AP Photo/Gerry Broome

21

Water Pollution

Overview of Chapter 21

- Types of Water Pollution
- Water Quality Today
  - Agricultural, Municipal, Industrial, Groundwater, Water pollution internationally
- Improving Water Quality
- Laws Controlling Water Pollution

Coal Ash Spill in Dan River, VA, NC

- Jan 14, 2014- 30,000 gallons of coal ash into Dan River
- Coal ash (fly ash) – solids left over after coal is burned
  - Can contain toxic and radioactive chemicals, heavy metals
- Water used in fossil fuel extraction

AP Photo/Gerry Broome

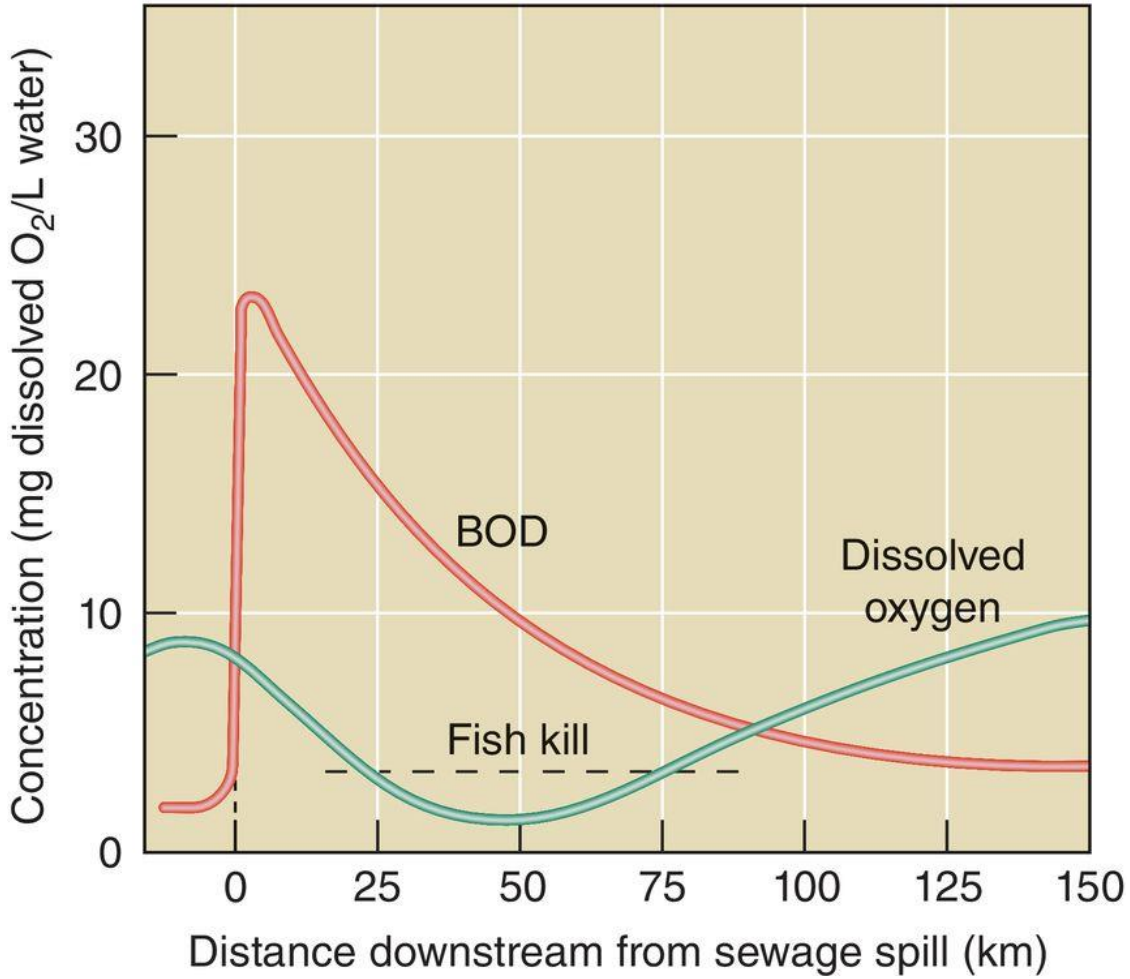
Types of Water Pollution

- Water pollution
  - Any physical or chemical change in water that adversely affects the health of humans and other organisms
- Eight categories of pollutants (many overlaps among categories)
  - Sewage, disease-causing agents, sediment pollution, inorganic plant and algal nutrients, organic compounds, inorganic chemicals, radioactive substances, and thermal pollution

Sewage

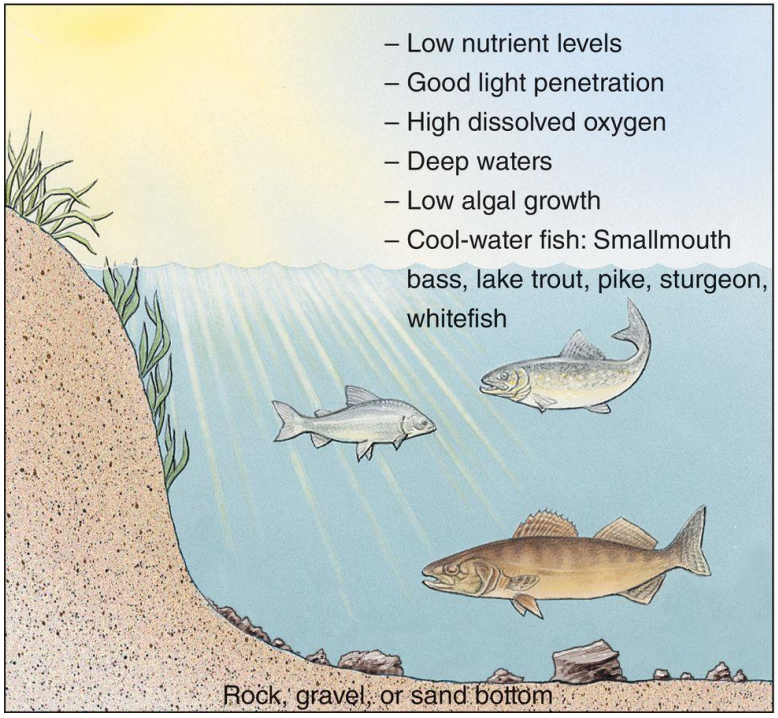
- The release of wastewater from drains or sewers (often contains disease-causing agents)
- Causes 2 serious environmental problems:
  - Enrichment
    - Fertilization of a body of water by high levels nitrogen and phosphorus
  - Increase in Biological Oxygen Demand (BOD)
    - Amount of oxygen needed by microorganisms to decompose biological wastes
      - Via cellular respiration
    - As BOD increases, Dissolve Oxygen (DO) decreases

Sewage



Sewage - Eutrophication

- Oligotrophic
  - Unenriched, clear water that supports small populations of aquatic organisms



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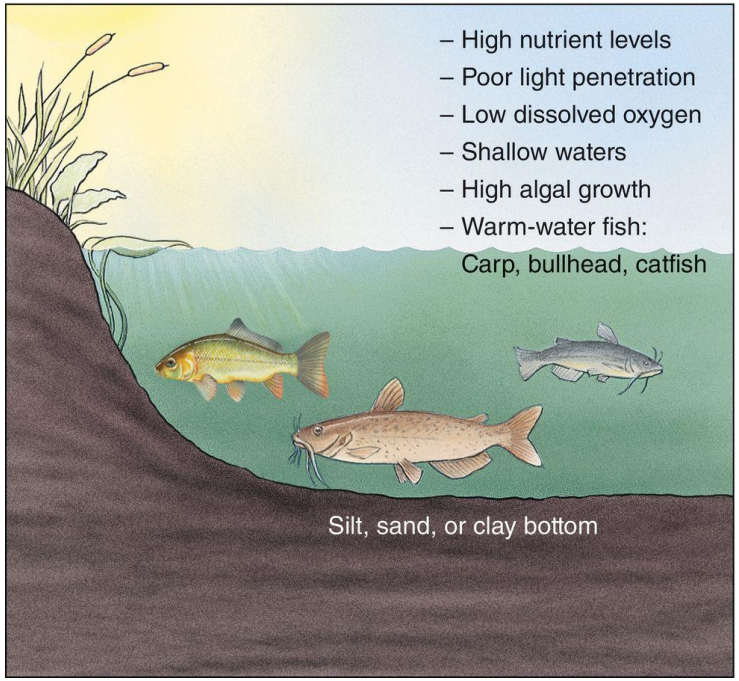
Sewage - Eutrophication

