

Water Quality Notes

General Types of Water Pollution

Chapter Overview Questions

- What pollutes water, where do these pollutants come from, and what effects do they have?
- What are the major water pollution problems in streams and lakes?
- What causes groundwater pollution, and how can it be prevented?
- What are the major water pollution problems affecting oceans?

Chapter Overview Questions (cont'd)

- How can we prevent and reduce surface water pollution?
- How safe is drinking water, and how can it be made safer?

Core Case Study: Using Nature to Purify Sewage



- Ecological wastewater purification by a *living machine*.
 - Uses the sun and a series of tanks containing plants, snails, zooplankton, crayfish, and fish (that can be eaten or sold for bait).

Figure 21-1

Sediment Pollution

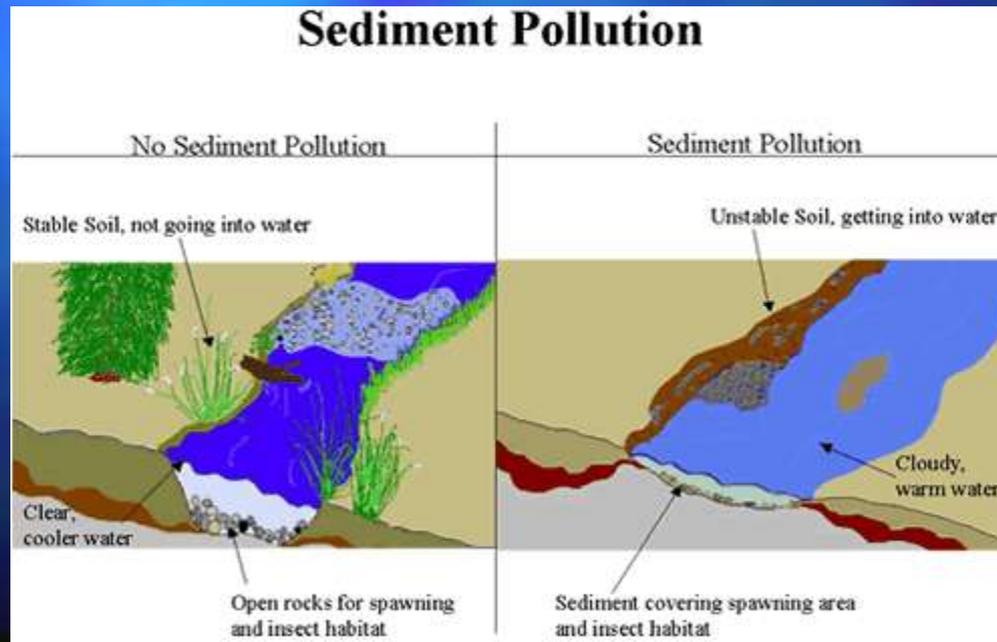
Definition

- Excessive amounts of suspended soil particles that eventually settle out and accumulate on the bottom of a body of water.



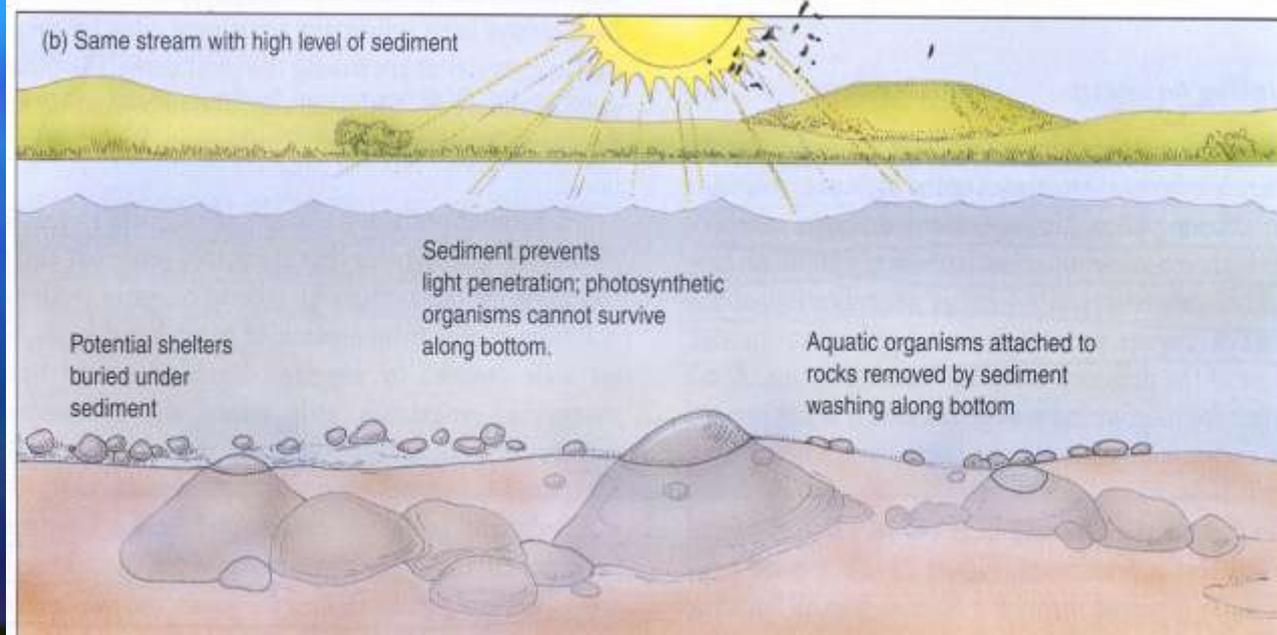
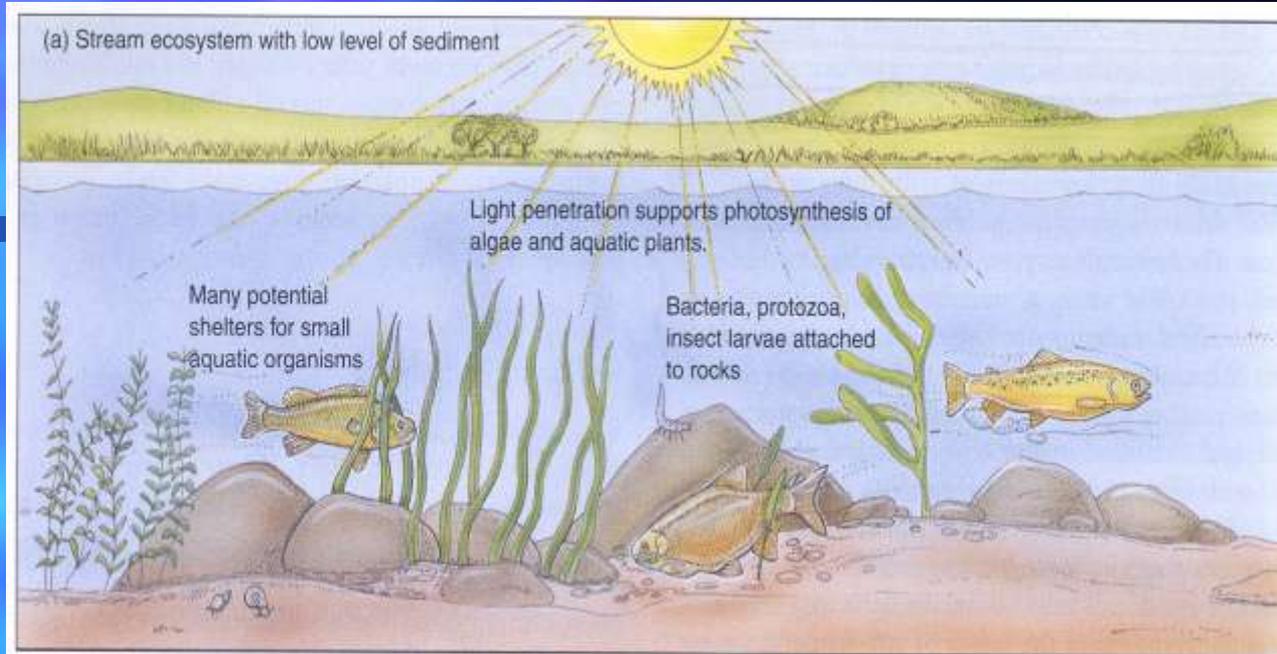
Causes

- Erosion of agricultural lands, forest soils exposed by logging, degraded stream banks, overgrazed rangelands, strip mines, and construction.



