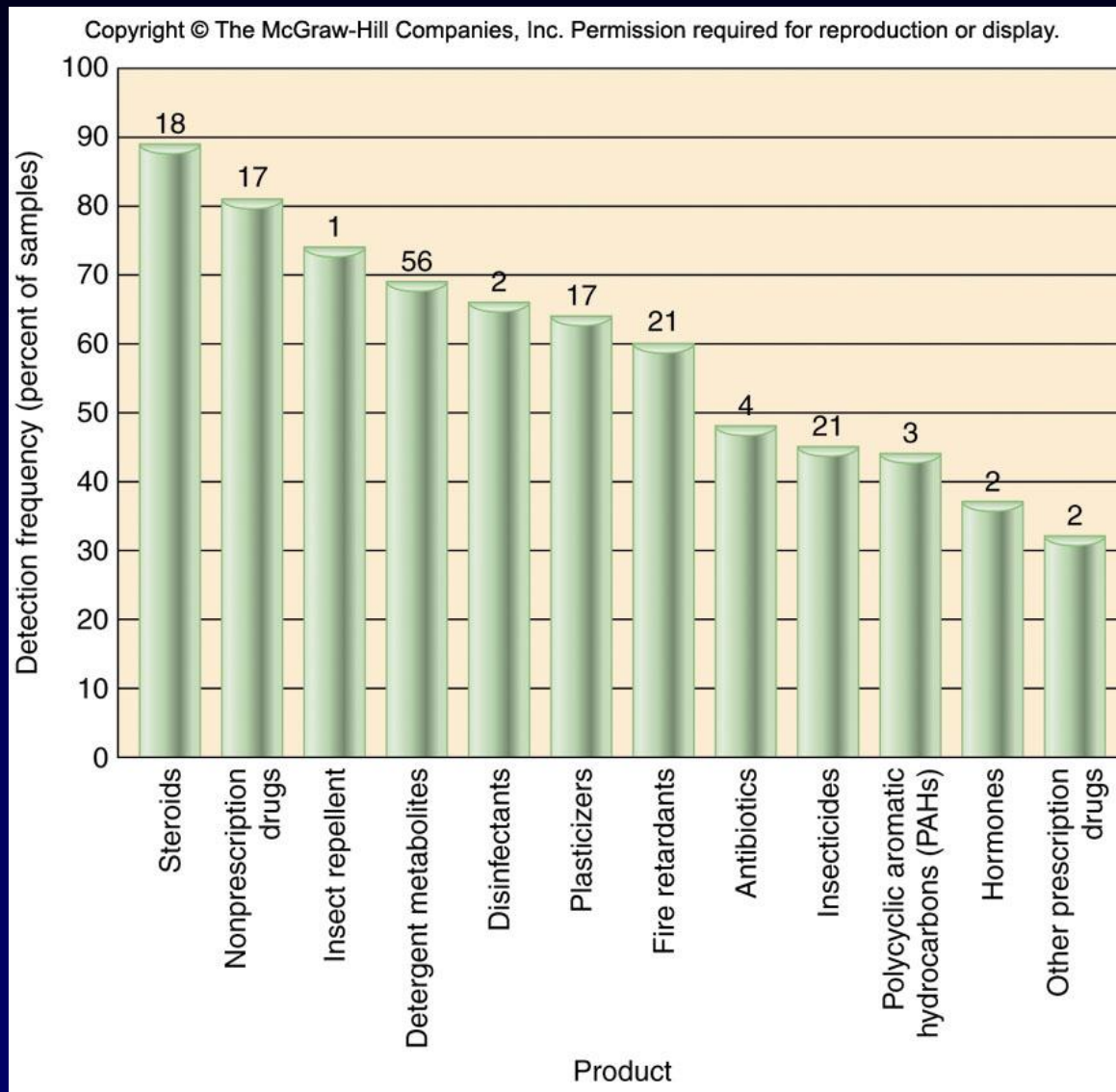
- **Acids and Bases**

- ❖ Often released as by-products of industrial processes
- ❖ Coal mining is an especially important source of acid water pollution.
 - Many streams acidified by acid mine drainage are lifeless
- ❖ Combustion of fossil fuels releases sulfuric and nitric acids that are deposited in water.
 - Thousands of lakes are empty of fish and support only a few mosses and fungi due to low pH.