- Eutrophic
  - Slow-flowing stream, lake or estuary enriched by inorganic plant and algal nutrients such as phosphorus
- Artificial eutrophication – over nourishment of nutrients due to human activities



Michael P. Gadomski / Science Source

Disease-causing Agents

- Infectious organisms that cause diseases
  - Originate in the wastes of infected individuals
- Common bacterial or viral diseases:
  - Typhoid, cholera, bacterial dysentery, polio, and infectious hepatitis

Disease-causing Agents

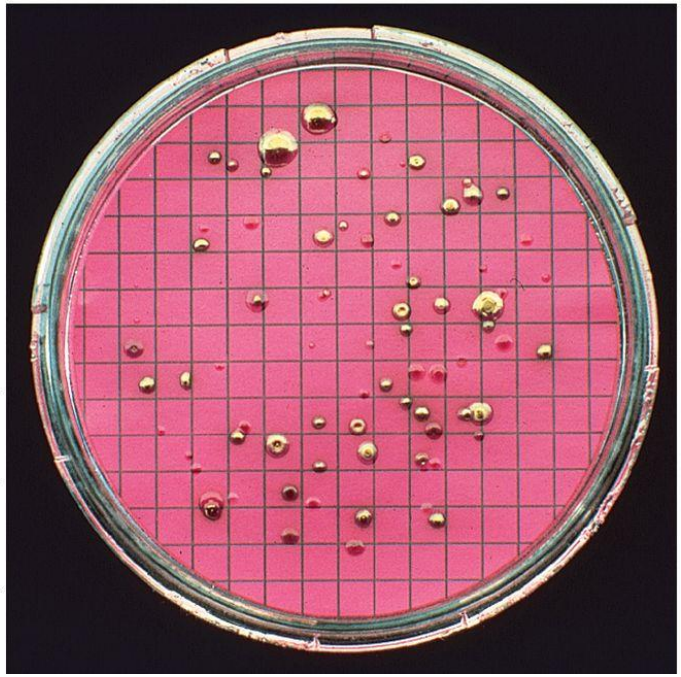
Table 21.1 Some Human Diseases Transmitted by Polluted Water

Disease	*Infectious Agent*	*Type of Organism*	*Symptoms*
Cholera	*Vibrio cholerae*	Bacterium	Severe diarrhea, vomiting; fluid loss of as much as 20 quarts per day causes cramps and collapse
Dysentery	*Shigella dysenteriae*	Bacterium	Infection of the colon causes painful diarrhea with mucus and blood in the stools; abdominal pain
Enteritis	*Clostridium perfringens*, other bacteria	Bacterium	Inflammation of the small intestine causes general discomfort, loss of appetite, abdominal cramps, and diarrhea
Typhoid	*Salmonella typhi*	Bacterium	Early symptoms include headache, loss of energy, fever; later, a pink rash appears along with (sometimes) hemorrhaging in the intestines
Infectious hepatitis	Hepatitis virus A	Virus	Inflammation of liver causes jaundice, fever, headache, nausea, vomiting, severe loss of appetite, muscle aches, and general discomfort
Poliomyelitis	Poliovirus	Virus	Early symptoms include sore throat, fever, diarrhea, and aching in limbs and back; when infection spreads to spinal cord, paralysis and atrophy of muscles occur
Cryptosporidiosis	*Cryptosporidium* sp.	Protozoon	Diarrhea and cramps last up to 22 days
Amoebic dysentery	*Entamoeba histolytica*	Protozoon	Infection of the colon causes painful diarrhea with mucus and blood in the stools; abdominal pain
Schistosomiasis	*Schistosoma* sp.	Fluke	Tropical disorder of the liver and bladder causes blood in urine, diarrhea, weakness, lack of energy, repeated attacks of abdominal pain
Ancylostomiasis	*Ancylostoma* sp.	Hookworm	Symptoms are severe anemia and sometimes symptoms of bronchitis

Disease-causing Agents

- Monitored by testing for presence of *E. coli* in the water via a fecal coliform test
  - Indicates the presence of pathogenic organisms

Courtesy EMD Millipore Corporation



Courtesy EMD Millipore Corporation

Sediment Pollution

- Excessive amounts of suspended soil particles eventually settle and accumulate on bottom
  - Originates from erosion of agricultural lands, forest soils exposed by logging, degraded stream banks, overgrazed rangelands, strip mines, and construction
- Problems
  - Limits light penetration
  - Covers aquatic animals and plants
  - Brings insoluble toxins into waterways
  - Changes available habitat for aquatic organisms

Sediment Pollution

- 7% of sediments in U.S. watersheds seriously contaminated with toxic pollutants
- Eating fish from these may threaten human health

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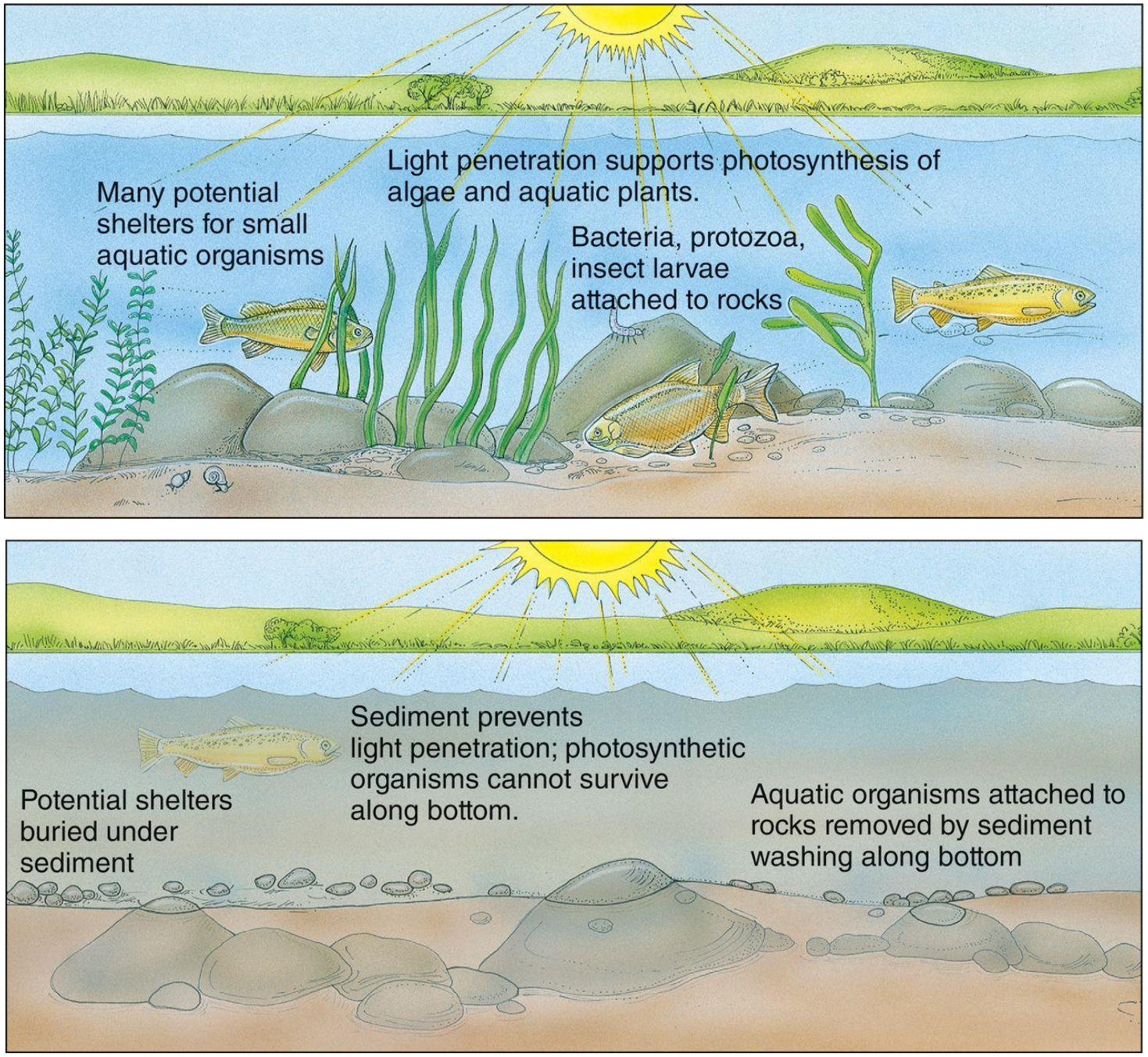
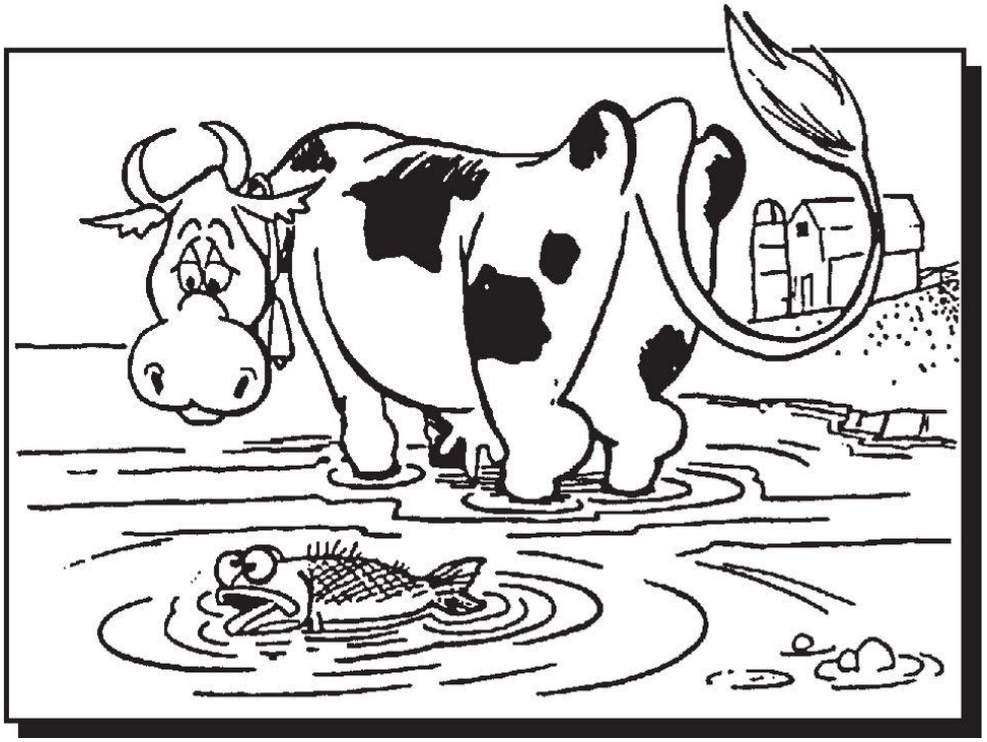

