

Unit 7: Water and Water Pollution

Chapter 14: WATER

Key Terms (Terms are listed in the same font as they appear in the text.)

aquifers (p. 307)

California Water Project (p. 320)

center-pivot low-pressure sprinklers (p. 325)

channelization (p. 331)

consumptive water use (p. 308)

Desalination (p. 322)

distillation (p. 323)

drainage basin (p. 307)

drip irrigation systems (p. 325)

flood irrigation (p. 324)

floodplain (p. 329)

gray water (p. 328)

groundwater (p. 308)

hydrologic cycle (p. 306)

hydrological connection (p. 307)

Hydrological poverty (p. 306)

land subsidence (p. 314)

lateral recharge (p. 307)

low-energy precision application (LEPA) sprinklers (p. 325)

microirrigation systems (p. 325)

natural recharge (p. 307)

nonconsumptive use (p. 308)

rainwater harvesting (p. 326)

reliable runoff (p. 307)

reverse osmosis (p. 323)

sinkholes (p. 314)

soil moisture detectors (p. 326)

surface runoff (p. 307)

surface water (p. 307)

tiered water-pricing system (p. 328)

user-pays approach (p. 324)

water hot spots (p. 310)

water table (p. 307)

watershed (p. 307)

withdrawal (p. 308)

xeriscaping (p. 328)

zone of saturation (p. 307)

Outline

14-1 Water's Importance, Availability, and Renewal

- A. Water is important for several reasons.
 1. It keeps us alive; most organisms are more than 70% water.
 2. It sculpts the earth's surface and moderates the climate.
 3. Water removes and dilutes wastes and pollutants.
- B. The management of water's supply, renewal, and use is a huge, twenty-first century challenge. Only about 0.01% of the earth's supply of water is available as fresh water in the soil, in usable groundwater, water vapor, lakes and streams, but this supply is recycled.
- C. The hydrologic cycle collects, purifies, recycles, and distributes the world's freshwater supply.
- D. Overloading the earth's water systems with slowly degradable and nondegradable wastes and withdrawing underground water faster than it is replenished is compromising the hydrologic cycle.
- E. Some countries have more water than they need; some countries have far less. Poor people have less access and less availability to water, just as to food supplies.
- F. Water that flows across the earth and empties into rivers, streams, lakes, etc., and so does not infiltrate the ground or evaporate into the atmosphere is called surface runoff.
 1. A watershed/drainage basin is that region from which surface water drains into a body of water.
 2. Reliable runoff is the runoff that is stable from one year to the next and can be counted on for a water supply.
 3. Water that percolates down through the ground and is stored in pores, crevices, etc. is groundwater, an important fresh water source.
 - a. In the zone of saturation, the spaces in the ground are filled with water.
 - b. The water table is located at the top of the zone of saturation.

- c. An aquifer is deeper down in the geologic layers and is like an elongated sponge with watertight layers of rock or clay below the aquifer to keep water from seeping out.
- d. A natural recharge replenishes an aquifer through the precipitation that percolates down through soil and rock. This recharge occurs extremely slowly.
- e. Lateral recharge is replenished from the side of nearby streams.
- f. Water mining withdraws water from deep underground, ancient deposits of water that are not generally recharged.
- G. The world's demand for water now required 54% of the world's reliable runoff of surface water. We could be using 70-90% by 2025. In some places usage rates are exceeding the reliable runoff available.
 - 1. Water taken from streams to cool power plants is returned to the stream, but the higher water temperature causes thermal pollution downstream from the return, disrupts aquatic life.
 - 2. Consumptive water is water not available for reuse due to evaporation, seepage into soil contamination, or movement to another area.
 - 3. 70% of the water we withdraw from surface water/aquifers is to irrigate crops, which account for 40% of the world's food. About 85% of this water is consumed, not returned to its water basin.
 - 4. Industries use 20% of such water.
 - 5. And cities and residencies use 10% of reliable runoff.
 - 6. The daily minimum amount of water needed to support 3/4th of the world's people is equal to the amount of water used to irrigate the world's golf courses.
 - 7. The U. S., unlike many other countries, has enough fresh water; but its availability is influenced by differences in climate. This unequal distribution of water could set off "water wars", especially in the Western states, in the next 20 years.

14-2 Too Little Freshwater

- A. Water resource problems rest on too little freshwater for too many people, lack of money to drill deep wells, dams, reservoirs, and water distribution systems.
- B. Almost 41% of the world's population lives in river basins located in 20 countries that suffer from either water stress or water scarcity. This figure could reach 40 countries by 2020 and 60 countries by 2050.
 - 1. The volumes of water in some of the world's largest lakes have shrunk by 85-92% since 1960 because of water diversion and periods of prolonged drought.
 - 2. A United Nations study found that one of six people do not have access to adequate, affordable, and clean water.
 - 3. Poor people live in hydrological poverty—they have no access and/or cannot afford clean water at a reasonable cost.
 - 4. Fresh water supply can be increased by building dams to store water for later use, importing water from elsewhere, use groundwater, and by desalination.
 - 5. People in developed countries live near water supplies, but people in developing countries must make do with what is available.
- C. Most people believe that everyone has a right to clean water.
 - 1. Most water resources are owned by governments and managed as publicly owned resources, but a number of governments hiring private companies to manage them. There have been mixed results and the lesson learned is that governments need to maintain strict oversight of these contracts.
 - 2. Two possible problems with a totally privatized water system are: First, private companies have an incentive to seal as much water as possible rather than conserve it; second, the poor will continue to be left out because they can't pay for the water.