Environmental Effects

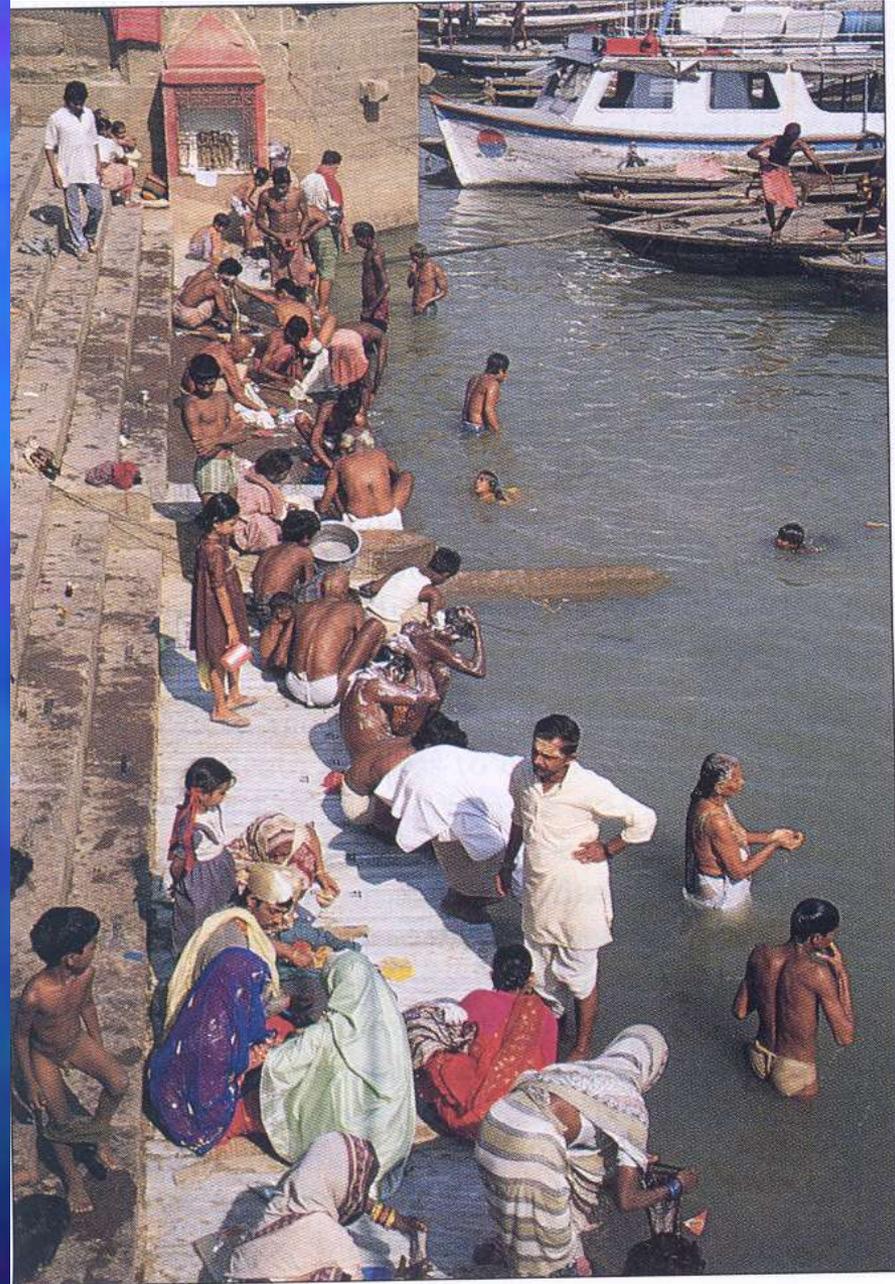
- Reduces light penetration, covering aquatic organisms, bringing insoluble toxic pollutants into the water, and filling in waterways.



Health Effects

- Sediments adversely affect water quality by carrying toxic chemicals.
 - The sediment particles provide surface area to which some insoluble, toxic compounds adhere; when the sediments enter the water, so do toxic chemicals.
- Disease-causing agents can also be transported into water via sediments.

Sewage



Causes

- Release of waste water from drains or sewers (toilets, washing machines, and showers) and include human wastes, soaps and detergents.

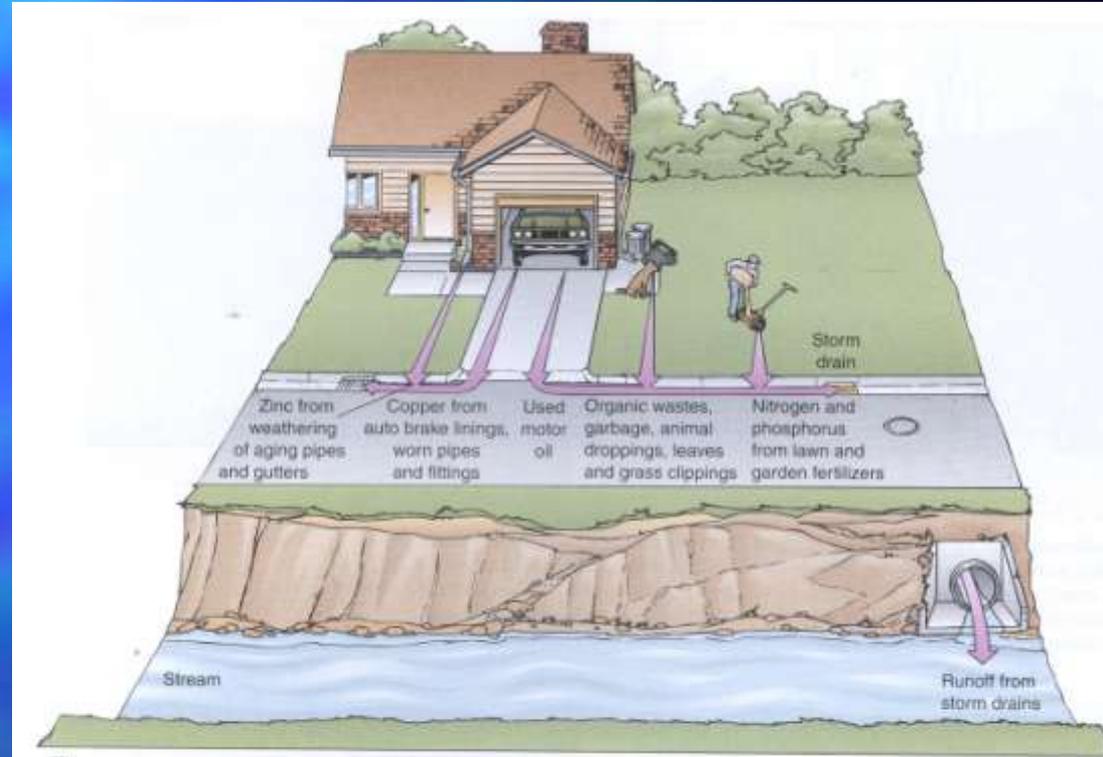


Figure 21-8

Urban runoff. The largest single pollutant in urban runoff is organic waste, which removes dissolved oxygen from water as it decays. Fertilizers cause excessive algal growth, which further depletes the water of oxygen, harming aquatic organisms. Other everyday pollutants include used motor oil, which is often poured into storm drains, and heavy metals. These pollutants may be carried from storm drains on streets to streams and rivers.

Environmental Effects

- Enrichment – the fertilization of a body of water, caused by the presence of high levels of plants and algal nutrients like nitrogen and phosphorus

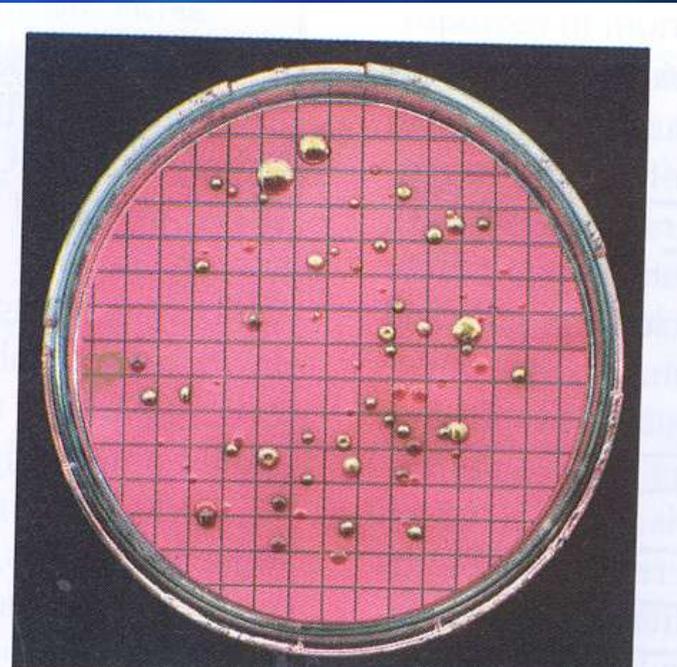
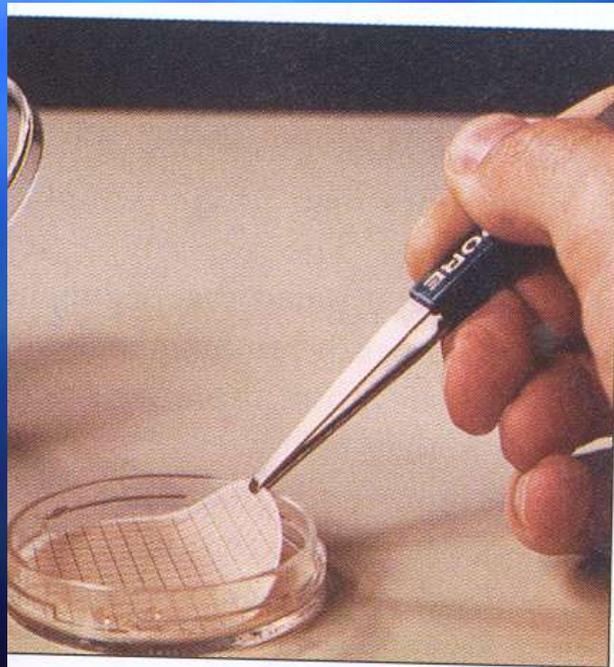
Health Effects

- Oxygen – dissolved oxygen is needed by organisms, like fish, but when sewage enters an aquatic ecosystem, the micro-organisms bloom, leaving less oxygen for the fish, etc., and then they die
- Sewage carries disease-causing agents.

Disease-Causing Agents

Definition

- Infectious organisms that cause disease.