Many potential shelters for small aquatic organisms
Light penetration supports photosynthesis of algae and aquatic plants.
Bacteria, protozoa, insect larvae attached to rocks
Potential shelters buried under sediment
Sediment prevents light penetration; photosynthetic organisms cannot survive along bottom.
Aquatic organisms attached to rocks removed by sediment washing along bottom

Inorganic Plant and Algal Nutrients

- Nitrogen and phosphorus that stimulate the growth of plants and algae
  - Harmful in large concentrations
- Sources:
  - Human and animal wastes, plant residues, atmospheric deposition, and fertilizer runoff
- Results in:
  - Enrichment, bad odors, and a high BOD

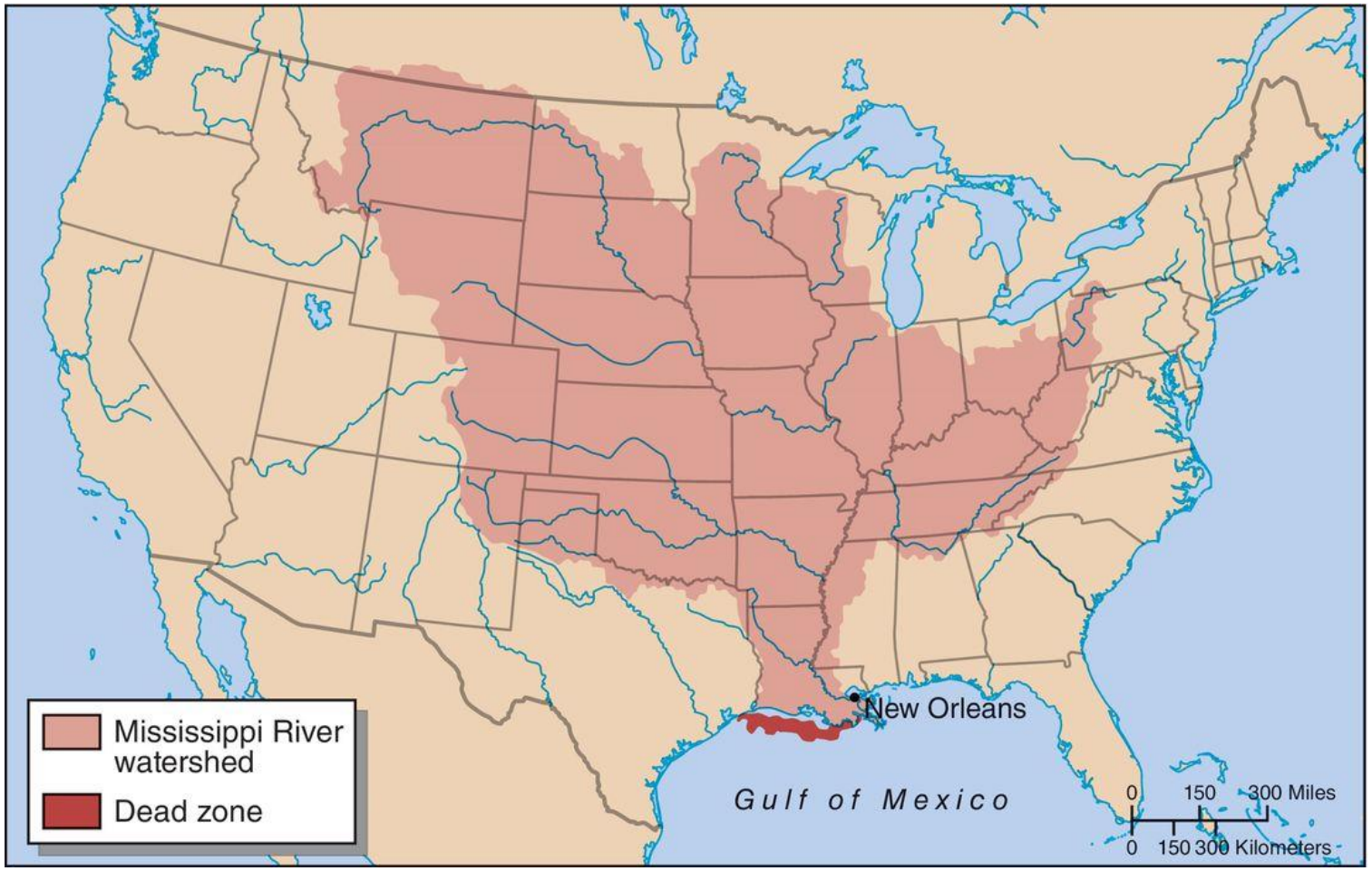
Inorganic Plant and Algal Nutrient-The Dead Zone

- Livestock produce 20x feces and urine of humans
- Laws do not require waste treatment
- High BOD can result in hypoxia
  - Low O_2 zones



Courtesy University of Wisconsin-Extension and the Wisconsin Department of Natural Resources

Inorganic Plant and Algal Nutrient-The Dead Zone



Organic Compounds

- Chemicals that contain carbon and hydrogen atoms
  - Natural examples: sugars, amino acids, and oils
  - Human-made examples: pesticides, solvents, industrial chemicals, and plastics