14-3 Withdrawing Groundwater to Increase Supplies

- A. Aquifers provide almost one-fourth of the world's water and are renewable unless water is removed faster than it can be replenished.
- B. Overpumping aquifers can cause sinkholes and contaminate freshwater.

14-4 Using Dams and Reservoirs to Supply More Water

- A. Dams and reservoirs capture and store runoff water. There are an estimated 800,000 dams that restrict the flow of rivers worldwide.
 - 1. The water is released to control floods, generate electricity, and to irrigate.
 - 2. Reservoirs also provide for swimming, fishing, and boating.
 - 3. But dam and reservoir construction displaces people and floods productive land.
 - 4. The ecological services that rivers provide are given no value when building dams/reservoirs.
 - 5. A series of dams on a river in an arid can disrupt the hydrologic cycle since the water may not reach the sea that it previously supplied with water.
 - 6. About 60% of the world's major river basins are strongly or moderately fragmented and disturbed. At least 24% of the world's freshwater fish species are threatened or endangered.
 - 7. The Colorado River is 1,400 miles long and has been altered by 14 major dams and reservoirs to the point that water rarely reaches the Gulf of California now. This endangers many species that spawn in the river system and has led to increased salt contamination of aquifers near the coast.
 - a. The dams and reservoirs make it possible to grow crops, have recreation, raise livestock, generate electric power, and increase the population of rather arid areas.

- b. The pacts that were drawn for water allocations to the U.S. and Mexico did not consider environmental needs; no allocations were made for the environment.
- c. Water was supplied to farmers and ranchers at a low price. This has led to inefficient use of this water including growing high water demand crops such as cotton, rice and alfalfa.
- d. Other problems include evaporation, leakage, and siltation from large reservoirs.
- 8. The Three Gorges Dam on the Yangtze River (in China) will be the largest hydroelectric dam and reservoir in the world.
 - a. 1.3 million people are being relocated on some land that will not grow much food.
 - b. The dam will reduce China's dependence on coal and hold back the Yangtze's floodwaters.
 - c. Large cargo-carrying ships will be able to go into China's interior and, thus, reduce current transportation costs.
 - d. The dam is built over a seismic fault and there is worry that millions of people will be killed should the dam collapse.

14-5 Transferring Water from One Place to Another

- A. Water transfer has proven controversial; an example of this is the Aral Sea disaster. Enormous amounts of water have been diverted from the inland Sea to irrigate very dry land to raise cotton and rice.
 - 1. Large-scale water diversion projects, droughts, and high evaporation rates has caused regional ecological, economic, and health disaster.
 - 2. This activity has tripled the salinity of the sea since 1960, the surface area has decreased 58% and 83% of its water has been lost.
 - 3. About 85% of the area's wetlands have been eliminated; roughly half the birds and mammal species have disappeared.
 - 4. Huge areas of the lake bottom are now white salt desert that appears to have caused the extinction of 20 of the 24 native fish species.
 - 5. The fishing industry has disappeared; salty dust from the exposed seabed blows onto fields as much as 190 miles away. Chemicals used to raise crop yields are poisoning the groundwater.
 - 6. The reduction in the size of the sea has changed the area's climate for the worse.
 - 7. Health problems from the toxic dust, salt, and contaminated water plague the people.
 - 8. Crop yields have decreased by 20-50% on almost a third of the area's cropland.
 - 9. Since 1999, the UN and the World Bank have spent about \$600 million to purify drinking water, upgrade irrigation efficiency, and flush salts from croplands.
 - 10. Some artificial wetlands and lakes have been constructed to help restore aquatic vegetation, wildlife, and fisheries. With the various improvements, the water volume in the Aral Sea has stabilized.
- B. California has been transferring water from northern California to the dry southern California area.
 - 1. Southern California is heavily populated while being used for agriculture.
 - 2. Water is used inefficiently and for water thirsty crops in southern California.
 - 3. Opponents to sending more water south state that this would degrade the Sacramento River, disrupt the fisheries and reduce the flushing action that helps to clean San Francisco Bay of pollutants.
- C. Diverting water from the Aral Sea for irrigation has caused the former Soviet Union ecological, economic, and health problems.

14-6 Desalting Seawater, Seeding Clouds, and Towing Icebergs and Giant Baggies

- A. Desalination removes salt from ocean or brackish groundwaters.
 - 1. One desalination method is distillation, which heats salt water until it evaporates and condenses as fresh water; the salts are left behind as solids.
 - a. Desalination is very expensive because of the amount of energy used.
 - b. Desalination produces large amounts of wastewater, which must be disposed of.
 - 2. Another method of desalination is to use reverse osmosis, a method of pumping salt water under high pressure through a thin membrane.
 - 3. Desalination is currently only feasible for rich, coastal areas due to its high cost.
- B. Cloud seeding has been tried by 25 countries. Dry ice or some other particles are seeded into clouds to act as a nucleus for raindrops.
 - 1. This does not work well in very dry areas because there are few clouds in these regions.
 - 2. This method introduces large amounts of the chemicals used into soil and water systems and may harm people and wildlife.
 - 3. Seeding has led to legal disputes over the ownership of cloud water.
 - 4. Some analysts proposed towing icebergs or huge bags of water to arid coastal areas from the Arctic of Antarctica, but there is no technology to do this and the expense would be too great.

14-7 Increasing Water Supplies by Wasting Less Water

- A. 65-70% of water that we now use is wasted through evaporation, leaks, and other losses.
- B. Being more careful of water use will provide water for the foreseeable future.
- C. Reasons for water being wasted are that it is underpriced and we do not reward conservation.
 - 1. Government subsidies should be for improving the efficiency of water use, not to support farmers' energy costs for obtaining water.