Organic Chemicals

- Thousands of natural and synthetic organic chemicals are used to make pesticides, plastics, pharmaceuticals, pigments, etc.
- Two most important sources of toxic organic chemicals in water are:
 - ❖ Improper disposal of industrial and household wastes
 - ❖ Runoff of pesticides from fields, roadsides, golf courses, lawns, etc.

Detection Frequency of Organic Contaminants



Sediment

- Human activities have accelerated erosion rates in many areas.
 - ❖ Human-induced erosion and runoff contribute about 25 billion metric tons of sediment and suspended solids to world surface waters each year.
 - Obstructs shipping channels, clogs hydroelectric turbines, smothers fish eggs, blocks out light needed for photosynthesis
 - Sediment can also be beneficial e.g. building coastal wetlands and nourishing floodplain fields

Thermal Pollution

- Raising or lowering water temperatures from normal levels can adversely affect water quality and aquatic life.
 - ❖ Oxygen solubility in water decreases as temperatures increase.
 - Species requiring high oxygen levels are adversely affected by warming water.
 - Humans cause warming by discharging heated water from power plants and other industries.

Thermal Pollution

- Industrial cooling processes often use heat-exchangers to extract excess heat, and then discharge heated water back into original source as a **thermal plume**.
 - ❖ Disrupts natural ecosystems
 - Die off of heat sensitive organisms
 - Other organisms are attracted to warmth, but die when flow of warm water is interrupted by plant shutdown.
 - ❖ Cooling ponds or towers needed

Water Quality Today

- Areas of Progress

- ❖ **Clean Water Act** (1972) established a National Pollution Discharge System which requires a permit for any entity dumping wastes in surface waters and requires disclosure of what is being dumped.
 - Significant improvement in water quality, mostly due to sewage treatment
 - But goals have not been fully met; 21,000 water bodies do not meet designated uses

Areas of Progress

- In 1998, EPA switched regulatory approaches. Rather than issue standards on a site by site basis, the focus is now on watershed-level monitoring and protection.
 - ❖ States are required to identify waters not meeting water quality goals and develop **total maximum daily loads** for each pollutant and each listed water body.
 - Encouraging example: Lake Erie

Remaining Problems

- Some of the greatest impediments to achieving national goals in water quality are sediment, nutrients, and pathogens, especially from non-point discharges.
 - ❖ About three-quarters of water pollution in the U.S. comes from soil erosion, air pollution fallout, and agricultural and urban runoff.
 - Cattle in feedlots produce 144 million tons of manure and pet waste does not go through sewage treatment.

Other Countries Also Have Water Pollution

- Sewage treatment in wealthier countries of Europe generally equals or surpasses the U.S.
- In Russia, only about half of the tap water supply is safe to drink and in China 70% of surface waters are unfit for consumption.
- South America, Africa and Asia have poor water quality due to poverty, population growth and shift of polluting industries from countries where laws are strict to where they are lax.
- The Yamuna River and 2/3 of the other surface waters in India are so polluted that it is dangerous to even have contact with the water.