Table 21.2 Some Synthetic Organic Compounds Found in Polluted Water

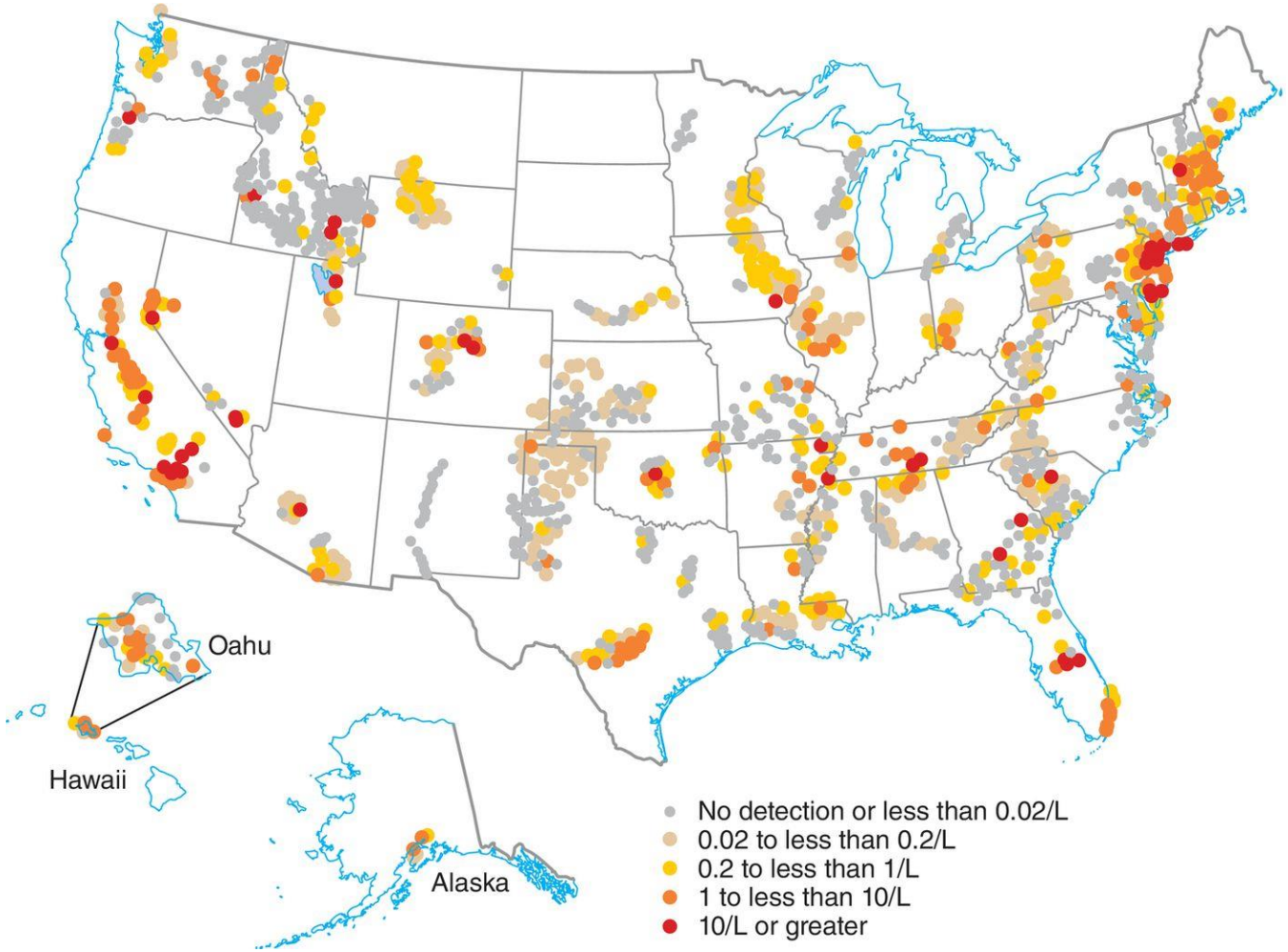
Compound	*Some Reported Health Effects*
Aldicarb (pesticide)	Attacks nervous system
Benzene (solvent)	Associated with blood disorders (bone marrow suppression); leukemia
Carbon tetrachloride (solvent)	Possibly causes cancer; liver damage; may also attack kidneys and vision
Chloroform (solvent)	Possibly causes cancer
Dioxins (TCDD) (chemical contaminants)	Some cause cancer; may harm reproductive, immune, and nervous systems
Ethylene dibromide (EDB) (fumigant)	Probably causes cancer; attacks liver and kidneys
Polychlorinated biphenyls (PCBs) (industrial chemicals)	Attack liver and kidneys; possibly cause cancer
Trichloroethylene (TCE) (solvent)	Probably causes cancer; induces liver cancer in mice
Vinyl chloride (plastics industry)	Causes cancer

Source: Adapted from the International Agency for Research on Cancer, an agency of the World Health Organization.

Organic compounds

- Volatile organic compounds (VOCs)
  - Organic compounds that easily enter the surrounding air, can redeposit
- Endocrine disruptors
  - Organic chemicals that mimic hormones
- Chemicals measure in parts per billion (ppb) or parts per millions (ppm)
  - ppm 1000X larger than ppb
  - Some chemicals cause problems at very low concentrations

Volatile Organic Compounds in Groundwater



Inorganic Chemicals

- Contaminants that contain elements other than carbon
  - Acids, salts, heavy metals
- Do not degrade easily
- Lead
  - Found in old paint, industrial pollutants, leaded gasoline
- Mercury
  - Mercury bioaccumulates in the muscles of top predators of the open ocean

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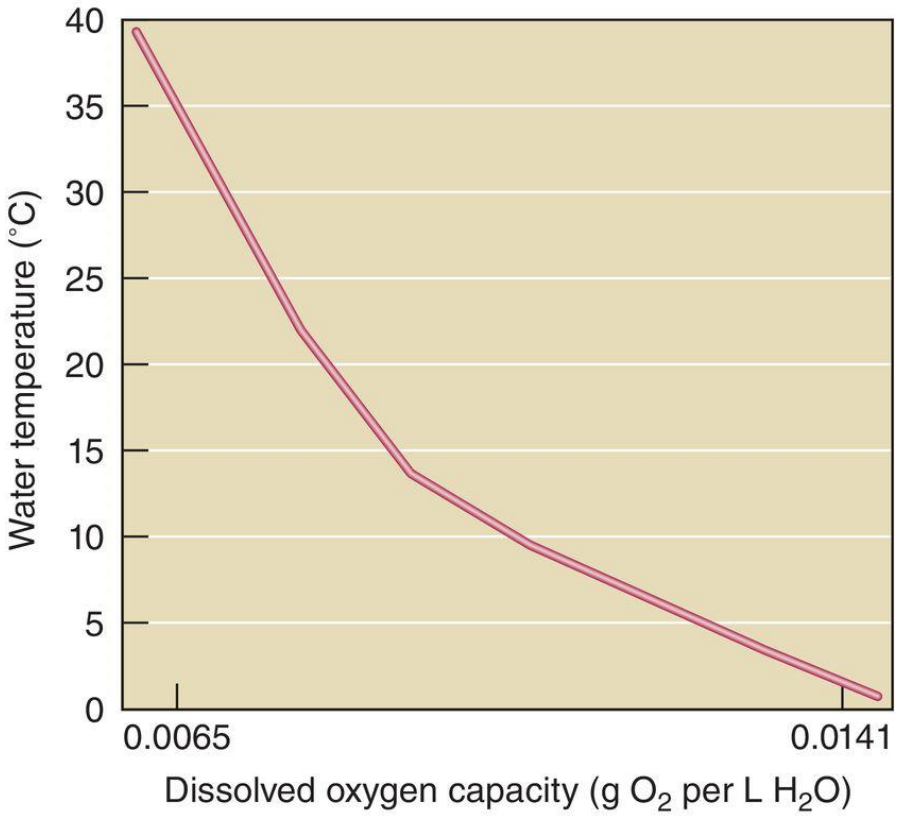
Radioactive Substances

- Contain atoms of unstable isotopes that spontaneously emit radiation
- Sources
  - Mining
  - Processing radioactive materials
  - Medical and Research Facilities
  - Nuclear power plants
  - Natural sources

Thermal Pollution

- Occurs when heated water produced during industrial processes is released into waterways
  - Commonly released
- Organisms affected
  - Temperature affects reproductive cycles, digestion rates, and respiration rates
  - Warm water holds less DO than cold water



Two Types of Water Pollution

- Point Source Pollution
  - Water pollution that can be traced to a specific origin
- Non-point Source Pollution
  - Pollutants that enter bodies of water over large areas rather than being concentrated at a single point of entry
  - Diffuse, but its cumulative effect is very large
- Differentiated because one is easier to decrease than other