2. Lifeline water pricing is a means of giving each household an amount of water for basic needs, excess usage means higher prices.
- D. Improved irrigation techniques could save water.
 1. Use center-pivot low-pressure sprinkler irrigation, which sprays water directly on a crop rather than flood irrigation, which provides water flowing in ditches in crop fields.
 2. Low-energy precision application (LEPA) sprinklers spray water closer to the ground than the center-pivot low-pressure sprinkler, using less energy and less water.
 3. Surge/time-controlled valves on conventional gravity flow irrigation systems send water down irrigation ditches in pulses, rather than in a continuous stream. This can increase efficiency to 80% and reduce water use by 25%.
 4. Use soil moisture detectors to water crops only when they need it.
 5. Drip irrigation/microirrigation systems are the most efficient ways to move small amounts of water to crops. Small holes in a network of perforated plastic tubing deliver drops of water at a slow and steady pace to plant roots.
 - a. It is very efficient with water input reaching crops.
 - b. Drip systems cost 1/10th as much per hectare as conventional drip systems.
- E. In order to waste less water in industries, homes, and businesses, we can:
 1. Replace green laws and ornamental shrubbery with vegetation that needs little water; this is called xeriscaping.
 2. Use drip irrigation.
 3. Raise water prices.
 4. Fix leaks. Mimic nature in dealing with wastes.
 5. Use water-saving toilets and like appliances. Discontinue dumping industrial toxic wastes into municipal sewer systems.
- F. We must use water more sustainably across the globe and reduce demand for water.
 1. We must discontinue wasting water.
 2. Raising water prices would cause less use.
 - a. High Quality is used to flush toxic industrial wastes into sewers, send them to treatment plants where they are not always removed.
 - b. Five principles can be used redesign the way we manage sewage and industrial wastes while saving great quantities of water.
 - 1) Use pollution prevention and waste reduction to decrease industrial wastes produced.
 - 2) Ban discharge of industrial toxic wastes into municipal sewer systems
 - 3) Rely more on waterless composting toilets rather than conventional ones.
 - 4) Return nutrient rich sludge produced at waste treatment plants to the soil as fertilizer.
 - 5) Shift to new ways to treat sewage that mimic the way nature breaks down and recycles nutrients in organic waste material.

14-8 Too Much Water

- A. Flooding occurs when heavy rain and snowmelt causes streams to overflow onto adjacent land, a floodplain.
- B. People settle on floodplains because of fertile soil, ample water, nearby rivers for transportation and recreation, flat land for crops, buildings, highways and railroads.
 1. Natural benefits include a regular supplement of nutrient-rich silt after a flood and a recharge of the groundwater and wetlands areas.
 2. Floods also kill thousands of people and cause great losses by property damage.
 3. Floods are usually considered natural disasters, but since the 1960's several types of human activities have contributed to a sharp rise in deaths and damages.
 4. Removal of water-absorbing vegetation contributes to greater flooding
 5. Draining wetlands removes a needed "sponge" to absorb floodwaters and reduce the severity of floods.
 6. Paving and building on floodplains also increases the chance of more severe floods.
- C. Clearing of forests in the Himalayas and clearing mangrove swamps on the coasts has increased flooding in Bangladesh.
 1. Great floods used to occur about every 50 years or so, but since the 1970's they now occur about every 4 years.
 2. Cutting of forests in the Himalayan foothills increased runoff and carried away vital topsoil.
 3. Floods and cyclones have destroyed many crops and have killed thousands of people and left many others homeless.
 4. Poor families have cleared many mangrove swamps for fuelwood, farming, and aquaculture ponds for raising shrimp, which ultimately led to greater flooding with the loss of those wetlands.
- D. Reduce flood risk by controlling river water flows, preserving and restoring wetlands, identifying and managing flood-prone areas.
 1. Channelization reduces upstream flooding, but increases stream velocity and removes bank vegetation.
 2. Levees or floodwalls can be built along the sides of streams. This method contains/accelerates the stream flow increases possibility for damage downstream.
 3. Building dams can also reduce the threat of flooding by storing water in a reservoir for later slow release.
 4. Preserve existing wetlands and restore degraded wetlands to take advantage of natural flood control.
 5. Identify and manage flood-prone areas.

6. Think carefully about where we choose to live.

14-9 Solutions: Using Water More Sustainably

- A. A blue revolution to conserve water would include several components:
 1. Use technology to irrigate more efficiently and to save water.
 2. Applying economic and political realities, remove subsidies that under-price water while guaranteeing low prices for low-income consumers. Subsidize reducing water waste with rewards.
 3. Develop new waste production and treatment systems that accept only non-toxic materials, use less/no water to treat wastes, return nutrients in waste to the soil, and mimic nature's decomposition and recycling processes.
 4. Leave enough water in rivers to protect wildlife, ecological processes, and the natural ecological services provided by rivers.
- B. Ecological restoration efforts show that wildlife and good ecological health will return.
 1. We can use and waste less water.
 2. Support government policies that result in more sustainable use of water and better ways to treat industrial and household wastes.
 3. Reducing meat consumption will also lower water use and water pollution.