Groundwater Is Hard To Monitor And Clean

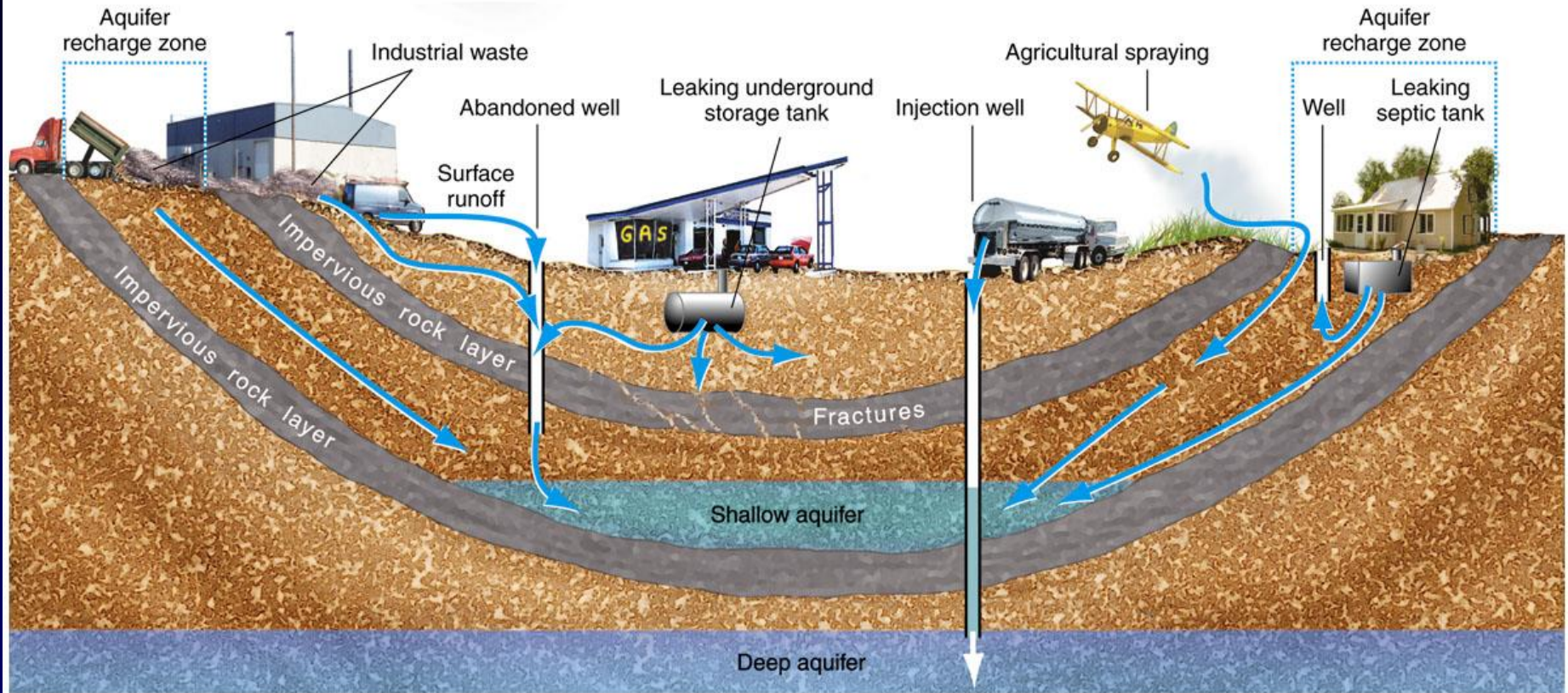
- About half the U.S. population, and 95% of rural residents, depend on underground aquifers for drinking water.
 - ❖ For decades, groundwater was assumed impervious to pollution and was considered the gold standard for water quality, but that is no longer true.
 - ❖ Methyl tertiary butyl ether (MTBE). a suspected carcinogen found in gasoline, now contaminates groundwater.

Groundwater and Drinking Water

- EPA estimates 4.5 trillion liters (1.2 trillion gal) of contaminated water seep into the groundwater in the U.S. every day.
 - ❖ Comes from septic tanks, cesspools, landfills, waste disposal sites, etc.
 - 1 gal of gasoline can make 1 million gal of water undrinkable.
 - ❖ In agricultural areas, fertilizers and pesticides commonly contaminate aquifers and wells.
 - ❖ Contaminants remain for thousands of years

