CHAPTER 20: WATER POLLUTION

APES 2013

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SOURCES OF WATER POLLUTION

- Water pollution - any chemical, biological, or physiological change in water quality that harms living organisms or makes water unsuitable for desired uses
- Point sources - discharge of pollutants at specific locations through drain pipes, ditches, or sewer lines
  - Examples: factories, sewage treatment plants, underground mines, and oil tankers
- Nonpoint sources - broad, diffuse areas from which pollutants enter bodies of surface water
  - Examples: runoff from croplands, livestock feedlots, logged forests, urban streets, parking lots, lawns, and golf courses

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COMMON SOURCES

- Agricultural activities - sediment eroded from agricultural lands, fertilizers, pesticides
- Industrial facilities - emit inorganic and organic chemicals
- Mining - erosion of sediments and toxic runoff

Fig. 20-3

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PARKING LOTS

- Major source of nonpoint pollution
- Grease, toxic metals, and sediments
  - Tires
- Disrupt hydrologic cycle
- Worsen local flooding and erosion

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STREAMS AND LAKES

- Can cleanse themselves through dilution and biodegradation of waste by bacteria.
- This can not happen if overloaded with pollutants, or when drought, damming, or water diversions reduce flow.

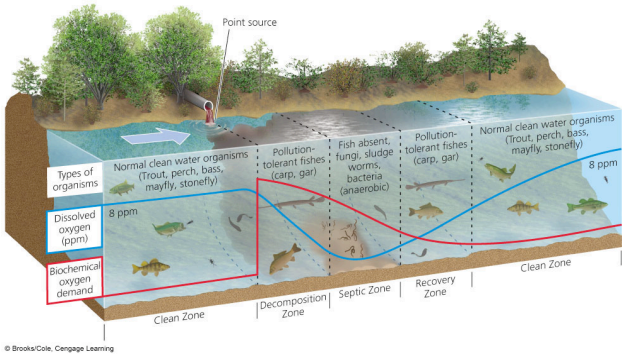

Fig. 20-5

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WATER CONTROL LAWS

- Enacted in the 1970s
- Increased number and quality of wastewater treatment plants
- Require industries to reduce or eliminate point source discharges
- Success story: Cuyahoga River, Ohio
  - Caught fire several times in the 1950s and 1960s
  - Today river is no longer flammable and is being used for recreation

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DEVELOPING COUNTRIES

- Pollution from untreated sewage and industrial wastes
- Half of the world's 500 rivers are heavily polluted (most run through developing countries)

Fig. 20-7

Fig. 20-8

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LAKES

- Less effective at diluting pollutants
  - Contain stratified layers that have little vertical mixing
  - Little or no flow (can take 1-100 years to change water - rivers only take days)
- More vulnerable than streams to contamination by runoff, oil, pesticides, toxic substances (lead, mercury...)
- Kill organisms (birds, fish, plants)

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EUTROPHICATION

- Eutrophication - natural nutrient enrichment from runoff of plant nutrients
- Oligotrophic lake - low in nutrients (clear water)
- Human activities greatly accelerate this natural process = cultural eutrophication
- Can produce dense growths of algae and cyanobacteria known as blooms
- As the algae die, they are decomposed by bacteria which deplete dissolved oxygen which leads to fish kills
- If excess nutrient levels continue, anaerobic bacteria take over producing hydrogen sulfide and methane

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CONTROLLING EUTROPHICATION

- Waste treatment to remove nitrates and phosphates before water enters lakes
- Ban or limit use of phosphates in detergents and cleaning agents
- Employing soil conservation to reduce runoff
- Remove excess weeds and undesirable plant growth
- Pump air through lakes to prevent oxygen depletion
- Most of these are expensive so as usual prevention is best

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POLLUTION IN THE GREAT LAKES

- Contain 95% of fresh surface water in United States (one-fifth of the world's)
- 38 million people obtain drinking water from the lakes
- Vulnerable to pollution
  - Less than 1% of water entering the lakes flows out each year (can take as long as 100 years for pollutants to be flushed out to sea)
  - 1960s - extensive cultural eutrophication, fish kills, contamination