Summary

1. Approximately 0.01% of the earth's water supply is available as fresh water. Management of the world's water supply is a huge, 21st century challenge.
2. Freshwater shortages are caused by dry climate, droughts, desiccation, and water stress. Solutions for this problem include building dams and reservoirs, transport of freshwater between locations, withdrawing of groundwater, and desalination.
3. Advantages of dams and reservoirs include cheap electricity, reduction of downstream flooding, and year-round water for irrigation. Disadvantages include displacement of people and disruption of aquatic systems, and the hydrological cycle.
4. Transferring large amounts of water from one area to another can give stream runoff from water-rich areas to water-poor areas and aid in irrigation of farmland. It can also cause ecological, economical, and health disasters.
5. The advantages of withdrawing groundwater include water for drinking and irrigation, availability and locality, low cost, no evaporation losses, and it is renewable. Disadvantages include aquifer depletion from overpumping, subsidence, pollution, saltwater intrusion, and reduced water flow. Desalination increases the supply of fresh water but is expensive and produces large quantities of wastewater.
6. We can waste less water by lining canals, leveling fields, irrigating at night or using new irrigation techniques, polyculture or organic farming, seasonal farming, irrigating with treated waste water, and importing water-intensive crops and meat.
7. Flooding is caused by heavy rain or melting of snow within a short time. To reduce flood damage or the risk of flooding we must avoid building on floodplains, removing water-absorbing vegetation, or draining wetlands.
8. Methods for achieving more sustainable use of the earth's water include not depleting aquifers, preserving aquatic systems and water quality, integrated watershed management, agreements among regions and countries sharing surface water resources, outside party mediation of water disputes nations, marketing of water rights, raising water prices, wasting less water, decreasing government subsidies for reducing water waste, and slowing population growth.

Chapter 21: WATER POLLUTION

Key Terms (Terms are listed in the same font style as they appear in the text.)

advanced (tertiary) sewage treatment (p. 511)

agricultural activities (p. 494)

bacterial source tracking (BST) (p. 495)

bioreactor (p. 513)

biosolids (p. 512)

bleaching (p. 511)

chemical analysis (p. 496)

Chesapeake Bay (p. 506)

chlorination (p. 511)

composting toilet systems (p. 512)

crude oil (p. 508)

crude petroleum (p. 508)

cultural eutrophication (p. 499)

degradable wastes (p. 502)

discharge trading policy (p. 510)

disinfection (p. 511)

dissolved oxygen (p. 496)

Escherichia coli (p. 495)

eutrophication (p. 499)

Exxon Valdez (p. 508)

fecal coliform bacteria (p. 495)

harmful alga blooms (HABs) (p. 504)

indicator species (p. 496)

industrial facilities (p. 494)

integrated coastal management (p. 507)

living machines (p. 493)

maximum contaminant levels (p. 515)

mining (p. 494)
nitrate ions (p. 503)
nondegradable wastes (p. 502)
nonpoint sources (p. 494)
oligotrophic lake (p. 499)
oxygen sag curve (p. 496)
oxygen-depleted zone (p. 504)
plume (p. 502)
point sources (p. 494)
Prestige (p. 508)
primary sewage treatment (p. 510)
refined oil (p. 508)
refined petroleum (p. 508)
secondary sewage treatment (p. 510)
septic tank (p. 510)
slowly degradable wastes (p. 502)
sludge (p. 512)
wastewater (sewage) treatment plants (p. 510)
water pollution (p. 494)

Outline

21-1 Water Pollution: Sources, Types, and Effects

- A. Water is polluted by infectious bacteria, inorganic and organic chemicals, and excess heat.
 1. Water pollution is any chemical, biological, or physical change in water quality that has a harmful effect on living organisms.
 2. Table 21-1 lists the major classes of water pollutants and their major human sources and harmful effects.
 3. The WHO estimates that 3.2 million people die prematurely each year from waterborne diseases.
- B. Scientists monitor water quality by using bacterial counts, chemical analysis, and indicator organisms.
 1. One method of measuring water quality involves measuring the number of colonies of fecal coliform bacteria present in a water sample.
 2. Drinking water should not contain any colonies/ 100 milliliters and safe swimming water should not have more than 200 colonies/100 milliliters.
 3. A new field of science called bacterial source tracking (BST) uses molecular biology techniques to determine subtle differences in strains of *E. coli* based on their animal host.
 4. Scientists measure biological oxygen demand (BOD), the amount of dissolved oxygen consumed by aquatic decomposers.
 5. Chemical analysis includes checking inorganic and organic chemicals present, sediment content and turbidity of water.
 6. Indicator species are living organisms that are monitored to determine levels of pollution.
 7. Genetic techniques are being used to develop organisms that will glow in the presence of specific pollutants such as toxic heavy metals in the ocean and carcinogens in food.
- C. Water pollution can come from a single source or from a variety of dispersed sources.
 1. Point sources discharge pollutants at specific locations through drain pipes, ditches, or sewer lines into bodies of surface water.
 2. These sources are easy to identify, monitor, and regulate.
 3. Non-point sources are scattered and diffuse and can't be traced to any single site of discharge. Such things as runoff from croplands, livestock feedlots, etc., are non-point sources.
 4. It is difficult and expensive to identify and control these discharges from diffuse sources.
- D. The leading sources of water pollution are agriculture, industries, and mining.
 1. Agricultural activities are the leading cause of water pollution from erosion, and overgrazing, fertilizers and pesticides and excess silt from irrigated soils.
 2. Industrial facilities are another large source of water pollution and mining is a third source.
- E. One of every five people in the world lack access to safe drinking water.
 1. Ninety-five percent of people in developed countries and 74% of people in developing countries have access to clean drinking water.
 2. The UN estimates a cost of \$23 billion a year for 8-10 years to bring clean drinking water and sanitation to those who do not have it.
- F. In a warmer world, too much rain and too little rain can increase water pollution.
 1. Increased moisture with more intense rains can flush harmful chemicals, plant nutrients, microorganisms into waterways.
 2. Prolonged drought can reduce river flows so there is less dilution available. Warmer water contains less dissolved oxygen and can threaten aquatic life in several ways.