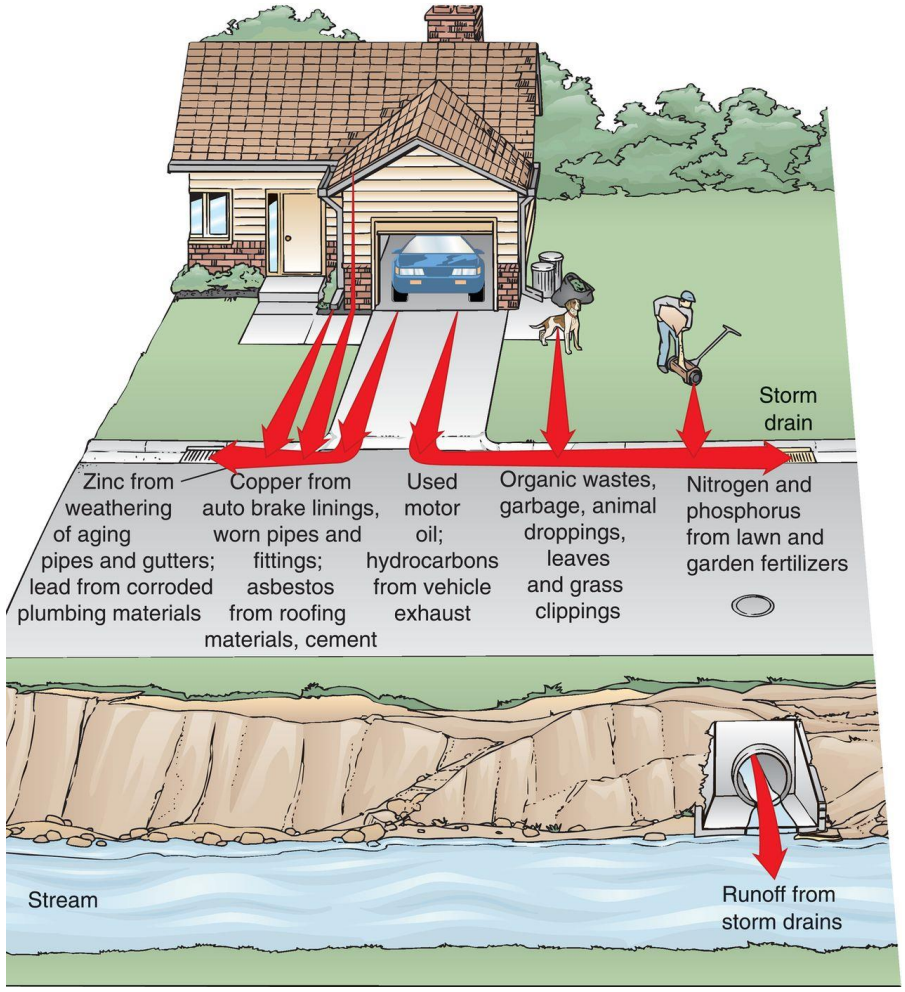
Water Pollution from Agriculture

- Agriculture is leading source of water pollution in U.S.
  - Animal wastes and plants residues have high BOD
  - Chemical pesticides can leach into groundwater
- Almost all streams and rivers are polluted with agricultural pesticides
  - 72% of water pollution in rivers is from agriculture

Municipal Water Pollution

- Sewage treatment is point source
- Urban runoff is nonpoint source
- Combined sewer systems
  - Human and industrial wastes combined before sent to waste water treatment
- Infrastructure is old and processing can be backed up
- High rainfalls can overflow sewers
  - Combined sewer overflows into nearby waters without being treated (untreated sewage)