Groundwater Pollution

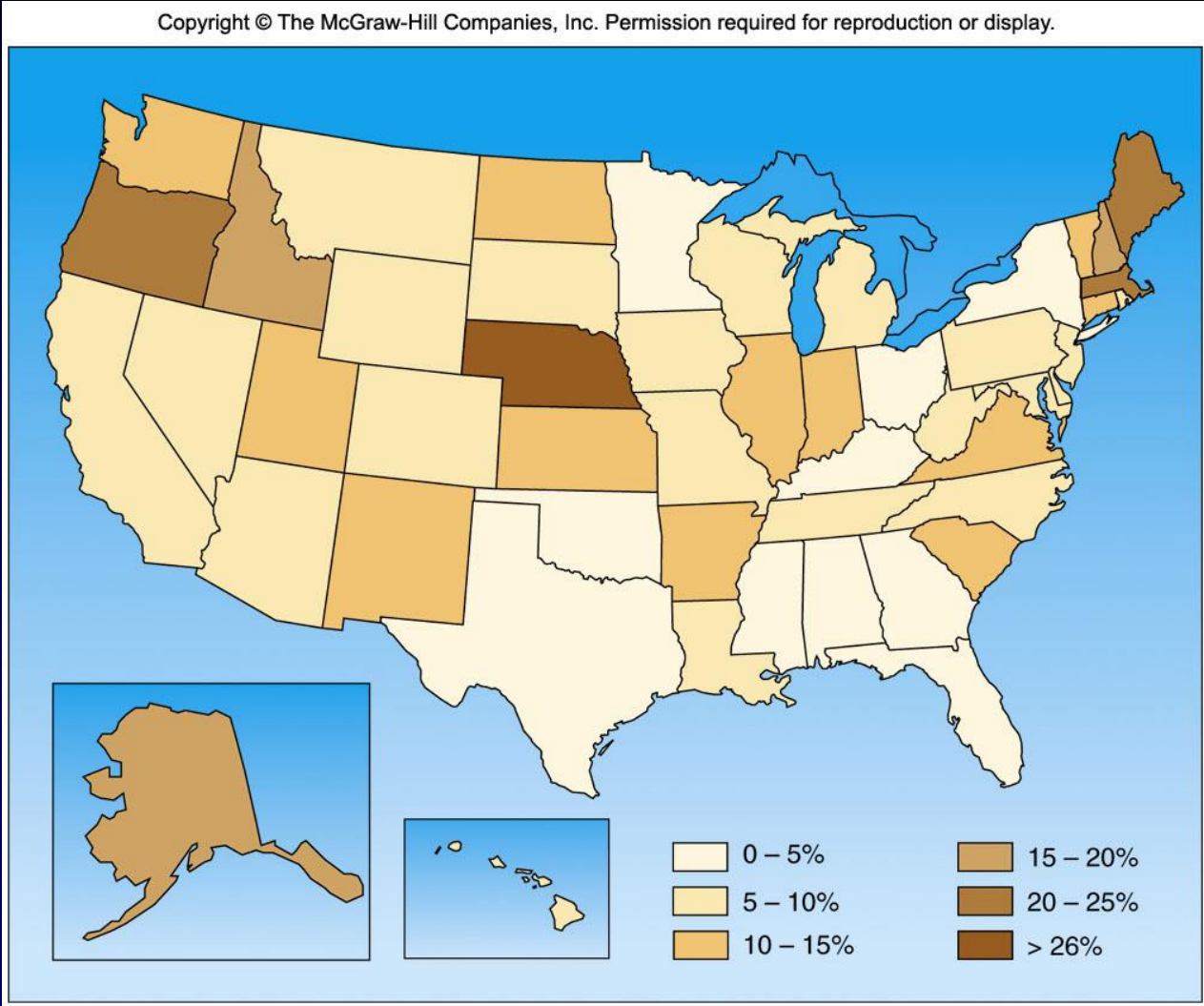
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Groundwater and Drinking Water

- In addition to groundwater, contaminated surface waters can make drinking water unsafe.
 - ❖ 2008 EPA data show that 30,000 people in the U.S. get water from community systems that don't meet all health-based drinking water standards
- An estimated 1.5 million Americans fall ill from fecal contamination annually
 - ❖ *Cryptosporidium* outbreaks
 - Milwaukee - 400,000 sick, 100 dead

Drinking Water Systems with EPA Violations



There Are Few Controls On Ocean Pollution

- Coastal zone often overwhelmed by contamination from heavy metals, toxic chemicals, oil, pathogens, sediment. These zones would otherwise be among most productive.
 - ❖ Discarded plastics are non-biodegradable, last for years, and are carried by currents around the world.
 - Often ensnare bird and mammals, choking them

Ocean Pollution

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Courtesy of Joe Lucas/Marine Entanglement Research Program/National Marine Fisheries Service NOAA

Oil Pollution

- Few coastlines in the world remain uncontaminated by oil pollution.
 - ❖ 3 to 6 million tons of oil are released into ocean each year, about half of which is due to marine transport.
 - ❖ Major oil spills from transport, military conflict, oil drilling in risky locations such as the North Sea
 - ❖ There are plans to drill in seismically active California and Alaskan coasts.

Source Reduction Can Reduce Water Pollution

- Cheapest and most effective way to reduce pollution is avoid producing it or releasing it into the environment.
 - Studies show as much as 90% less road salt can be used without significantly affecting safety.
 - Carefully dispose of oil
 - Recover metals from industrial waste and sell them

Land Management Controls Nonpoint Sources

- Some main causes of nonpoint pollution:
 - ❖ Agriculture
 - ❖ Urban runoff
 - ❖ Construction sites
 - ❖ Land disposal
- Generally, soil conservation methods also help protect water quality.
- In urban areas, reducing materials carried away by storm runoff is helpful.