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POLLUTION IN THE GREAT LAKES

- Since 1972, Canada and U.S. have joined forces to spend more than $20 billion
  - decreased algal blooms
  - increased dissolved oxygen
  - increased sport and commercial fishing
  - allowed for most beaches to reopen
- Improved because of new or upgraded sewage treatment plants; better industrial waste improvement; bans on detergents, household cleaners, and water conditioners that contain phosphates

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POLLUTION IN THE GREAT LAKES

- Still problems:
  - Lakefront cities releasing 100 Olympic swimming pools of raw sewage each day (because of "emergency overflows")
  - Biggest threat is nonpoint source runoff of pesticides and fertilizers
  - Sediments still heavily polluted
  - Biological Pollution - invasive species
  - Half of toxic compounds come from air pollution (pesticides, mercury)
  - One in four fish is unsafe to eat
  - EPA funded cleanup has dropped 80% since 1992

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GROUNDWATER

- Drinking water for about half of the U.S. population is from groundwater
- Pollutants (fertilizers, pesticides, gasoline, organic solvents) seep from numerous sources
- Pollutants fill porous layers of sand, gravel, or bedrock. Contamination is difficult and expensive to remove
- Groundwater flows slowly (0.3m per day or less) so it does not clean easily
- It can take decades to thousands of years to cleanse of a pollutant

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DRINKING WATER PURIFICATION

- Developed countries have laws that are enforced, developing countries do not
- Developed countries depend on surface water stored in reservoirs to improve clarity and taste by increasing dissolved oxygen and allowing suspended particles to settle.
- Water is then pumped to a purification plant to meet government standards
- Some communities now protect their watershed so well that they do not have to build purification plants (saves money)
- Municipalities are now recycling wastewater (40% of El Paso, TX drinking water)

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Drinking Water Purification

- Developing Countries
  - Water in clear bottles exposed to intense sunlight (heat and UV rays kill microbes)
  - Nanofilters - low cost water filter that can be cleaned and reused (ex. LifeStraw)

Fig. 20-14

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Laws

- 54 countries have standards for drinking water (mostly in North America and Europe)
- U.S. Safe Drinking Water Act of 1974 requires EPA to establish national drinking water standards (maximum contaminant levels)
- Since Clean Water Act (1972), UN estimates that 5.6 million Americans drink water that does not meet EPA safety standards for one or more contaminants
- One in five Americans drinks water from a water treatment plant that has violated one or more safety standards in the past year

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Strengthening Laws

- Combine smaller drinking water treatment systems with larger systems to make it cheaper to meet standards
- Enforce and strengthen public notification requirements
- Ban lead in plumbing, faucets, and fixtures (currently these can be labeled “lead free” if they have up to 10% lead)

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INDUSTRY INPUT

- Industry is seeking to weaken the Safe Drinking Water Act and the Clean Water Act
  - Eliminate national tests
  - Eliminate any public notification
  - Provide waivers to allow for pollution
  - Remove regulations that force removal of cancer-causing contaminants
  - Reduce the EPA budget

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BOTTLED WATER

- United States has the some of the world's safest drinking water but still people purchase bottle water
- Bottled water use has increased from 7.5L to 113L per year between 1976 and 2006 (even though it costs 240 to 100,000 times more than tap water)
- On average 25% of bottled water is tap water
- Governmental standards for bottled water are actually lower than tap water
- Plastic bottles thrown away each year could circle the Earth eight times
- Amount of oil used to produce water bottles could fuel 100,000 cars for an entire year (if we include the oil used to pump, process, and transport, it would be 3 million cars)

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OCEAN POLLUTION

- 80-90% of sewage in coastal cities in developing countries is dumbed into the ocean
- Cruise ships generate as much waste as a small city and many dump their wastes in the sea
- 4 out of 5 U.S. estuaries are threatened or impaired and 1 in 4 coastlines are not suitable for swimming.
- Large concentrations of nitrates and phosphates
- Algal blooms have caused over 200 oxygen depleted zones around the world (43 in U.S.)