Causes

- Comes from the wastes of infected individuals.

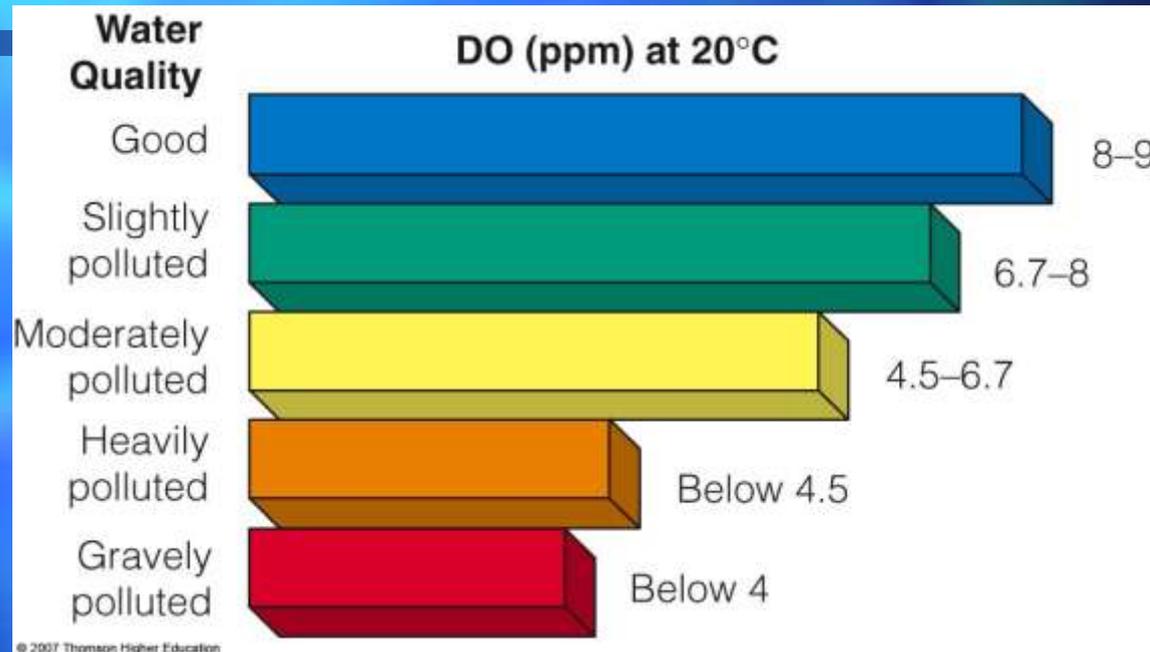
Environmental Effects

- Municipal wastewater contains bacteria, viruses, protozoa, parasitic worms, and other infectious agents that cause human or animal diseases.

Health Effects

- Typhoid, cholera, bacterial dysentery, polio and infectious hepatitis are some of the more common bacteria or viruses that are transmitted through contaminated food and water.

Major Water Pollutants and Their Effects



- Water quality and dissolved oxygen (DO) content in parts per million (ppm) at 20°C.
 - Only a few fish species can survive in water less than 4ppm at 20°C.

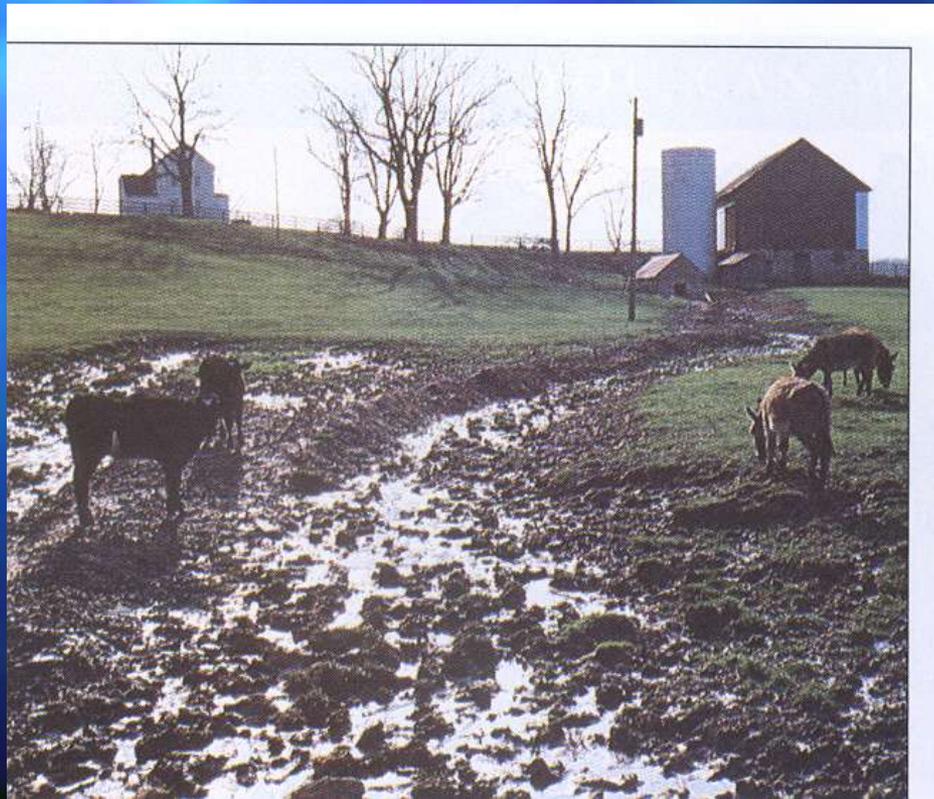
Inorganic Plant and Algal Nutrients

- Chemicals such as nitrogen and phosphorus that stimulate the growth of plants and algae. Read "The Dead Zone" Raven, page 517.



Causes

- Nitrates and phosphates come from sources such as human and animal wastes, plant residues, atmospheric deposition and residential land.



Environmental Effects

- Inorganic plant and algal nutrients encourage excessive growth of algal and aquatic plants. This causes problems, including enrichment and bad odor.



Organic Compounds

Causes

- Chemicals that contain carbon atoms. Most of the thousands of organic compounds found in water are synthetic chemicals that are produced by human activities; these included pesticides, solvents, industrial chemicals and plastics, and seepage from landfills.

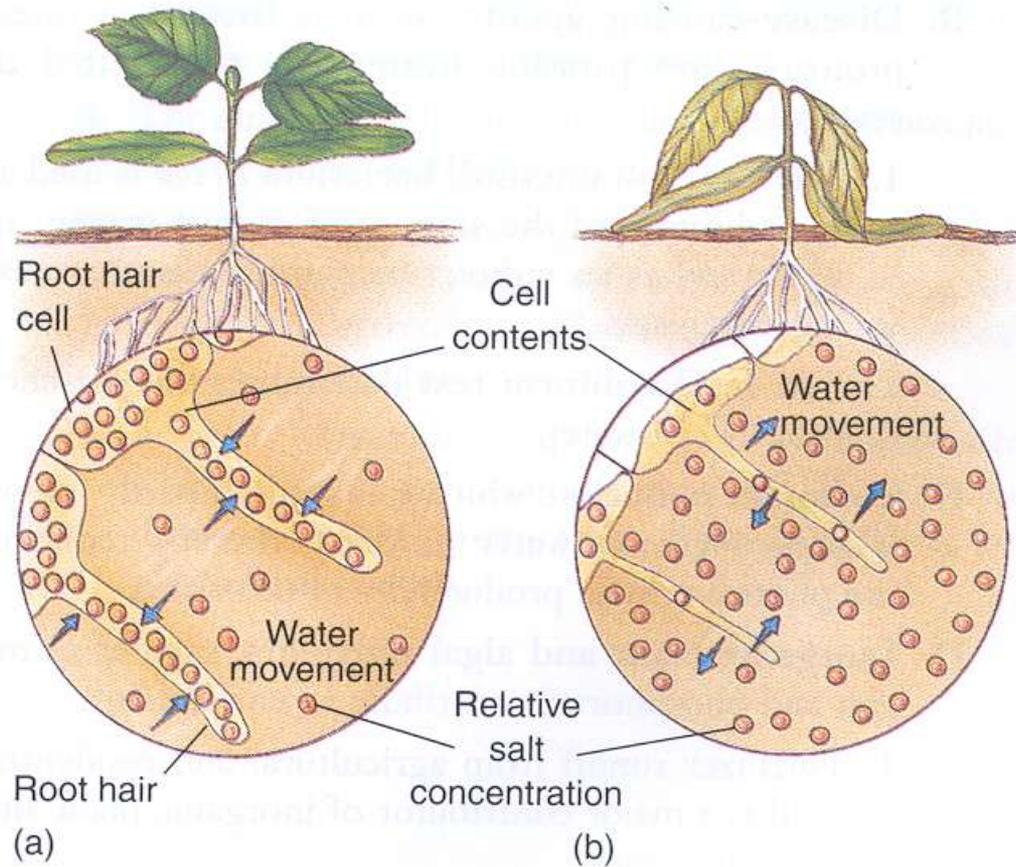
Health Effects

- Hundreds of synthetic organic compounds are toxic and some of these have been shown to cause cancer or birth defects.

Environmental Effects

- Pollutes streams and groundwater.

Inorganic Compounds



Causes

- Chemicals are contaminants that contain elements other than carbon. Examples include acids, salts, and heavy metals. Many inorganic chemicals find their way into both surface water and groundwater from sources such as industries, mines, irrigation runoff, oil drilling and urban runoff from storm sewers.