Municipal Water Pollution

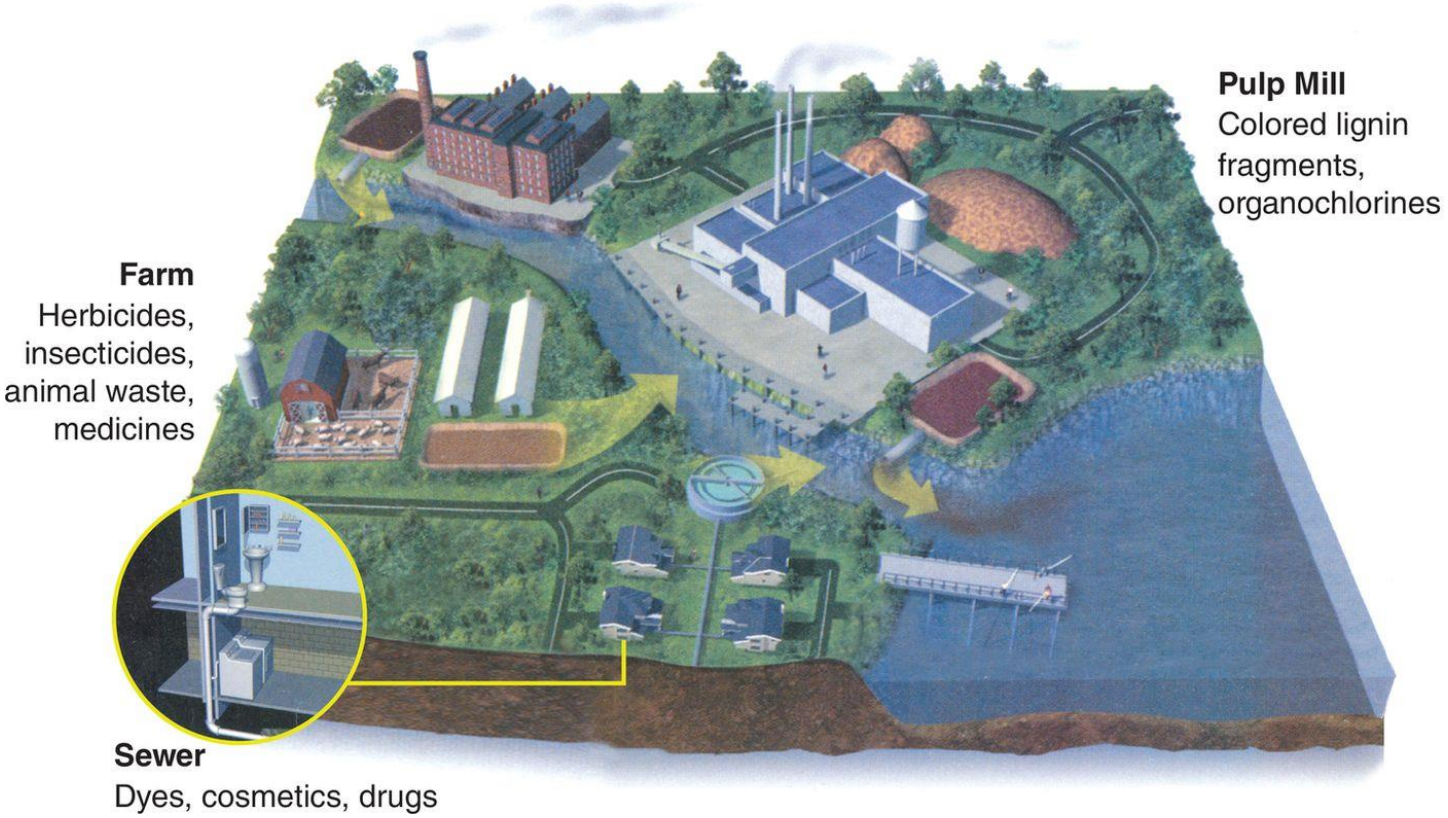


Industrial Wastes in Water

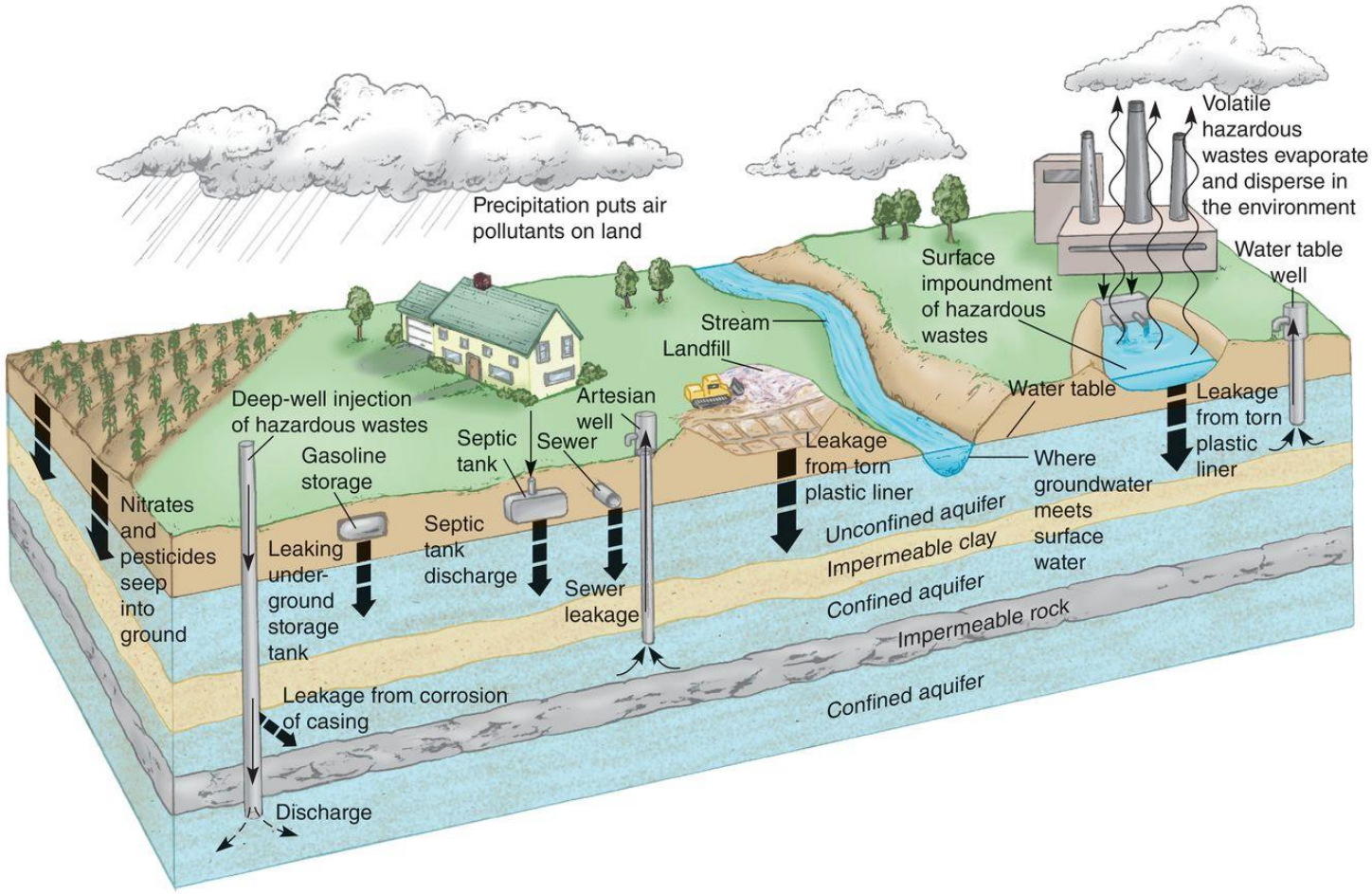
- Different industries generate different pollutants
  - Food processing plants - high BOD
  - Paper mills - High BOD and toxic compounds
- Many industries recover toxins before they go into the waste stream

Case-In-Point Green Chemistry-
Sources of synthetic pollutants in water

- Green chemistry – chemistry designed to reduce or halt use/production of hazardous substances



Groundwater Pollution



Water Pollution in Other Countries

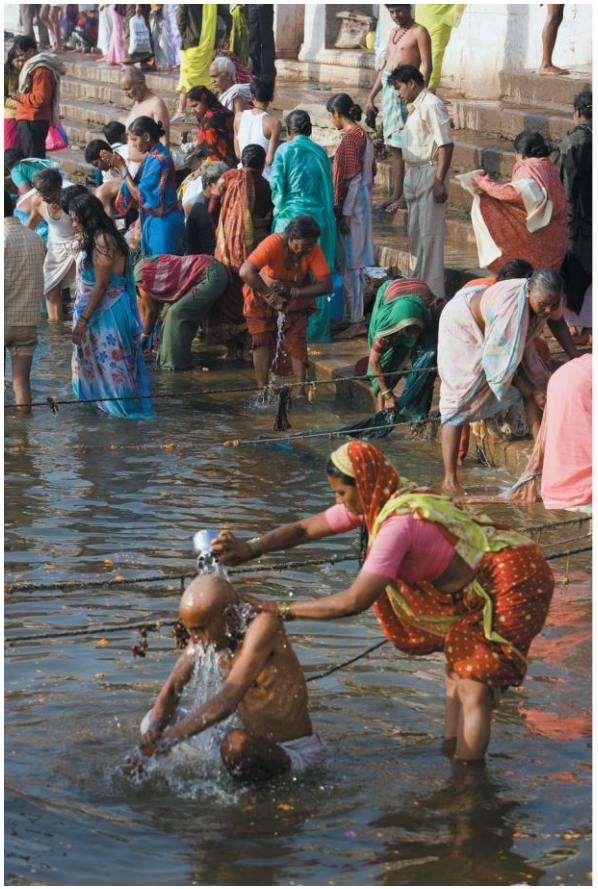
- Lake Maracaibo, Venezuela
  - 10,000 drill platform oil wells tap lake bottom
    - Leak oil into lake
  - Agricultural wastes from local fields
  - Until recently, raw human waste polluted the lake

Water Pollution in Other Countries

- Po River, Italy
  - Similar to Mississippi River
  - Pollutants: Sewage, industrial wastes, sediment
  - ~17 million Italians depend on the river for drinking water
  - Cleanup will require a national management plan and may take decades

Water Pollution in Other Countries

- Ganges River, India
  - Used for bathing and washing clothing
  - Sewage and industrial waste discharged into river
  - Ganga Action Plan initiated by government
    - Construction of 29 sewage treatment plants



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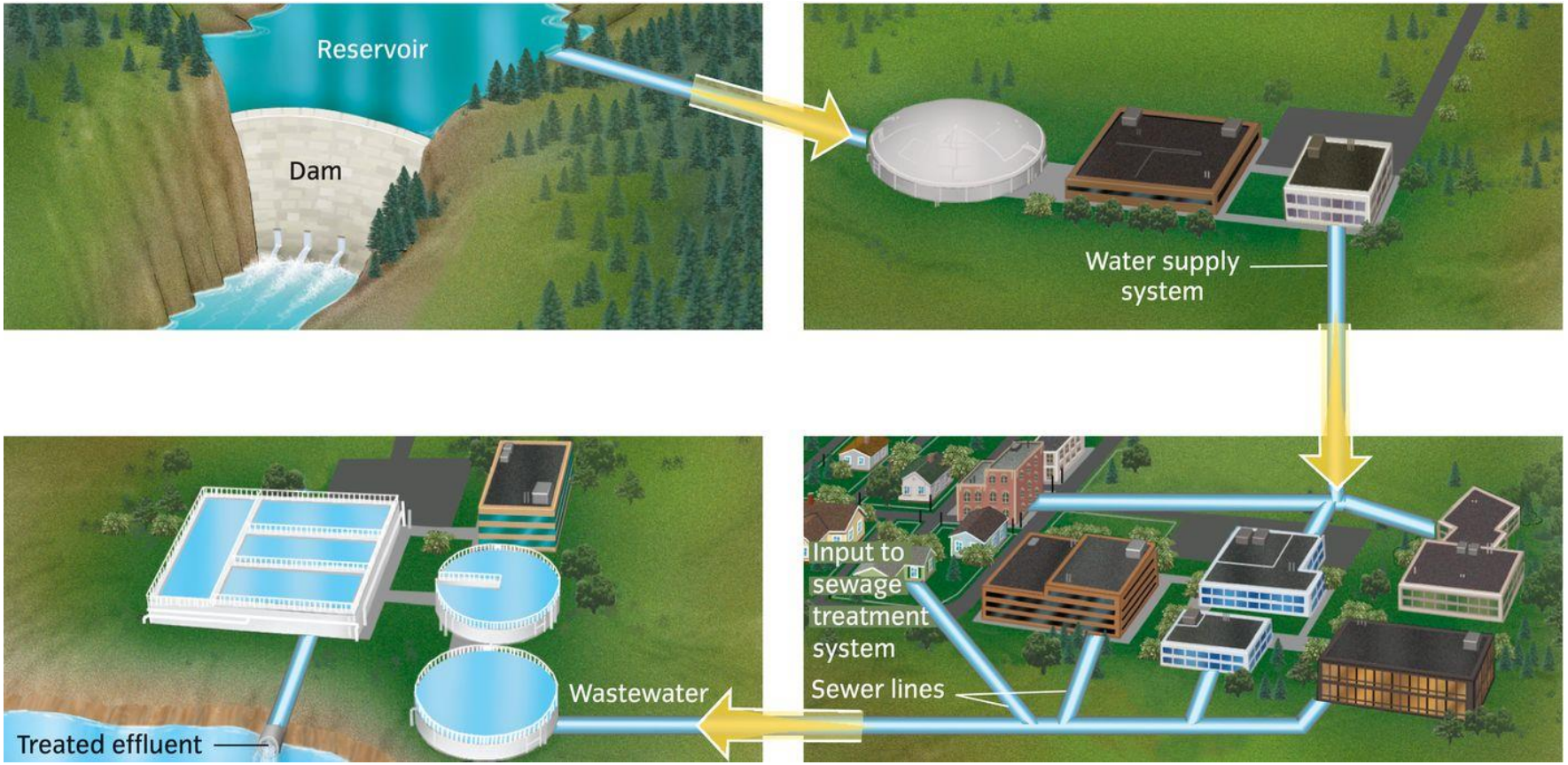
Water Pollution in Other Countries