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OIL POLLUTION

- Crude petroleum - oil out of the ground
- Refined petroleum - fuel oil, gasoline, processed petroleum products
- 1989 - *Exxon Valdez* - 40.8 million liters on Alaska's Prince William Sound
    - Cost Exxon billions in cleanup, fines, damages to fishers and Alaskan citizens
- 2002 - *Prestige* - about 80 million liters over 2 years off the coast of Spain
- 2010 - *Deepwater Horizon* - 779 million liters over about 3 months in the Gulf of Mexico
- Still the largest source of ocean oil pollution is urban and industrial runoff

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EFFECT OF OIL POLLUTION

- VOCs (Volatile Organic Compounds) immediately kill many aquatic organisms
- Other chemicals form tar-like globs that float on the surface and coat feathers of birds and fur of marine mammals
    - Destroys their natural heat insulation and buoyancy; thus, many die of drowning or exposure from body heat loss
- Heavy components sink to the ocean floor or wash into estuaries and can smother bottom dwelling organisms like crabs, oysters, mussels, and clams.
- Marine ecosystems can recover from crude oil spills within 3 years. Refined oil can take 10-20 years
- In 2006, patches of oil were still found from the *Exxon Valdez*, 17 years after the spill.

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OIL POLLUTION CLEANUP

- Partially cleaned up by by mechanical means (floating booms, skimmer boats, and absorbent devices like pillows of feathers or hair)
- Chemical dispersants
- Fire
- Bacteria that speed up oil decomposition
- The above "traditional" methods are estimated to only cleanup 15% of oil
- Prevention is obviously most effective and least costly approach
    - Double hulls - After *Exxon Valdez*, oil companies promised to do this but only half have.

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Reducing Surface Water Pollution from Nonpoint Sources

- Most from agriculture
  - Soil erosion reduction by keeping cropland covered with vegetation
  - Reduce fertilizer that runs off and leaches into aquifers
    - Slow-release fertilizers, no fertilizers on sloped land, planting buffer zones
  - Organic farming techniques

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Laws

- Federal Water Pollution Control Act of 1972 (renamed Clean Water Act in 1977)
  - Sets standards for allowed levels of key water pollutants and requires polluters to get permits limiting how much they can discharge
- 1987 Water Quality Act
- EPA experimenting with a **Discharge Trading Policy** (similar to cap and trade for air pollution)
  - Caps must be continually lowered to work
  - Discharges could be disproportionate based on who is buying credits

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U. S. Point Source Pollution

- According to EPA, between 1992 and 2002 the Clean Water Act of 1972 has let to:
  - Americans served by water systems that meet federal standards increased from 79% to 94%
  - Percentage of stream length found to be fishable and swimmable increased from 36% to 60%
  - Amount of lost topsoil was cut by 1.1 billion metric tons per year
  - Percentage of Americans served by sewage treatment plants increased from 32% to 74%
  - Wetland losses decreased by 80% annually

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CONTINUING PROBLEMS

- Still have 45% of lakes and 40% of streams are still too polluted for swimming or fishing
- Runoff from animal wastes pollute 7 of 10 rivers
- Fish in more than 1,400 waterways are unsafe to eat because of pesticides, mercury, and other toxics
- Half of water treatment plants have illegally discharged toxic or biological wastes without fines
  - Average polluting facility discharges 4 times the legal limit with no consequences
- U.S. government reports show tens of thousands of gasoline storage tanks are leaking (estimated $12 billion in cleanup costs)

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SEWAGE TREATMENT

- In rural and suburban areas, sewage is often discharged into a septic tank with a large drainage field
  - Wastewater pumped into a settling tank so grease and oil float to the top and solids fall to the bottom to be decomposed by bacteria
  - Partially treated wastewater is discharged into a drainage field through small holes in pipes embedded in gravel or crushed stone to be biodegraded by soil and bacteria
  - Every two years the tank needs to be emptied and waste taken to a treatment plant