Environmental Effects

- Some of these inorganic pollutants are toxic to aquatic organisms.

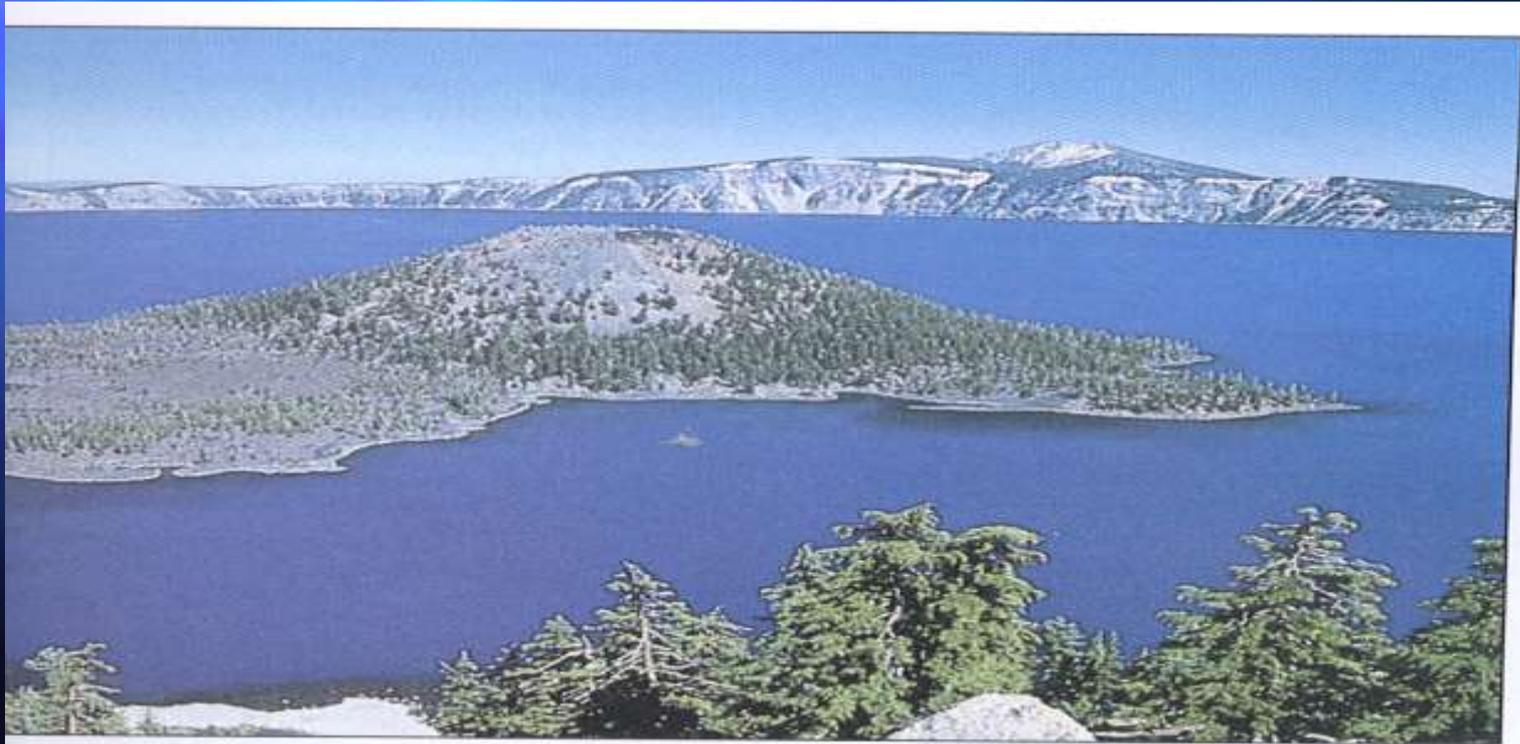


Health Effects

- Lead and mercury are poisonous. Mercury exposure to developing fetuses in pregnant women has been linked to a variety of conditions such as mental retardations, cerebral palsy, and developing delays, causes kidney disorders and several damage the nervous and cardiovascular systems.
- Low levels of mercury in the brain cause neurological problems such as headache, depression, and quarrelsome behavior.

Radioactive Substances

- Contains atoms of unstable isotopes that spontaneously emit radiation



Causes

- Radioactive substances get into water from several sources like the mining and processing of radioactive minerals such as uranium and thorium.
- The nuclear weapons industry use the largest amounts.
- Medical and scientific research facilities also use them.

Health Effects

- Mutations, birth defects, mental retardation, genetic disease, leukemia, cancer (breast, bone, thyroid, skin, lung), burns, cataracts, male sterility.

Environmental Effects

- Pollutes air, water and soil.

Thermal Pollution

Causes

- When heated water produced during certain industrial processes is released into waterways.

Environmental Effects

- Decomposition of wastes occurs faster, depleting the water of oxygen; this affects aquatic life.

Health Effects

- Typically affects animals, not humans.

WATER POLLUTION: SOURCES, TYPES, AND EFFECTS

- ***Water pollution*** is any chemical, biological, or physical change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired uses.
 - ***Point source***: specific location (drain pipes, ditches, sewer lines).
 - ***Nonpoint source***: cannot be traced to a single site of discharge (atmospheric deposition, agricultural / industrial / residential runoff)

Point Source Pollution

- Water pollution that can be traced to a specific spot (such as a factory or sewage treatment plant) because it is discharged into the environment through pipes, sewers or ditches.

Non-Point Source Pollution

- Pollutants that enter bodies of water over large areas rather than being concentrated at a single point of entry. Ex. Agricultural fertilizer runoff and sediments from construction.

Table 21-2 Common Diseases Transmitted to Humans through Contaminated Drinking Water

Type of Organism	Disease	Effects
Bacteria	Typhoid fever	Diarrhea, severe vomiting, enlarged spleen, inflamed intestine; often fatal if untreated
	Cholera	Diarrhea, severe vomiting, dehydration; often fatal if untreated
	Bacterial dysentery	Diarrhea; rarely fatal except in infants without proper treatment
	Enteritis	Severe stomach pain, nausea, vomiting; rarely fatal
Viruses	Infectious hepatitis (Type B)	Fever, severe headache, loss of appetite, abdominal pain, jaundice, enlarged liver; rarely fatal but may cause permanent liver damage
Parasitic protozoa	Amoebic dysentery	Severe diarrhea, headache, abdominal pain, chills, fever; if not treated can cause liver abscess, bowel perforation, and death
	Giardiasis	Diarrhea, abdominal cramps, flatulence, belching, fatigue
	Cryptosporidium	Severe diarrhea and possible death for people with weakened immune systems
Parasitic worms	Schistosomiasis	Abdominal pain, skin rash, anemia, chronic fatigue, and chronic general ill health

Sources of Pollution

Agriculture

- Fertilizers, animal wastes, etc.

Municipal Waste

- Sewage, fertilizers, dumping into drainage ditches, etc.

Industrial Waste

- Chemicals left over from manufacturing, waste products, etc.

Cultural Eutrophication

- ***Eutrophication***: the natural nutrient enrichment of a shallow lake, estuary or slow moving stream, mostly from runoff of plant nutrients from the surrounding land.
- ***Cultural eutrophication***: human activities accelerate the input of plant nutrients (mostly nitrate- and phosphate-containing effluents) to a lake.
 - 85% of large lakes near major population centers in the U.S. have some degree of cultural eutrophication.

Eutrophication

Definition

- The enrichment of a lake or pond by inorganic plant and algal nutrients such as phosphorus.

Relation to Pollution

- Because this gets into our water supply from runoff, etc., and is something that is not normally in the water, it is considered pollution.