Signs Can Remind People Where Wastes Go

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Human Waste Disposal

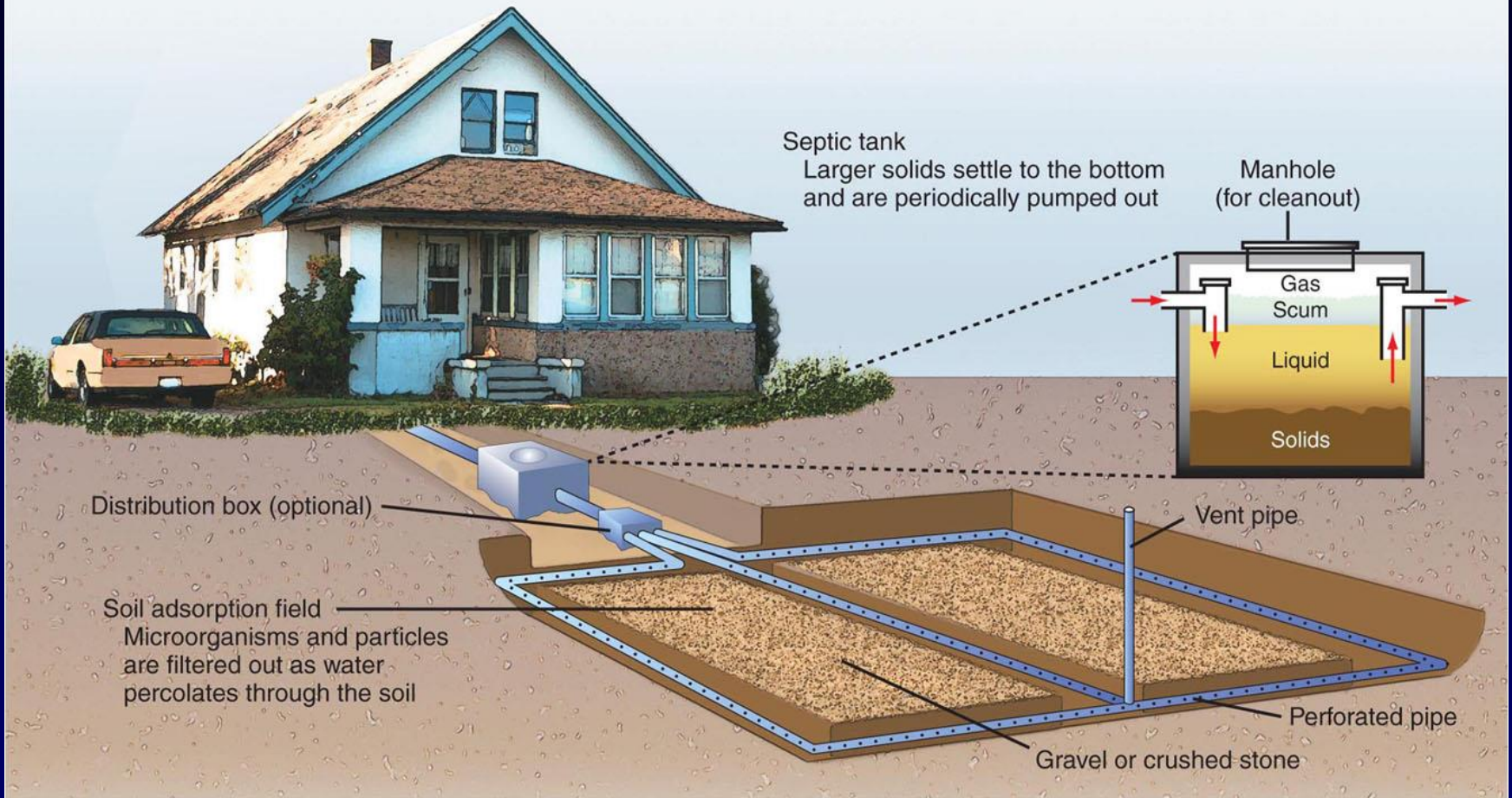
- More than 500 pathogenic bacteria, viruses, and parasites can travel from human or animal excrement through water.
- **Natural Processes**
 - ❖ In many areas, outdoor urination and defecation is the norm.
 - When population densities are low, natural processes can quickly eliminate waste, but in cities this is unworkable.
 - A significant proportion of dust in Mexico City is actually dried feces.