21-2 Pollution of Freshwater Streams

- A. Streams can recover from moderate levels of degradable water pollutants if the flows are not reduced
 1. A combination of dilution and biodegradation can allow recovery of stream pollution if they are not overloaded, or have reduced flow due to damming, agricultural diversion, or drought.
 2. The breakdown of pollutants by bacteria creates an oxygen sag curve. Organisms that have a high oxygen demand can't survive in the curve.

3. Volume of the stream, volume of wastes entering, flow rate, temperature, and pH levels all affect how great a sag curve is produced.
- B. Most developed have reduced point source pollution, but toxic chemicals and pollution from non-point sources are still problems.
 1. The U.S. has managed to avoid increase in pollution from point sources in most streams.
 2. There have been several examples of amazing clean-up of rivers such as the Cuyahoga River in Ohio, and the Thames River in Great Britain.
 3. There are still examples of large fish kills and contamination of drinking water from releases of chemicals from industry and mining, and also from non-point runoff of fertilizers and pesticides.
- C. Stream pollution in most developing countries is a serious and growing problem. Half of the world's 500 major rivers are heavily polluted and most of them run through developing countries where waste treatment is minimal or nonexistent.
- D. Religious beliefs, cultural traditions, poverty, little economic development, and a large population interact to cause severe pollution of the Ganges River in India.
 1. About 350 million people live in the Ganges River basin with little treatment of sewage produced by them.
 2. Hindu beliefs add pollution to the air when bodies are cremated and to the water when partially cremated or non-cremated bodies are thrown into the river in order to find their way to heaven.
 3. The government is working to clean up the river by building waste treatment plants in the 29 large cities along the Ganges and by building electric crematoriums on its banks. It has also introduced snapping turtles as body scavengers.
 4. Most of these plans are not yet in place, and religious and cultural conditions are difficult to change.

21-3 Pollution of Freshwater Lakes

- A. Lakes have little flow and so are less effective at diluting pollutants that enter them.
 1. Lakes and reservoirs are often stratified into layers with little vertical mixing and they also have very little flow occurring. It may take from 1-100 years to flush and change water in lakes and reservoirs.
 2. Lakes and reservoirs are much more vulnerable to runoff contamination of all kinds of materials.
 3. Chemical concentrations build up as they pass through the food webs in lakes.
- B. Human activities can overload lakes with plant nutrients that reduce dissolved oxygen and kill some aquatic species.
 1. Natural nutrient enrichment of lakes from runoff is called eutrophication. The amount of natural eutrophication depends on the composition of the surrounding drainage basin.
 2. Natural eutrophication can enrich the abundance of desirable organisms, but cultural eutrophication occurs near urban or agricultural areas and can lead to serious pollution problems.
 3. During hot weather or drought, "blooms" of organisms can reduce lake productivity.
 4. Reduced sunlight, and the subsequent decomposition of the "blooms" increase populations of bacteria and decreases dissolved oxygen available. Fish kills can occur and the problem can become so bad that anaerobic bacteria take over.
 5. The EPA states the about 1/3rd of 100,000 medium to large lakes and 85% of large lakes near major population centers in the AU.S. have some amount of cultural eutrophication.
 6. Cultural eutrophication also occurs in coastal water, enclosed estuaries and bays due to runoff.
 7. Cultural eutrophication can be reduced or prevented by banning or limiting phosphates in detergents and using advanced treatment methods to remove nitrates and phosphates from wastewater, and by use of soil conservation to reduce runoff.
 8. Clean up of lakes includes removing excess weeds, controlling plant growth and pumping air through lakes and reservoirs to avoid oxygen depletion.
 9. Pollution prevention is less expensive than control methods.
- C. An example of lake recovery is Lake Washington in Seattle, Washington.
 1. Recovery occurred in about 4 years once sewage was diverted from the lake because the lake hadn't filled with weeds and sediment, and it had not become shallow. Diversion was to Puget Sound where there is rapid exchange of water to dilute the sewage.
 2. There is concern about Puget Sound due to increased urban runoff and the population of the area grows rapidly.
 3. The best way is to prevent most waste from reaching either body of water.

21-4 Pollution of Groundwater

- A. Groundwater is vulnerable to contamination because it can't effectively cleanse itself and dilute and disperse pollutants
 1. Spilling gasoline, oil, paint thinners and other organics onto the ground can contaminate groundwater.
 2. Experts rate groundwater pollution as a low-risk ecological problem, it is rated as a high-risk health problem.
 3. Contaminated water in the aquifer will slowly flow along and create a plume of contaminated water.
 4. Contaminants in groundwater are not diluted or dispersed because this water moves usually less than 0.3 meter, or 1 foot per day.
 5. Factors such as lower oxygen content, colder temperature of the water and smaller populations of decomposing bacteria mean that cleansing is extremely slow.
 6. It can take hundreds of years to cleanse degradable wastes, nondegradable wastes are there permanently.
- B. The extent of groundwater contamination is generally unknown since there has been little tracking and testing done on aquifers.