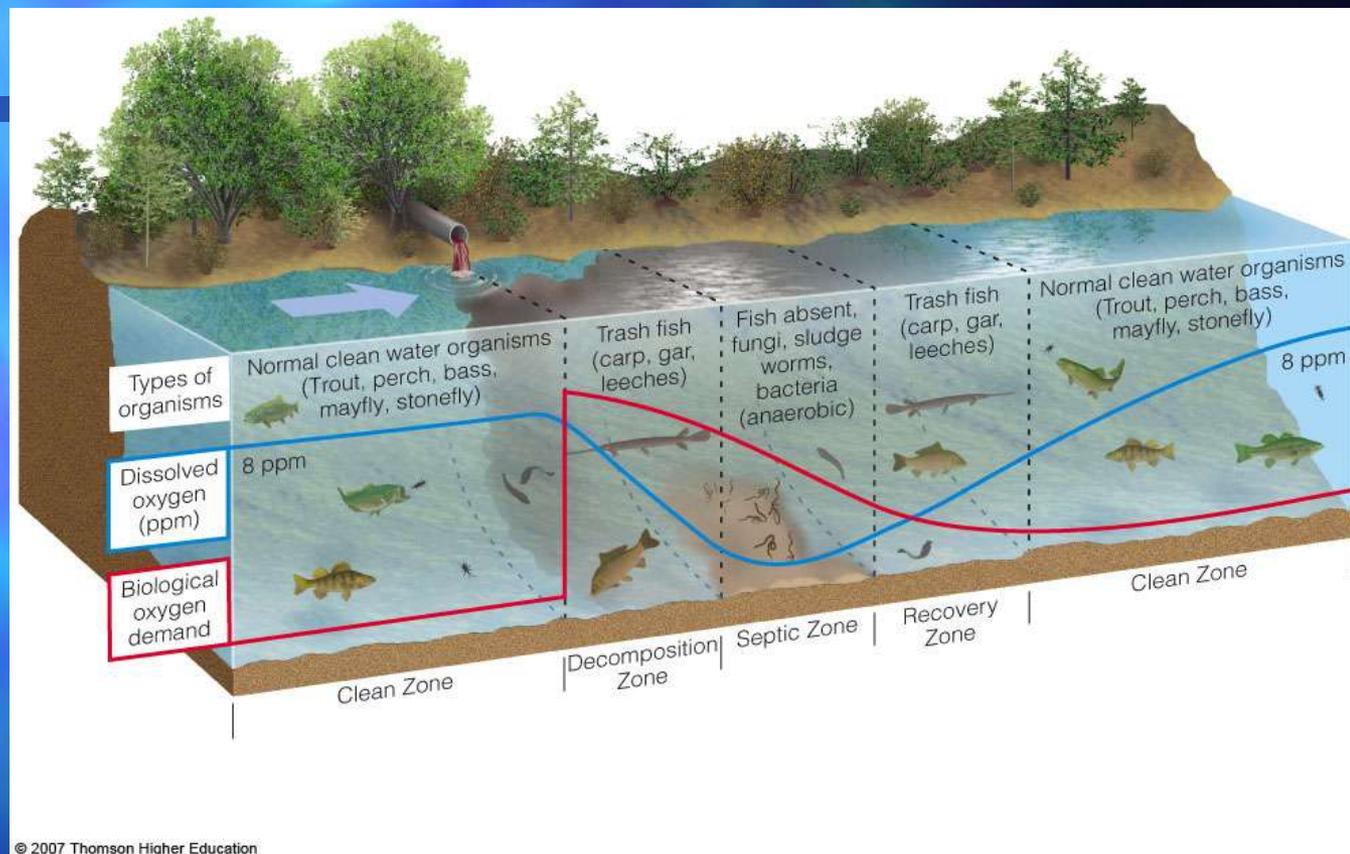
Cause/Effect

- Fertilizers, erosion, sewage, etc. get into water and the effect is high photosynthetic productivity.
- Thus, the water is cloudy and usually resembles pea soup because of the algae and cyanobacteria that are supported by the nutrients.

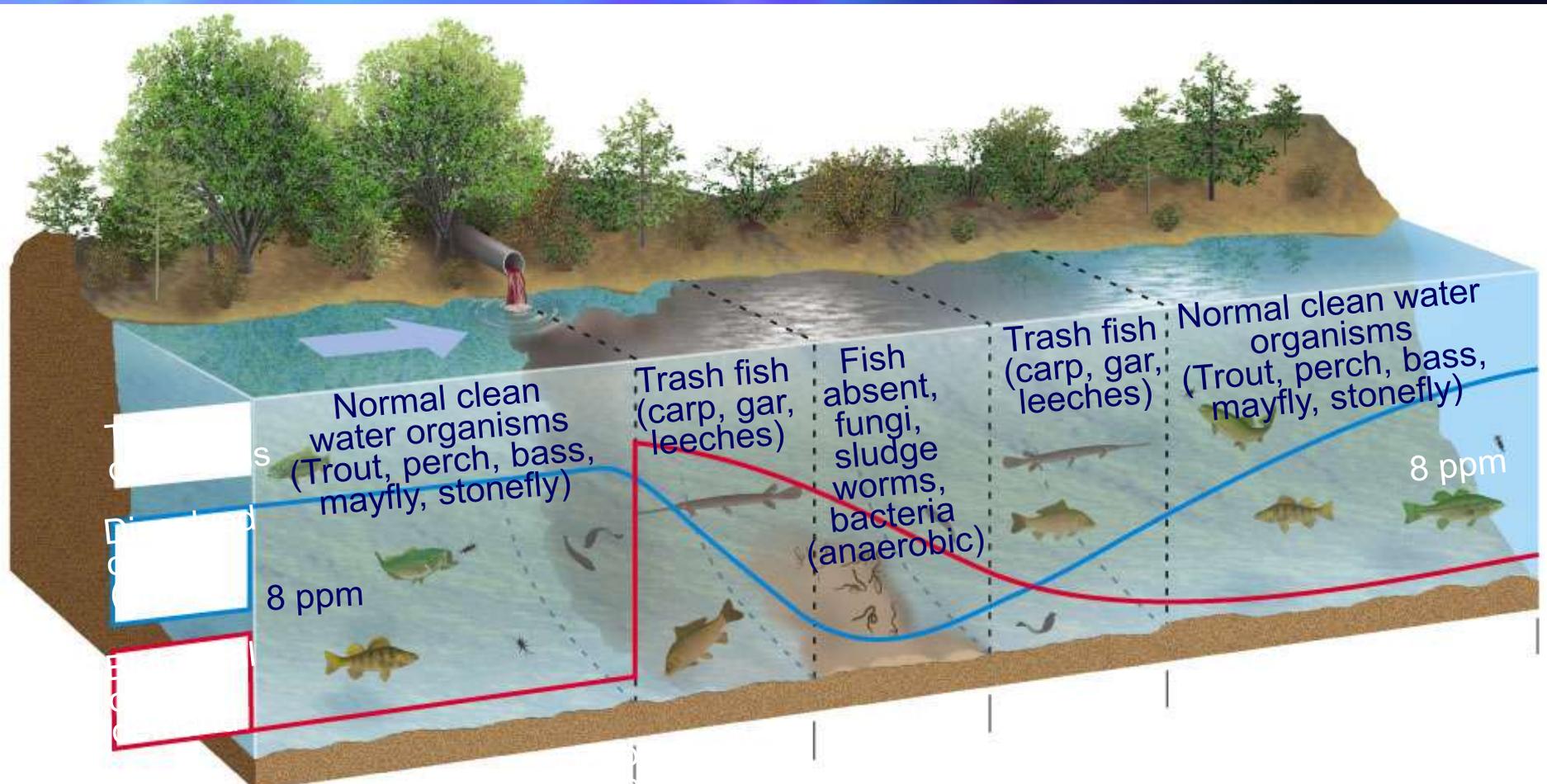
POLLUTION OF FRESHWATER STREAMS

- Flowing streams can recover from a moderate level of degradable water pollutants if they are not overloaded and their flows are not reduced.
 - In a flowing stream, the breakdown of degradable wastes by bacteria depletes DO and creates an *oxygen sag curve*.
 - This reduces or eliminates populations of organisms with high oxygen requirements.

Water Pollution Problems in Streams



- Dilution and decay of degradable, oxygen-demanding wastes and heat in a stream.



Normal clean water organisms (Trout, perch, bass, mayfly, stonefly)

Trash fish (carp, gar, leeches)

Fish absent, fungi, sludge worms, bacteria (anaerobic)

Trash fish (carp, gar, leeches)

Normal clean water organisms (Trout, perch, bass, mayfly, stonefly)

8 ppm

8 ppm

Blue=oxyggen sag
Red=oxyggen demand

POLLUTION OF FRESHWATER STREAMS

- Most developed countries have sharply reduced point-source pollution but toxic chemicals and pollution from nonpoint sources are still a problem.
- Stream pollution from discharges of untreated sewage and industrial wastes is a major problem in developing countries.

Global Outlook: Stream Pollution in Developing Countries



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- Water in many of central China's rivers are greenish black from uncontrolled pollution by thousands of factories.

Case Study: India's Ganges River: Religion, Poverty, and Health

- Religious beliefs, cultural traditions, poverty, and a large population interact to cause severe pollution of the Ganges River in India.
 - Very little of the sewage is treated.
 - Hindu believe in cremating the dead to free the soul and throwing the ashes in the holy Ganges.
 - Some are too poor to afford the wood to fully cremate.
 - Decomposing bodies promote disease and depletes DO.

Case Study: India's Ganges River: Religion, Poverty, and Health



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- Daily, more than 1 million Hindus in India bathe, drink from, or carry out religious ceremonies in the highly polluted Ganges River.

POLLUTION OF FRESHWATER LAKES

- Dilution of pollutants in lakes is less effective than in most streams because most lake water is not mixed well and has little flow.
 - Lakes and reservoirs are often stratified and undergo little mixing.
 - Low flow makes them susceptible to runoff.
- Various human activities can overload lakes with plant nutrients, which decrease DO and kill some aquatic species.

Coral Reefs

Characteristics

- Built from layers of calcium carbonate, coral reefs are found in warm, shallow sea water. The living portions must grow in shallow waters where light hits. They are the most diverse of all marine ecosystems.



About Coral Reefs

Examples

- Many coral reefs are made of red coralline algae that photosynthesize.
- Others have zooxanthellae (symbiotic algae) that live and photosynthesize in their tissues.
- Not all corals have zooxanthellae, those with it build reefs.
- Coral animals also capture food at night with stinging tentacles that paralyze zooplankton and small animals that drift nearby.

Coral Reef Waters

- The waters where coral reefs are found are often poor in nutrients. Yet, other factors are favorable such as temperature, sunlight year round, and zooxanthellae.

Growth

- Coral reefs grow slowly; as one dies, another organism grows on it.

Ecological Importance of Coral Reefs

Provides a Habitat

- Provides a habitat for a wide variety of marine organisms.

Coastline Protection

- Protects coasts from shoreline erosion.