Human Waste Disposal

- In many countries, especially in Asia, “night soil” (human and animal waste) is spread on fields as fertilizer, but it can cause disease.
- Until about 70 years ago, most rural areas in the U.S. depended on outhouses, which contaminated drinking water supplies.
- Development of septic fields which clean water by aeration and remove excess nutrients through bacterial action. Solids are pumped out and taken to a treatment plant.

Septic Tank

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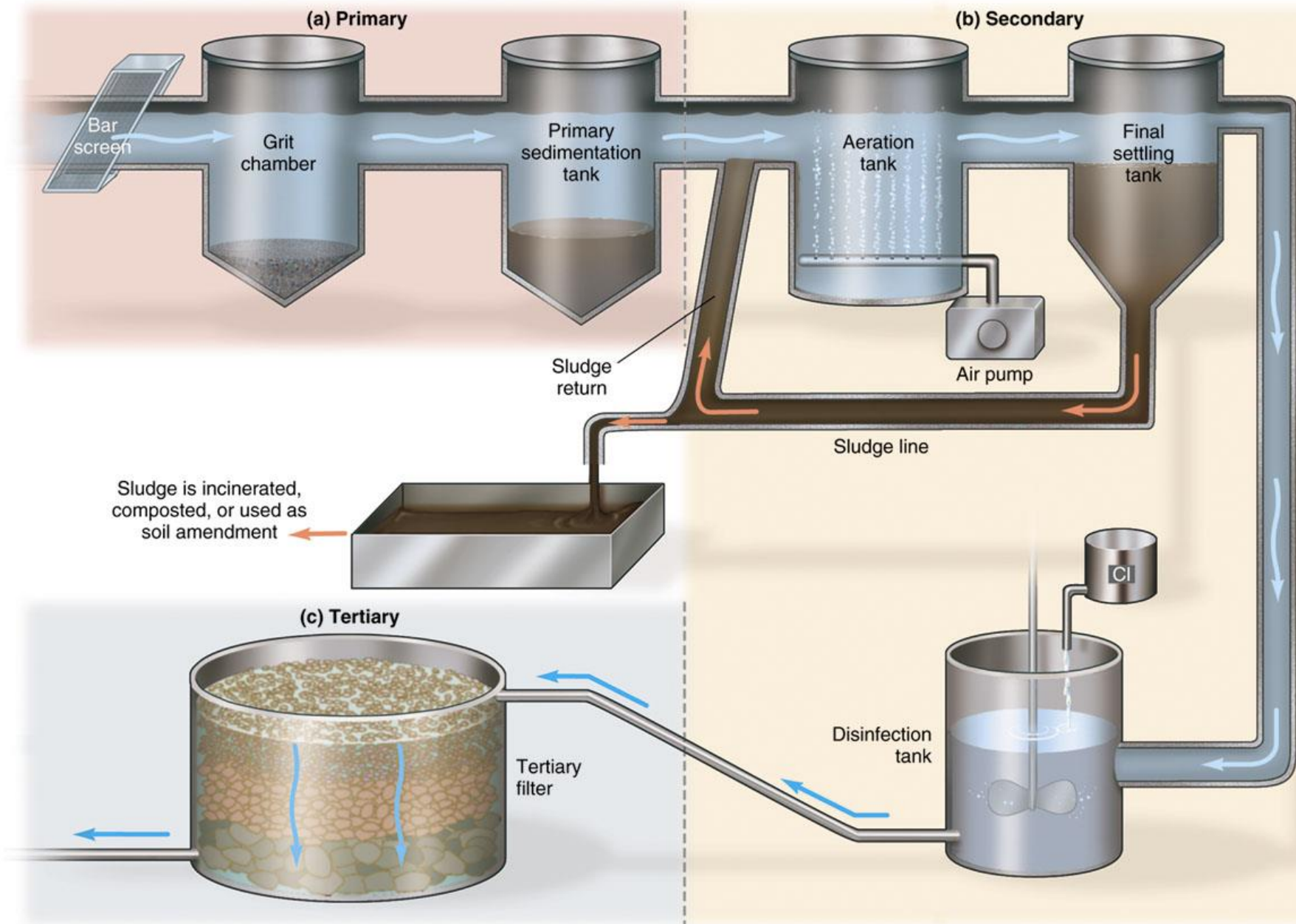


Municipal Sewage Treatment

- **Primary Treatment** - physical separation of large solids from the waste stream
- **Secondary Treatment** - biological degradation of dissolved organic compounds
 - ❖ Effluent from primary treatment transferred into trickling bed, or aeration tank
 - Effluent from secondary treatment is usually disinfected (chlorinated) before release into nearby waterway.