1. EPA and U.S. Geological Survey figures state that one or more organic chemicals contaminate about 45% of municipal groundwater supplies in the U.S.
2. Some 26,000 industrial waste ponds and lagoons in the U.S. do not have a liner to prevent toxic waste seepage.
3. A great many of the underground storage tanks containing organic solvents have been found to have leaks.
4. Determining the extent of a leak is costly and the cost of cleanup is more costly yet.
5. In China and India millions of people drink water contaminated with high levels of fluoride that cause back and neck damage and dental problems.
6. Nitrates can also contaminate groundwater, especially in agricultural areas. Nitrates converting to nitrites in the body can cause various forms of cancer, and in babies under 6 months old causes “blue baby syndrome” because the blood can’t carry sufficient oxygen to the cells.
7. Arsenic is released into drinking water when a well is drilled into arsenic-rich soils and rock. WHO estimates that more than 112 million people drink water containing 5-100 times the recommended level of 10 parts/billion.
8. Bangladesh has a serious problem with arsenic, but the UN and several NGOs have started a program to assess wells and mark those that are too contaminated with red paint.
9. The 1-ppb level is considered to still be too high a level for safe drinking water.
- C. Prevention is the most effective and affordable way to protect groundwater from pollutants.
 1. Figure 22-10 lists ways to prevent and clean up groundwater contamination, not an easy task nor cheap.
 2. Underground tanks in the U.S. and some other developed countries are now strictly regulated. Old, leaky tanks are being removed and the surrounding soils are being treated.

21-5 Ocean Pollution

- A. Oceans can disperse and break down large quantities of degradable pollutants if they are not overloaded.
 1. Raw sewage, sludge, oil and some degradable industrial wastes can be degraded, especially in deep-water areas.
 2. Some marine animals have been less affected by pollutants than expected.
 3. There is controversy as to whether this is a viable solution to the problem.
- B. Pollution of coastal water near heavily populated areas is a serious problem.
 1. About 40% of the world’s population lives on or within 62 miles of the coast and this puts a tremendous burden on the wetlands, estuaries, coral reefs and mangrove swamps found along the coast.
 2. In most coastal developing countries and some developed countries sewage is dumped into the sea without treatment. This causes beach pollution and shellfish contamination.
 3. Human viruses (not removed by waste treatment) have been found in coastal waters.
 4. Nutrient enrichment from nitrate and phosphate runoffs have caused harmful algal blooms, called red, brown and green toxic tides. Toxins from these algae kill fish, fish-eating birds and poison seafood.
 5. Extensive non-point runoffs have caused seasonal, large oxygen-depleted zones in temperate coastal waters due to oxygen depletion. The second largest of these zones forms each summer at the mouth of the Mississippi River in the Gulf of Mexico.
 6. Experiments with very fine clay particles are being done to determine if this will pull the algae out of the water and reduce the pollution.
 7. Preventive measures to reduce the number and size of these oxygen-depleted zones include reduction of nitrogen inputs from various sources, planting forest and grasslands to soak up excess nitrogen, restore coastal wetlands, improve sewage treatment, require further reduction of NOx emissions and phase in forms of renewable energy to replace fossil fuels.
- C. Pollutants from six states contaminate the shallow Chesapeake Bay estuary, but cooperative efforts have reduced some of the pollution inputs.
 1. Human activities and increase in the human population in the Bay area has contributed to pollution of the Bay.
 2. A huge drainage basin adds both point and non-point pollutants to the waters. The bay is shallow and so only 1% of the waste that enters is flushed into the Atlantic Ocean.
 3. Commercial harvest of oysters, crabs, and fish have fallen sharply since 1960 because of overfishing, pollution and disease.
 4. Point sources account for about 60% of the phosphates. Nonpoint sources account for about 60% of the nitrates.
 5. In 1983, the U.S. started an integrated coastal management plan that works with citizen groups, state legislatures, and the federal government to reduce pollution using a number of strategies such as reduction of runoff, upgrading waste treatment plants, better monitoring of industrial discharges and banning phosphates from detergents.
 6. Between 1985 and 2000 there has been a 27% decline in phosphorus levels, 16% drop in nitrogen levels and a recovery of grasses growing on the bottom of the bay.
 7. Reduction in funding has slowed the progress of cleanup in the bay, but it demonstrates what can be done with cooperation of diverse groups.
- D. Introduction of disease-resistant oysters into the Chesapeake Bay could greatly reduce water pollution because oysters filter algae and silt from water.
 1. Oysters were once a natural filtration system for the bay and recycled the entire volume of the bay in 3-4 days.
 2. Over-harvesting, coupled with two parasitic oyster diseases reduced the oyster population to about 1% of its population. It now takes the oyster population about a year to filter the bay’s water.