Benefits for Humans

- Provides humans with seafood, pharmaceuticals, and recreational/tourism dollars

Coral Reef Risks

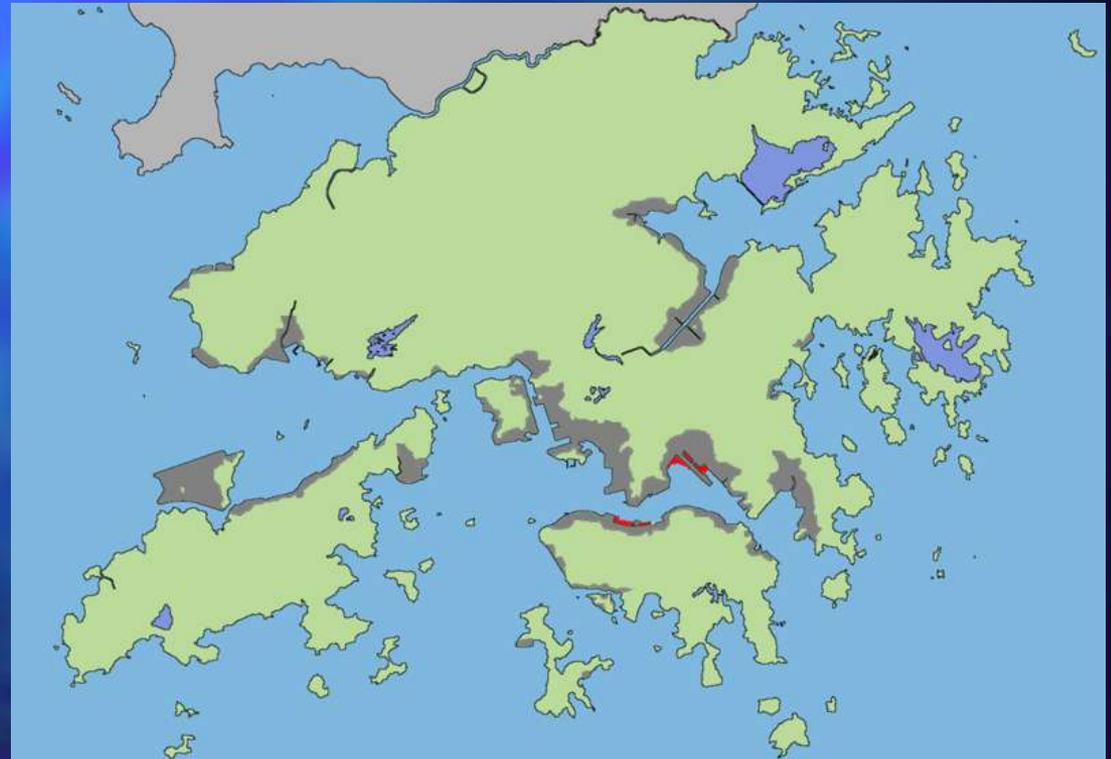
- Of the 109 countries with large reefs, 90 are damaging them, and 27% of the coral reefs are at high risk, especially off the coast of Southeastern Asia.
- In the western Atlantic, 30-50% of all coral species are either rare or endangered.

Coral Reef Risks Con't

- Silt washing from downstream has smothered the reefs
- High salinity from fresh water diversion, over-fishing, boat groundings, fishing with dynamite or cyanide, hurricane damage, disease, coral bleaching, land reclamation, tourism, and the mining of coral for building materials.

Land Reclamation

- <http://coralreef.nus.edu.sg/>



This bottle still shows a slightly burned fuse from its use to blow up the coral.



Differences of Opinion

- Oceans dilute, disperse, and degrade large amounts of raw sewage, sewage sludge, oil, and some types of industrial waste, especially in deep-water areas.
- Marine life has proved to be more resilient than some scientists expected, some suggest it is safer to dump sludge & other hazardous wastes into the deep ocean than to bury them on land or burn them.

Differences of Opinion

Other scientists disagree, pointing out that we know less about the deep ocean than we do about space. They say that dumping waste in the ocean would delay urgently needed pollution prevention and promote further degradation of this vital part of the earth's life-support system.

Oil Spills

- When a tanker accident happens, it gets lots of publicity.
- But, more oil is released by normal operation of offshore wells, washing tankers & from pipeline or storage tank leaks.
- One estimate says that oil companies spill, leak, or waste per year an amount of oil equal to that shipped by 1000 huge Exxon Valdez tankers.

Floating Oil

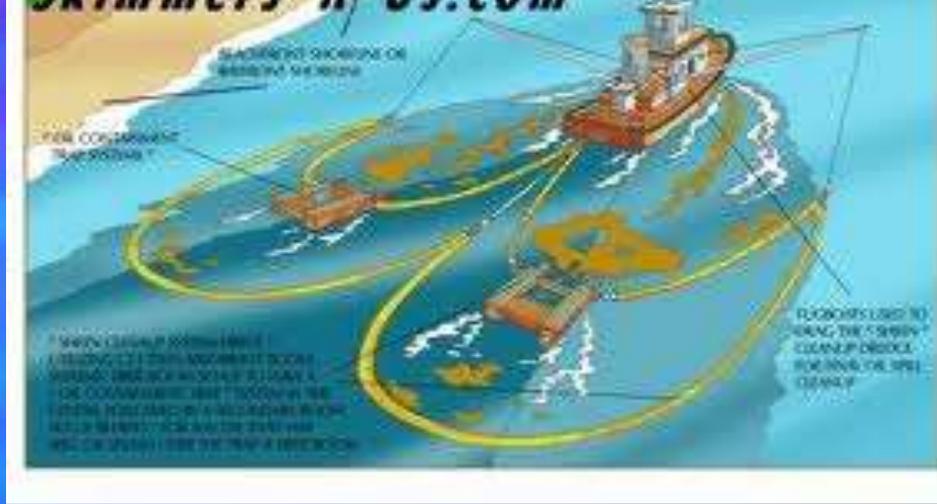
- Oil coats the feathers of birds (especially diving birds) and the fur of marine animals, destroying the animals' natural insulation and buoyancy
- Many drown or die of exposure from loss of body heat.



Other Information

- Oil is broken down by bacteria over time; slower in cold waters.
- Heavy oil components can smother bottom-dwelling organisms such as crabs, oysters, mussels, and clams, or make them unfit to eat.
- Oil spills have killed coral reefs. A recent study showed that diesel oil becomes more toxic to marine life with the passage of time.

Mechanical Methods

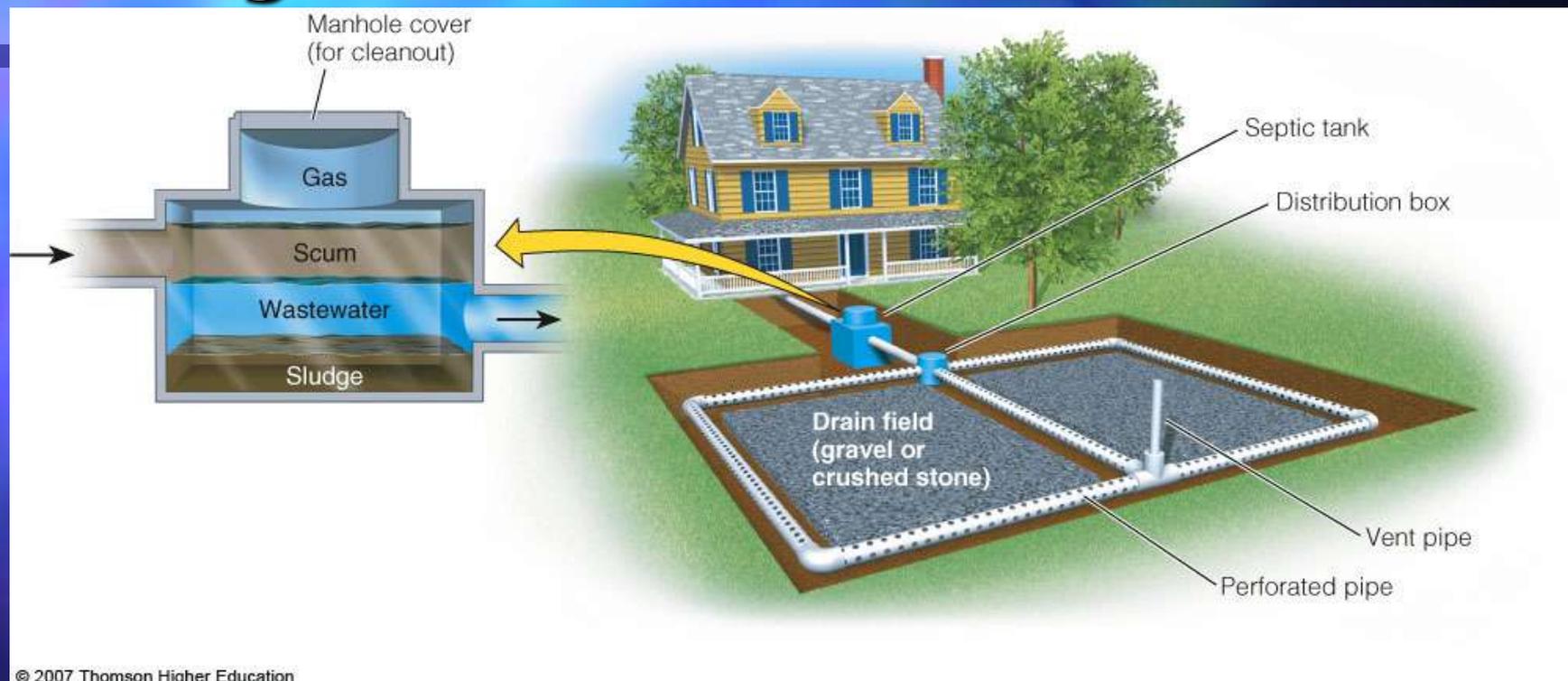


- Floating booms contain the oil spill or keep it from reaching sensitive areas
- Skimmer boats are used to vacuum up some of the oil into collection barges
- Absorbent pads or large feather-filled pillows are used to soak up oil on beaches or in waters that are too shallow for skimmer boats