- Zimbabwe
  - 2008 -2010 – cholera outbreak
  - 4000 deaths, 100,000 cases
  - Uneducated about cause of disease
- Bangladesh
  - Arsenic poisoning from project to increase access to clean water
  - Project installed hand pumps for groundwater rather than contaminated surface water
  - Groundwater had high natural concentrations of arsenic (lead to deaths from cancer)

Purification of Drinking Water



Purification of Drinking Water

- In U.S., most municipal water supplies are treated
- Collected from water or reservoir
- Treated
- Treated water distributed to customers
- Sewer lines bring sewage to treatment plant
- Sewage treated at sewage treatment plant

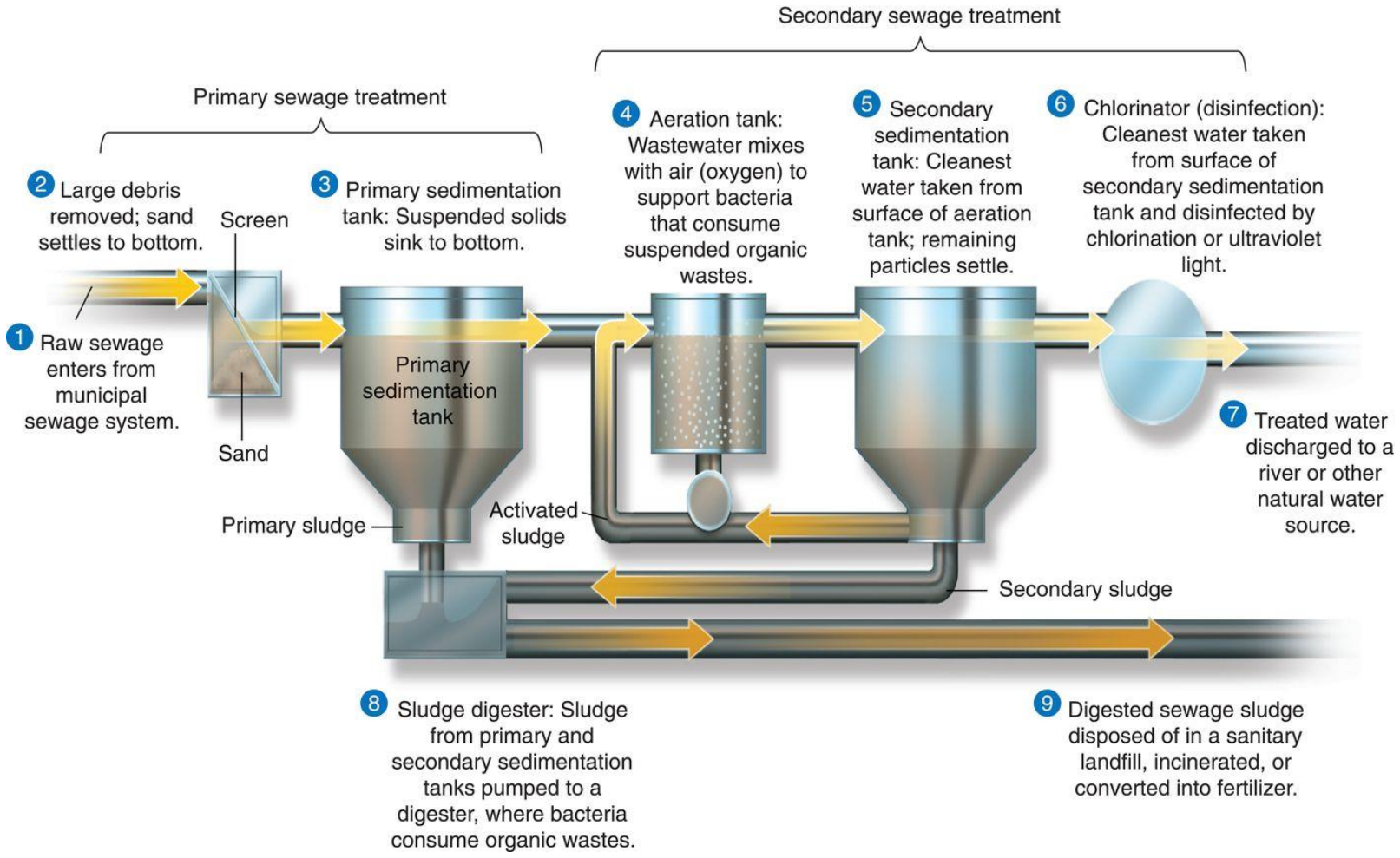
Purification of Drinking Water

- Chlorine Dilemma
  - Chlorine byproducts are linked to numerous cancers, miscarriages and birth defects
  - Peru stopped using chlorine
    - 1991 - huge cholera epidemic that infected 300,000 people
- Fluoridation
  - 70% of U.S. drinking water is fluoridated
  - Prevents tooth decay
  - Once believed to be linked to cancer, kidney disease - current studies do not show this

Municipal Sewage Treatment

- Primary treatment
  - Removing suspended and floating particles by mechanical processes
- Secondary treatment
  - Treating wastewater biologically to decompose suspended organic material; reduces BOD