3. Several ways to reintroduce oysters into the bay are being considered.
- E. Parts of the world's oceans are dump sites for a variety of toxic materials, sewage, and garbage from ships.
 1. Dumping industrial wastes off U.S. coasts has stopped, but large quantities of dredge spoils are still legally dumped at 110 sites in the Atlantic, Pacific, and Gulf Coasts of the U.S.
 2. Many countries also dump sewage sludge into the ocean.
 3. Since 1992, the U.S. has banned this practice.
 4. Fifty countries with at least 80% of the world's merchant fleet have agreed not to dump sewage and garbage at sea.
 5. The London Dumping Convention of 1972 stated that 100 countries agreed not to dump highly toxic pollutants and high-level radioactive wastes in the open sea. In 1994 it became a permanent ban.
- F. Most ocean pollution comes from human activities on land such as changing and dumping motor oil.
 1. Crude petroleum and refined petroleum reach the ocean from a number of sources.
 2. More oil is actually released from day-to-day activities such as oil wells off-shore, leaks from pipelines, tankers being washed out, loading and unloading of tankers and leaks from pipelines and storage tanks.
 3. Studies show that most ocean oil pollution comes from activities on land.
- G. Oil pollution can have a number of harmful ecological and economic effects, but most disappear within 3-15 years.
 1. A number of factors are important when determining the effects of oil on ocean ecosystems.
 2. Volatile organic hydrocarbons in oil kill some aquatic organisms, especially the larval forms.
 3. Tarlike globs coat bird feathers and fur of marine mammals and these organisms then either drown or die from loss of body heat.
 4. Bottom-dwelling organisms are killed when heavy components sink to the sea floor.
 5. Recovery from crude oil exposure may only take 3 years for most organisms, but recovery from refined oil products takes 10-15 years. Recovery in cold waters takes longer.
 6. Oil slicks on shore also negatively impact the local economy.
- H. Only about 15% of the oil spilled can be recovered with current techniques, so prevention is the best strategy.
 1. Methods available include mechanical methods such as floating booms, skimmers and absorbent devices.
 2. Chemical methods use coagulating agents for clumping oil and dispersing agents to break up slicks. Fire can also burn off floating oil.
 3. Biological methods are being developed to utilize bacteria that are able to degrade oil. It is less expensive and more effective than other methods.
 4. The Oil Pollution Act of 1990 set up a trust fund of \$1million per spill for cleanup. By 2015 all oil tankers operating in U.S. waters must be double hulled.
- I. Preventing or reducing pollution from the land and from streams is the key to protecting the oceans.
 1. Figure 22-14 lists ways suggested to prevent and reduce excessive pollution of coastal waters.
 2. Ocean pollution control must be linked with land-use and air pollution policies to be effective.

21-6 Preventing and Reducing Surface Water Pollution

- A. Reduce non-point pollution by preventing it from reaching bodies of surface water.
 1. Agricultural non-point pollution can be reduced by reducing soil erosion, reforestation of watersheds, keep cover crops on farmland, reduce fertilizer use or use slow-release fertilizer and plant buffer zones between farmland and surface water nearby.
 2. Rely more on biological control methods rather than pesticides.
 3. In 2002 a federal court forced EPA to uphold the intent of the Clean Water Act and require 15,500 of the largest feedlots to apply for EPA permits. This means that these "factories" will have to obey the same pollution controls that are used by other industries since 1972.
 4. Research on how to use animal wastes more effectively is underway.
- B. Most developing countries do not have laws to set water pollution standards.
 1. The Clean Water Act sets standards for allowed levels of key water pollutants and requires polluters to obtain permits that specify the amounts of pollutants they can discharge into aquatic systems.
 2. EPA is experimenting with a discharge trading policy that would allow a permit holder to purchase unused credits from another permit holder.
 3. There are good and bad point to credit trading, such as a possible buildup of pollutants in areas where credits are bought.
 4. Most cities in developing countries discharge 80-90% of untreated sewage into rivers, lakes and streams used for drinking water, bathing, and washing clothes.
- C. Septic tanks and various levels of sewage treatment can reduce point-source water pollution.
 1. About 1/4th of homes in the U.S. are served by septic tanks.
 2. Most urban areas are served by sewage treatment plants.
 3. Some 1,200 cities have combined storm runoff and sewer lines because it is cheaper. These systems can overflow and discharge untreated sewage directly into surface water with too many users or when there is a heavy storm.
 4. Aging sewer systems, and combined sewer systems in the U.S. are estimated to cost \$10 billion a year for 10 years to install dual systems, add capacity, and repair the aging sewer network.
 5. Raw sewage generally undergoes one or two levels of treatment.