Chemical Methods

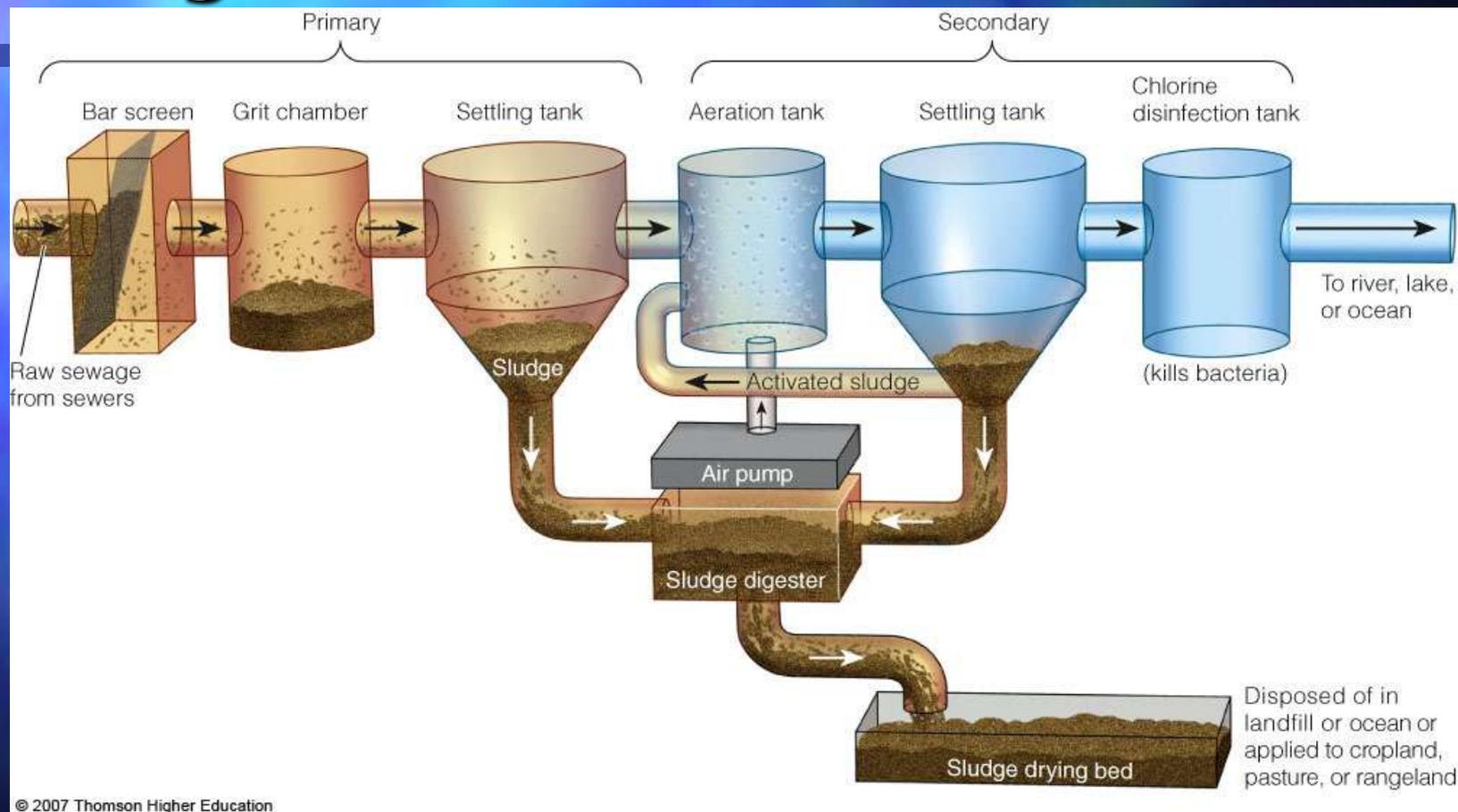
- Coagulating agents cause floating oil to clump together for easier pickup or sink to the bottom, where it usually does less harm.
- Dispersing agents break up oil slicks. However, these can also damage some types of organisms.
- Fire can also burn off floating oil, but crude oil is hard to ignite.

Reducing Water Pollution through Sewage Treatment



- Septic tanks and various levels of sewage treatment can reduce point-source water pollution.

Reducing Water Pollution through Sewage Treatment



- Primary and Secondary sewage treatment.

Reducing Water Pollution through Sewage Treatment

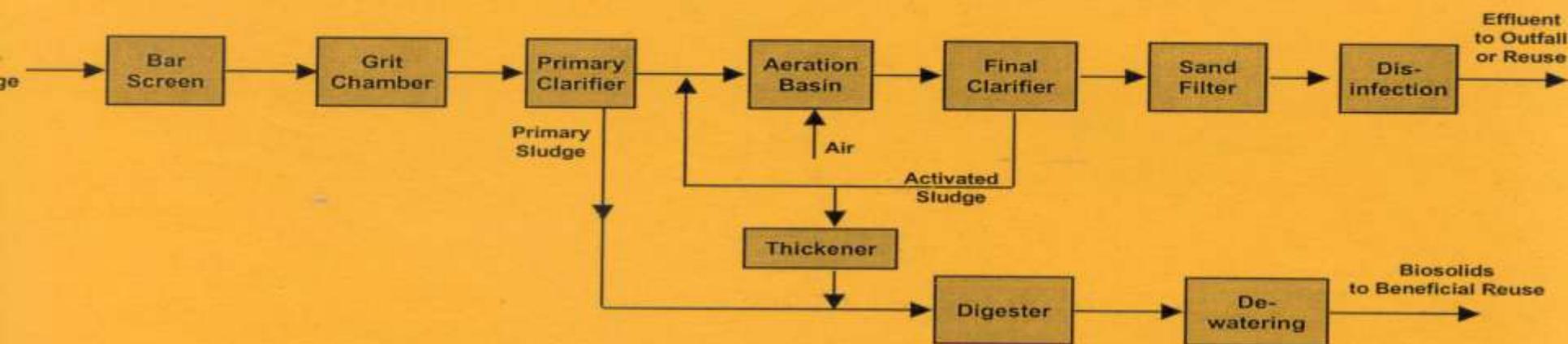
- Advanced or tertiary sewage treatment:
 - Uses series of chemical and physical processes to remove specific pollutants left (especially nitrates and phosphates).
- Water is chlorinated to remove coloration and to kill disease-carrying bacteria and some viruses (disinfect).

Reducing Water Pollution through Sewage Treatment

- Raw sewage reaching a municipal sewage treatment plant typically undergoes:
 - ***Primary sewage treatment***: a physical process that uses screens and a grit tank to remove large floating objects and allows settling.
 - ***Secondary sewage treatment***: a biological process in which aerobic bacteria remove as much as 90% of dissolved and biodegradable, oxygen demanding organic wastes.

Water Treatment

Water Recycling Process



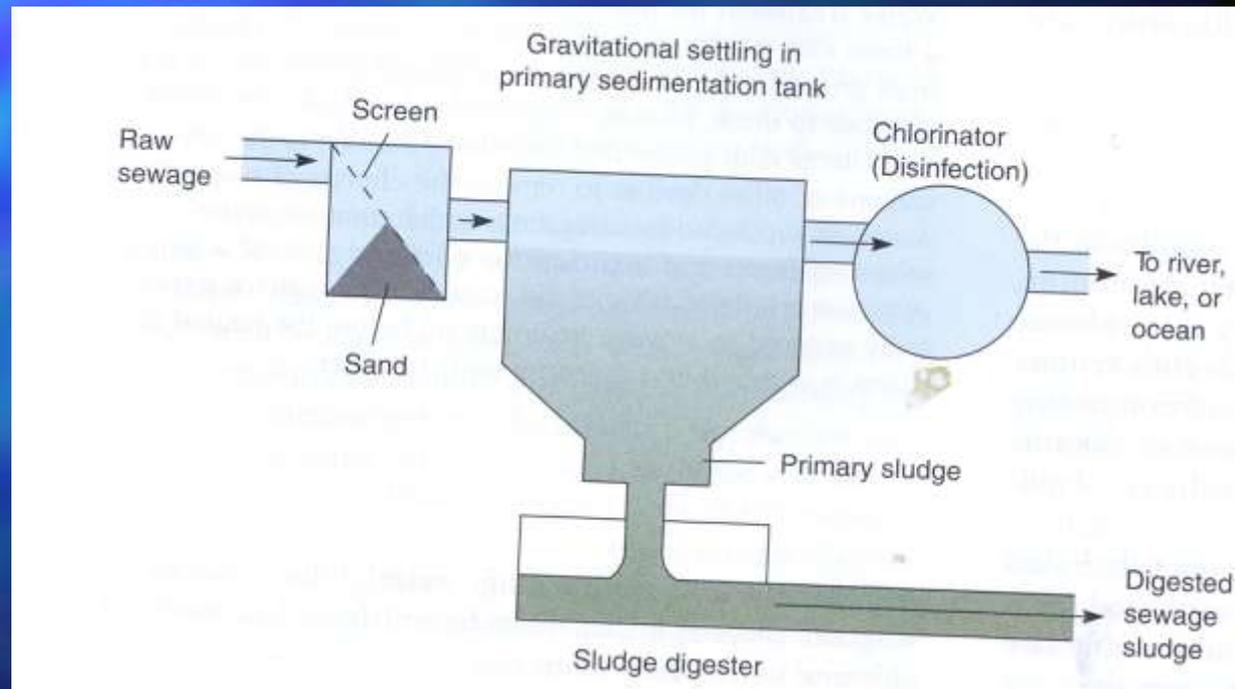
Includes:

- Physical systems***
- Biological systems***
- Chemical systems***

Primary

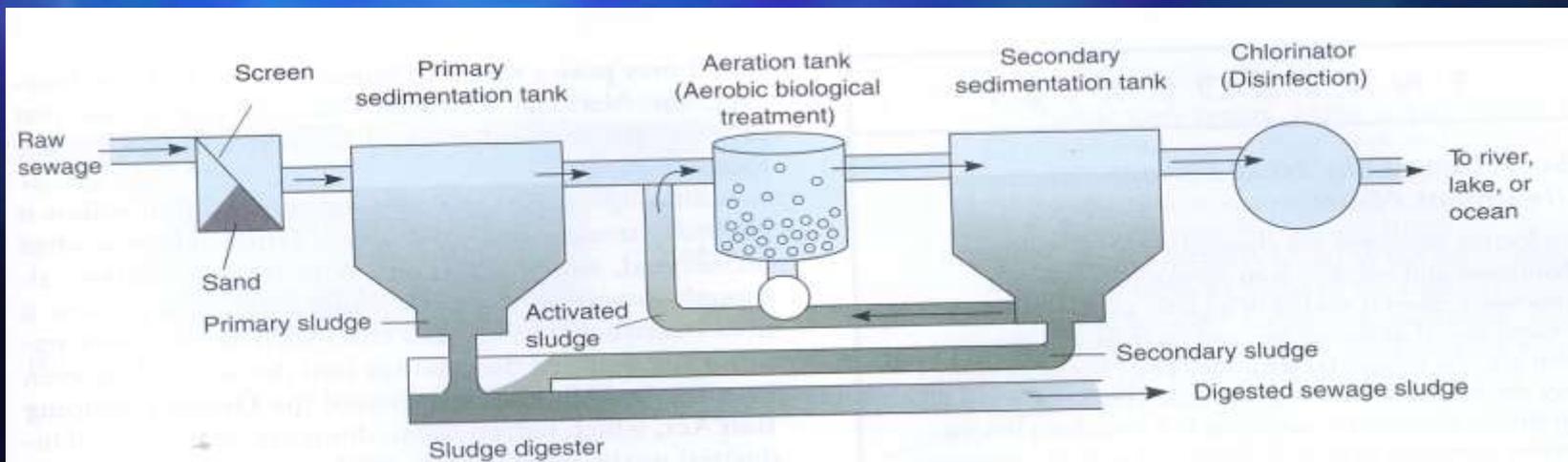
- Removes suspended and floating particles, such as sand and silt, by mechanical processes such as screening and gravitational settling. The solid material that is settled out is called primary sludge.

Bar screens, grit chambers, primary clarifiers, digesters and pre-aeration



Secondary

- Uses microorganisms to decompose the suspended organic material in wastewater. Ex. trickling filters – where wastewater trickles through aerated rock beds that contain bacteria and other microorganisms, which degrade the organic material in the water.



Secondary (Cont.)

- Or activated sludge process – wastewater is aerated and circulated through bacteria-rich particles; the bacteria degrade suspended organic material. After several hours, the particles and microorganisms are allowed to settle out, forming secondary sludge.
- Use aeration basins, settling tanks and sand filters

Tertiary

- This includes a variety of biological, chemical and physical processes used to remove phosphorus and nitrogen, the nutrients most commonly associated with enrichment. Tertiary treatment can also be used to purify wastewater so that it can be reused in communities where water is scarce.
- Use chlorine as a disinfection and then chlorine is removed by SO_2 so it can be released into river.

Reducing Water Pollution through Sewage Treatment

- Sewage sludge can be used as a soil conditioner but this can cause health problems if it contains infectious bacteria and toxic chemicals.
- Preventing toxic chemicals from reaching sewage treatment plants would eliminate such chemicals from the sludge and water discharged from such plants.

Reducing Water Pollution through Sewage Treatment

- Natural and artificial wetlands and other ecological systems can be used to treat sewage.
 - California created a 65 hectare wetland near Humboldt Bay that acts as a natural wastewater treatment plant for the town of 16,000 people.
 - The project cost less than half of the estimated price of a conventional treatment plant.

Water Quality

United States

- Groundwater contamination still occurs, especially due to non-point source pollution, but laws like the Safe Drinking Water Act, Clean Water Act, and Water Quality Act have helped in the U.S.

Global Problems

- According to the World Health Organization, an estimated 1.4 billion people still do not have access to adequate sanitation systems. Worldwide, at least 250 million cases of water-related illnesses occur each year, with 5 million or more of these resulting in death.

Specific Water Quality Measures

Dissolved Oxygen

- The amount of oxygen gas dissolved in a given volume of water at a particular temperature and pressure.

Carbon Dioxide

- Enters aquatic systems from the atmosphere and from respiration by animals.
- The concentration of CO₂ varies at different depths because of light/photosynthesis.

Nitrate

- Contaminates shallow groundwater (100 feet or less) and usually comes from fertilizers. It's a concern in rural areas where 80-90% of the residents use shallow groundwater for drinking. This harms humans because it reduces the blood's ability to transport oxygen.

Sulfate

- Problem because too much can kill fish. Gets in water from industrial processes and mining.

Iron

- Causes problems because it separates out of the water and forms particulates (sediment), it tastes bad if it gets in our water, and can coat fish's gills.
Groundwater problems in wells, from natural minerals in rocks.

Phosphate

- Plant nutrients that cause algae blooms. It comes from detergents, human wastes and fertilizers.

Coliform

- General group of bacteria from animal wastes. It uses up available oxygen. Also causes e-coli disease.

Giardia

- Organism (protozoa) that can cause diarrhea if you drink unchlorinated water. It is a natural organism that lives in the guts of animals.

Chloride

- Part of salts, but too many can cause too much salt in the water. Too much is bad; a little is okay. It is naturally found in water, but can come from pollution.

pH

- Too high/too low can be bad; fish like 6.5-9.5; acid mine drainage can kill fish.

Hardness

- Calcium and magnesium dissolved in the water. A little is good (50-400 ppm for fish is good), but very low or high is a problem. Low is more of a problem. Affects fish eggs, poor bone development.

Turbidity

- Cloudiness/muddiness; blocks the light; coats fish gills.

Hard Water

Definition

- Calcium and magnesium in the water. Can cause problems with cleaning clothes. Soap doesn't bubble as much.

Methods of Treating

Ion Exchange

- Substitute sodium for calcium and magnesium. Water softeners usually do this.

Reverse Osmosis

- Membrane system that allows water to go through but calcium and magnesium cannot.

Water Usage

Major Users – United States & global

- Agricultural users are the biggest by volume, then industrial and municipal.

POLLUTION OF GROUNDWATER

- Leaks from a number of sources have contaminated groundwater in parts of the world.
 - According to the EPA, one or more organic chemicals contaminate about 45% of municipal groundwater supplies.
 - By 2003, the EPA had completed the cleanup of 297,000 of 436,000 underground tanks leaking gasoline, diesel fuel, home heating oil, or toxic solvents.

Case Study: Arsenic in Groundwater - a Natural Threat

- Toxic Arsenic (*As*) can naturally occur at high levels in soil and rocks.
- Drilling into aquifers can release *As* into drinking water supplies.
- According to WHO, more than 112 million people are drinking water with *As* levels 5-100 times the 10 ppb standard.
 - Mostly in Bangladesh, China, and West Bengal, India.

Water Legislation

Safe Drinking Water Act

- It required the EPA to determine the maximum contaminant level, the max permissible amount of any pollutant that might adversely affect human health.

PREVENTING AND REDUCING SURFACE WATER POLLUTION

- Most developed countries use laws to set water pollution standards, but such laws rarely exist in developing countries.
 - The U.S. Clean Water Act sets standards for allowed levels of key water pollutants and requires polluters to get permits.
 - EPA is experimenting with a *discharge trading policy* similar to that for air pollution control.

Clean Water Act

- Has two basic goals:
 - To eliminate the discharge of pollutants in U.S. waterways
- To attain water quality levels that make these waterways safe to fish and swim in.

Water Quality Act

- controlling toxic pollutant discharges
- control non-point sources of pollution
- authorized \$18 billion for wastewater treatment
- address problems such as coastal estuaries, the Great Lakes, and the Chesapeake Bay

Using Laws to Protect Drinking Water

- The U.N. estimates that 5.6 million Americans drink water that does not meet EPA standards.
- 1 in 5 Americans drinks water from a treatment plant that violated one or more safety standard.
- Industry pressures to weaken the Safe Drinking Act:
 - Eliminate national tests and public notification of violations.
 - Allow rights to pollute if provider cannot afford to comply.

Is Bottled Water the Answer?

- Some bottled water is not as pure as tap water and costs much more.
 - 1.4 million metric tons of plastic bottles are thrown away.
 - Fossil fuels are used to make plastic bottles.
 - The oil used to produce plastic bottles in the U.S. each year would fuel 100,000 cars.