Municipal Sewage Treatment

- **Tertiary Treatment** - removal of plant nutrients (nitrates and phosphates) from secondary effluent
 - ❖ Chemicals which bind or natural wetlands
- In many U.S. cities, sanitary sewers are connected to storm sewers.
 - ❖ Heavy storms can overload the system, causing by-pass dumping of raw sewage and toxic runoff directly into watercourses.



Low-Cost Waste Treatment

- Effluent Sewerage

- ❖ Hybrid between traditional septic tank and full sewer system
 - Pump liquid tank contents to central treatment plant rather than use drainfield

- Wetlands

- ❖ Effluent flows through wetlands where it is filtered and cleaned by aquatic plants and microscopic organisms.

Water Remediation

- Containment methods confine liquid wastes in place, or cap surface with impermeable layer to divert water away from a site that is causing pollution.
- Extraction techniques are used to pump out polluted water for treatment.
 - ❖ Oxidation, reduction, neutralization, or precipitation of contaminants
- Living organisms can also be used to break down pollution (called bioremediation).

Ecological Engineering

- Ocean Arks International designs vessels that combine living organisms with containment. In a machine, water flows through a series of containers, each with a distinctive biological community. Waste from one vessel becomes the food for the next vessel.
- Final effluent is technically drinkable, but more often used for irrigation or flushing toilets.

Water Legislation

- U.S. Clean Water Act (1972)
 - ❖ Goal was to return all U.S. surface waters to “fishable and swimmable” conditions
 - For point sources, discharge permits and **best practicable control technology (BPT)** are required.
 - Set goals of **best available, economically achievable technology (BAT)** for zero discharge of 126 priority toxic pollutants

Clean Water Act (1972)

- Areas of Contention

- ❖ Draining or filling of wetlands is regulated
 - Farmers and developers consider this the taking of private lands
- ❖ Unfunded Mandates
 - State or local governments must spend monies to comply with regulations but are not repaid by Congress.
- ❖ Agricultural runoff is largest source of surface water degradation, but regulation remains a problem.

Other Important Water Legislation

- Safe Drinking Water Act regulates water quality in municipal and commercial systems
- **CERCLA** (1980) created Superfund program to clean up toxic waste sites
 - ❖ Amended in 1984 by SARA, which provides immediate response in emergency situations and permanent remedies for abandoned sites

Clean Water Legislation

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Table 18.2 Some Important U.S. and International Water Quality Legislation

1. *Federal Water Pollution Control Act* (1972). Established uniform nationwide controls for each category of major polluting industries.
2. *Marine Protection Research and Sanctuaries Act* (1972). Regulates ocean dumping and established sanctuaries for protection of endangered marine species.
3. *Ports and Waterways Safety Act* (1972). Regulates oil transport and the operation of oil handling facilities.
4. *Safe Drinking Water Act* (1974). Requires minimum safety standards for every community water supply. Among the contaminants regulated are bacteria, nitrates, arsenic, barium, cadmium, chromium, fluoride, lead, mercury, silver, pesticides; radioactivity and turbidity also are regulated. This act also contains provisions to protect groundwater aquifers.
5. *Resource Conservation and Recovery Act* (RCRA) (1976). Regulates the storage, shipping, processing, and disposal of hazardous wastes and sets limits on the sewerage of toxic chemicals.
6. *Toxic Substances Control Act* (TOSCA) (1976). Categorizes toxic and hazardous substances, establishes a research program, and regulates the use and disposal of poisonous chemicals.
7. *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) (1980) and *Superfund Amendments and Reauthorization Act* (SARA) (1984). Provide for sealing, excavation, or remediation of toxic and hazardous waste dumps.
8. *Clean Water Act* (1985) (amending the 1972 Water Pollution Control Act). Sets as a national goal the attainment of “fishable and swimmable” quality for all surface waters in the United States.
9. *London Dumping Convention* (1990). Calls for an end to all ocean dumping of industrial wastes, tank washing effluents, and plastic trash. The United States is a signatory to this international convention.