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SEPTIC SYSTEM CAUTIONS

- Can backup if not properly maintained or pollute groundwater
- Chlorine bleach, drain cleaner, and antibacterial soap SHOULD NEVER BE USED in these systems
- Kitchen sink garbage disposals SHOULD NEVER BE USED

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Sewage Treatment

- Urban areas use sewers that run to wastewater treatment plants
  - Primary Sewage Treatment - physical process that removes about 60% of suspended solids and 30-40% of the oxygen-demanding organic wastes
    - Screens and grit tanks - remove large floating objects and allows large solids to settle out
    - Primary settling tank - solids settle out as sludge
    - DOES NOT REMOVE: pathogens, phosphates, nitrates, salts, radioisotopes, or pesticides

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Sewage Treatment

- Secondary Sewage Treatment - biological process where anaerobic bacteria remove as much as 90% of dissolved and biodegradable, oxygen demanding organic wastes
- Tertiary Sewage Treatment - specialized chemical and physical processes that remove specific pollutants left in water (Not often used)
  - Ex. special filters to remove phosphates and nitrates
- Before water leaves it is bleached (remove coloration) and disinfected (kill disease-causing bacteria - usually with chlorine)

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Sewage Treatment Plant

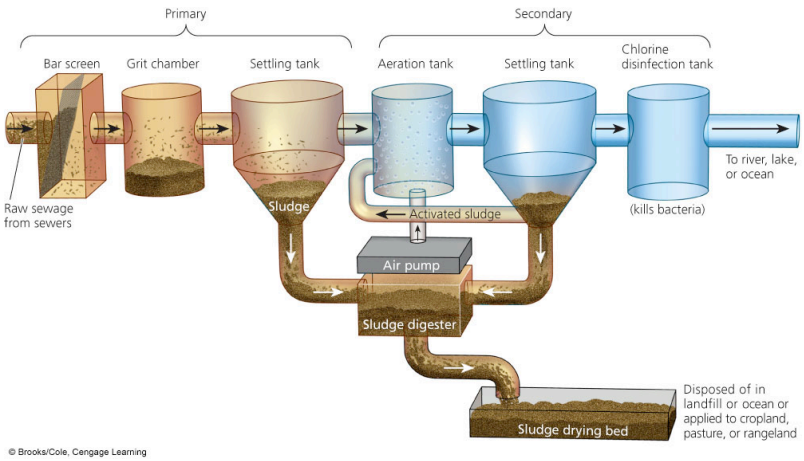

Fig. 20-19

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Sewage Treatment Problems

- Two-thirds have violated regulations
- Pipes for carrying storm water are often connected to sewer lines because it is cheaper. This can cause overflow. (40,000 overflows a year in the U.S.)
- Estimated each year 7.1 million people get sick in the U.S. from swimming in water contaminated by sewage
- In 2005, Bush Administration EPA authorized bypassing secondary treatment and blending with fully treated wastewater. Plants can dump this mixture into waterways anytime it rains or snows. Before this was only allowed in extreme circumstances like hurricanes.

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Improving Sewage Treatment

- Preventing toxic substances from reaching treatment plant
  - Require industries and business to remove toxic and hazardous wastes from water, or eliminate toxic chemicals
  - Composting toilet systems

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Improving Sewage Treatment

- Wetland-based sewage treatment - sewage flows into a passive solar greenhouse or outdoor site with rows of open tanks populated by increasingly complex organisms
  - 1st tanks - algae and microorganisms with sunlight to decompose organic wastes. Aquatic plants take up nutrients
  - Further down - artificial marsh of sand, gravel that filters out algae and remaining organic waste. Some plants absorb (sequester) toxic metals and secrete natural antibiotics
  - Aquarium tanks - snails and zooplankton consume microorganisms that are consumed by larger fish
  - After 10 days, clear water flows to a second artificial marsh for filtering and cleansing
  - Water is pure enough to drink after passing by UV light
  - Cost is about the same as a traditional treatment plant

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