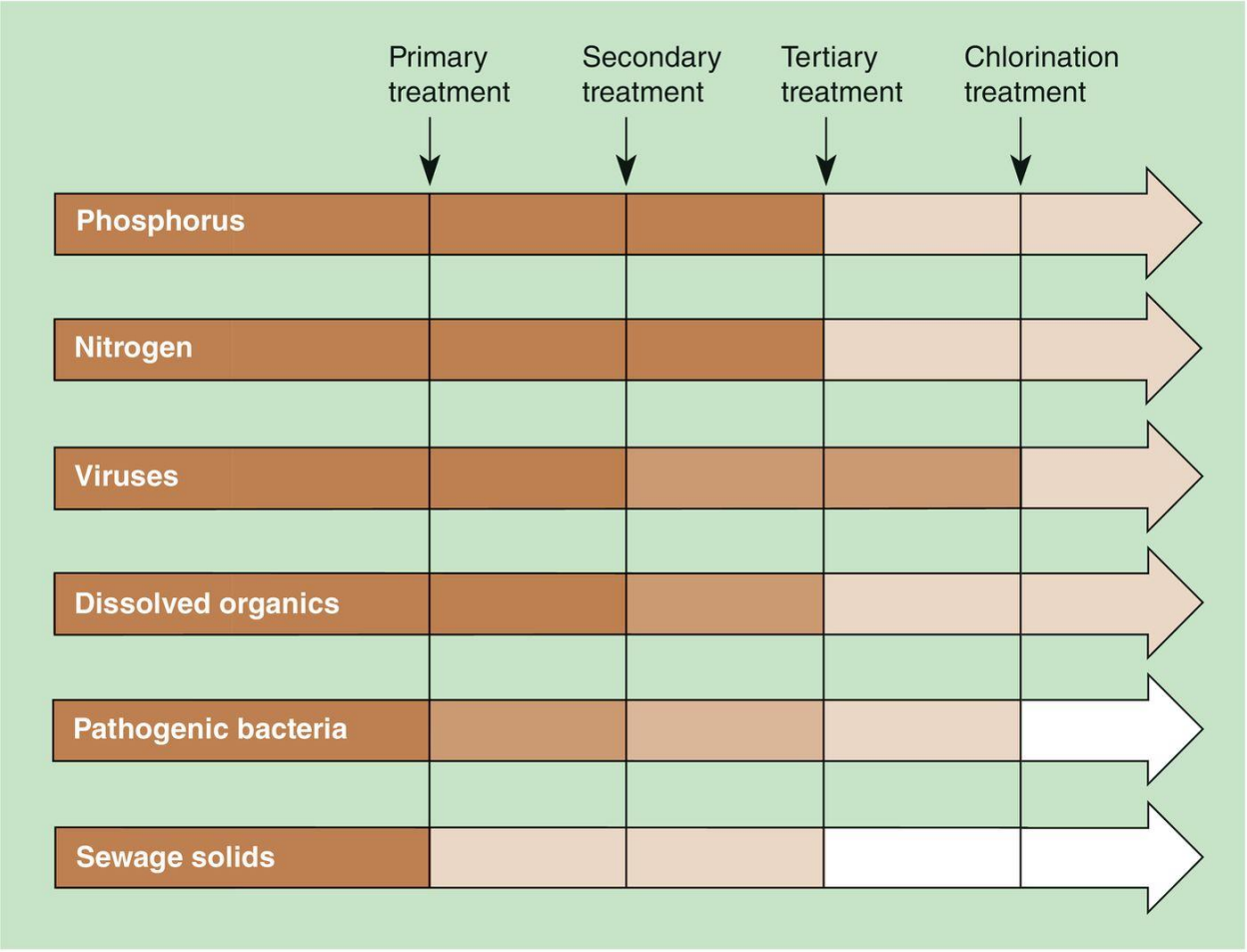
Municipal Sewage Treatment



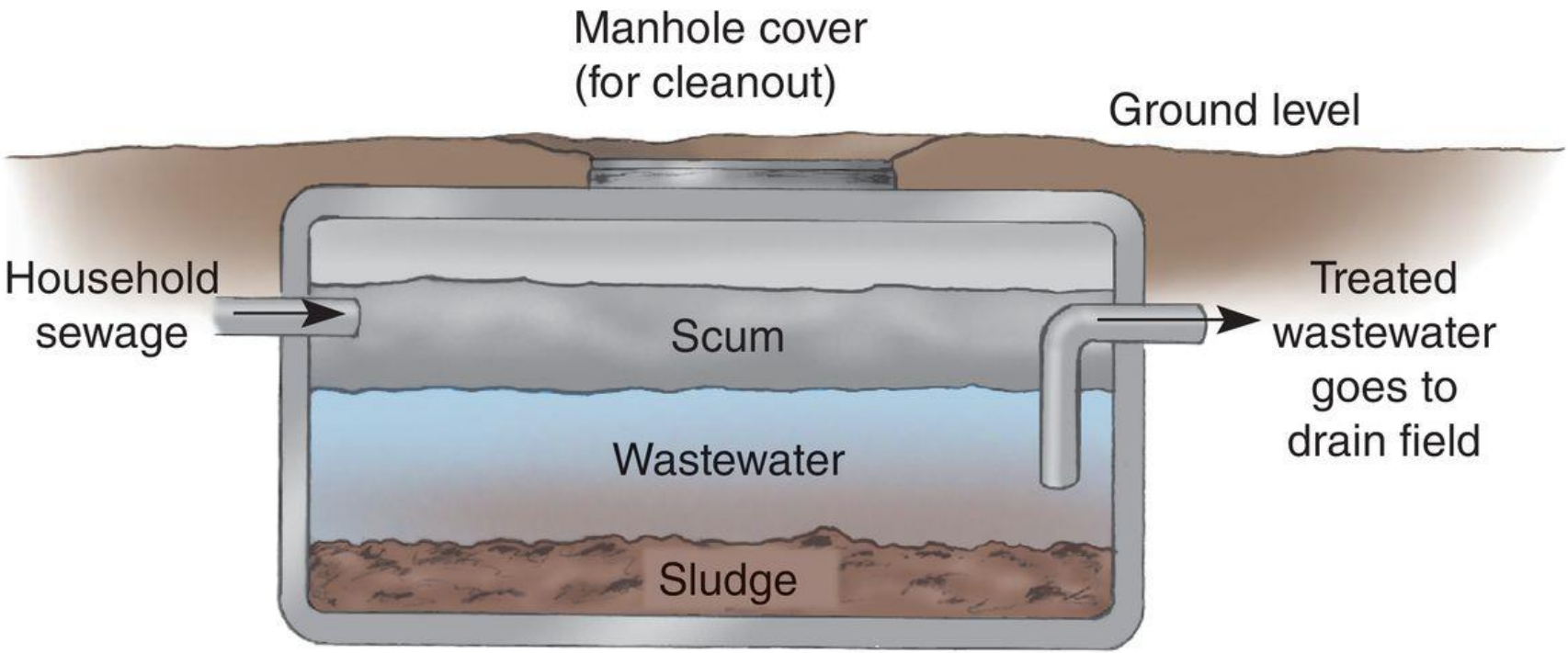
Municipal Sewage Treatment

- Sewage Sludge
  - Solids remaining after primary and secondary sewage treatment has been completed
- Tertiary treatment
  - Advanced wastewater treatment methods that are sometimes employed after primary and secondary treatments
  - Reduce phosphorus and nitrogen

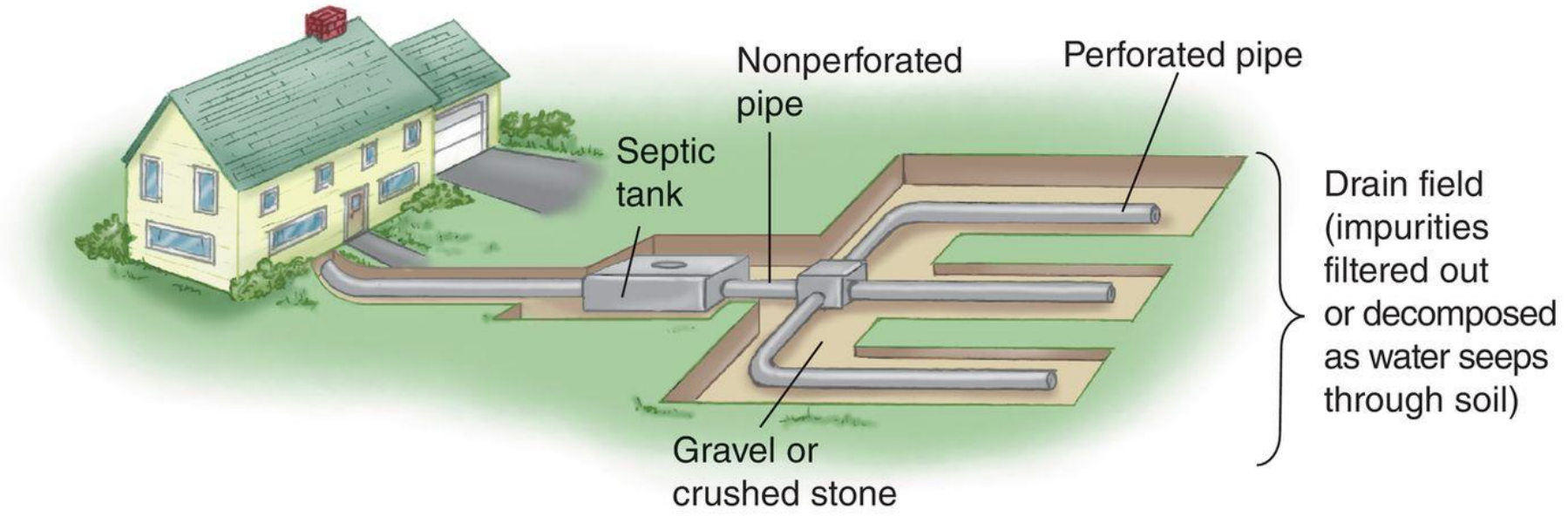
Municipal Sewage Treatment



Individual Septic System- Septic Tank



Individual Septic System-Drain Field



Laws Controlling Water Pollution

- Citizen Watchdogs to Monitor Pollution
- Safe Drinking Water Act (1974)
  - Set uniform federal standards for drinking water including maximum contaminant level
- Clean Water Act (1972)
  - EPA sets up and monitors National Emissions Limitations
  - Effectively improved water quality from point sources

Laws that Protect Groundwater

- Safe Drinking Water Act
- National Pollutant Discharge Elimination System (NPDES)
- Resource, Conservation and Recovery Act