6. Primary sewage treatment is a physical process that removes grit, floating objects and suspended solids. A settling tank allows suspended solids to settle out as sludge.
 7. Primary treatment removes about 60% of suspended solids and 30-4-% of organic wastes, but no phosphates, nitrates, salts, radioisotopes, or pesticides.
 8. Secondary sewage treatment is a biological process where aerobic bacteria remove up to 90% of dissolved and biodegradable, oxygen-demanding organic wastes.
 9. A combination of primary and secondary treatment removes 95-97% of the suspended solids and oxygen-demanding organic wastes, 70% of most toxic metal compounds, 70% of phosphorus, 50% of nitrogen and 5% of dissolved salts.
 10. Most U.S. cities have combined primary and secondary sewage treatment plants. A number of cities have been in violation at times, and 34 East Coast cities screen out large floating objects and discharge sewage into coastal waters.
 11. Tertiary sewage treatments is a third level of cleanup. Here a combination of chemical and physical processes remove specific pollutants left by the other methods. This is expensive and used to treat only 5% of the wastewater in the U.S.
 12. Water is bleached to remove colors and then disinfected to kill disease-causing bacteria and some viruses. Chlorination is the usual method of disinfection.
 13. Ozonation and use of ultraviolet light is increasing as the method of disinfection.
- D. Sewage sludge can be used as a soil conditioner, but may cause health problems if it contains infectious bacteria or toxic chemicals.
1. Sludge is a thick, gooey mixture of bacteria, solids and chemicals and metals when industrial and household wastes are combined.
 2. Some sludge undergoes anaerobic digestion to decompose the organic materials and produce compost.
 3. About 36% of these biosolids are used to fertilize farmland, forests, golf courses, cemeteries, etc. The rest is added to landfills or incinerated.
 4. Composting sludge to recycle the plant nutrients makes good ecological sense, but removing infectious bacteria, toxic chemicals and metals is expensive and seldom done in the U.S.
 5. It is thought that a number of health problems may be due to using sludge to fertilize crops in the U.S.
- E. Preventing toxic chemicals from reaching sewage treatment plants would eliminate these from sludge and water that is discharged.
1. Require industries and businesses to remove toxic and hazardous wastes from water sent to sewage treatment plants, encourage reduction or elimination of toxic chemical use and waste.
 2. Have households switch to waterless composting toilet systems maintained by professionals. These systems would be cheaper to install and maintain since they do not need underground pipes.
- F. Natural and artificial wetlands and other ecological systems can be used to treat sewage.
1. These systems are a low-tech, low-cost alternative to expensive waste treatment plants.
 2. Sewage goes to sedimentation tanks where solids settle as sludge that is removed. The liquid is pumped to oxidation ponds, bacteria break down remaining wastes. After a month, water is released to an artificial marsh where plants and bacteria filter and cleanse.
 3. Mark Nelson developed a small, low-tech, inexpensive artificial wetland system for use in developing countries at hotels, restaurants, and homes. It removes 99.9% of fecal coliform bacteria and over 80% of the nitrates and phosphates from sewage. The water thus cleaned could be used for garden irrigation, flush toilets and save water.
 4. Genetic engineering is developing a bioreactor where modified bacteria will consume pesticides.
 5. Without large investments in building adequate sanitation facilities more people will have inadequate sanitation.
- G. Water pollution laws have significantly improved water quality in many U.S. streams and lakes, but more needs to be done.
1. Between 1992 and 2002 American communities served by water systems meeting federal guidelines increased from 79% to 94%.
 2. Fishable and swimmable streams increased from 36% to 60% of those tested.
 3. Topsoil loss through runoff was cut by 111 billion metric tons annually.
 4. Annual wetland losses decreased by 80%.
 5. In 2000, 40% of streams and 45% of lakes surveyed were too polluted for swimming or fishing. This figure could be much higher since only 19% of stream lengths, 43% of lake and reservoir areas, and 36% of estuaries have been tested for water quality.
 6. Animal waste and waste lagoons continue to be a problem.
 7. Often fish caught in streams and lakes are unsafe to eat because of high levels of pesticides, mercury and other toxic substances.
 8. In 2003 the EPA found that at least half of the 6,000 largest industrial facilities have been illegally discharging toxic and biological wastes into waterways for years with impunity.
- H. There is controversy of strengthening the Clean Water Act.
1. A 2001 report by EPA's inspector general calls for strengthening the Clean water Act.
 2. Suggestions include increased funding, increased authority to control nonpoint pollution, modernize monitoring system, increase compliance with the law and strengthen programs.
 3. Work on integrating watershed and airshed planning to protect ground and surface water sources.
 4. Halt the loss of wetlands, increase standards for wetland restoration and create new wetlands before filling existing ones.

5. Farmers feel they should be compensated for property value losses that result from federal regulations protecting wetlands.
- 21-7 Drinking Water Quality
- A. Centralized water treatment plants can provide safe drinking water for city dwellers. Water is settled, filtered and chlorinated to meet government drinking standards.
 - B. The U.S. is upgrading on water purification and delivery systems. This is such a vast system that it is hard to secure, but also difficult to adequately poison. Both chemical and biological indicators are being developed to indicate a contamination problem.
 - C. Several simple, inexpensive ways for individuals and villages to purify drinking water have been developed.
 1. Exposure of contaminated water to intense sunlight in a clear plastic bottle is one method. It takes as little as 3 hours to kill bacteria in the sun and heat.
 2. Cholera incidences have been cut in half in Bangladesh by filtering water through strips of cloth.
 3. A third method is to add a small amount of chlorine to a plastic or clay storage vessel with a small mouth, cap, and a spigot. This has cut the rate of diarrheal disease in half in countries where it is used.
 - D. About 54 countries have standards for safe drinking water.
 1. Levels have been established called maximum contaminant levels, for any pollutants that may adversely affect human health.
 2. Privately owned wells don't have to meet these standards.
 3. Health scientists want the standards to be strengthened.
 4. Certain industries want to weaken the Safe Drinking Water Act.
 - E. Some bottled water is not as pure as tap water and costs much more.
 1. Bottled water is vastly more expensive than tap water and about 1/4th of it is tap water, 1/3rd of it is contaminated with bacteria, and various harmful organic chemicals contaminate about 1/5th of it.
 2. Use of bottled water also can cause environmental problems from all the throw away plastic bottles.
 3. Manufacture of the bottles releases toxic gases and liquids.
 4. Before buying costly home purification systems, have water tested by an independent company.
 5. Be sure to check out claims by a company that they are EPA approved because the EPA registers devices, but neither tests nor approves them.
 - F. We need to shift priorities from controlling to preventing and reducing water pollution and will require bottom-up political action by individuals and groups.
 1. Bottom-up political pressure on elected officials has reduced point-source water pollution.
 2. A shift needs to be made to how we can prevent water pollution in the first place. See figure 22-19.
 3. Prevention of water pollution will take action from individuals and groups to pressure elected officials.

Summary

1. Water pollutants include infectious agents from human or animal wastes, oxygen-demanding wastes from sewage, paper mills, and food processing, inorganic chemicals from surface runoff, industrial effluents, and household cleaners, organic chemicals from oil, plastics, pesticides, and detergents, sediment from erosion, and thermal pollution from power plant cooling.
2. Water pollution problems in streams and lakes relate to chemical and biological pollutants with the greater problems being cultural eutrophication.
3. Groundwater pollution is caused by leaks from waste ponds and underground storage tanks, chemical dumping or spilling, surface runoff, and fertilizers. It can be prevented by finding substitutes for toxic chemicals, installing monitoring wells near landfills and underground tanks, requiring leak detectors on underground tanks, banning hazardous waste disposal in landfills and injection wells, and storing harmful liquids in aboveground tanks.
4. Water pollution of oceans relates to nitrogen oxide from industry and cars, heavy metals from effluents, toxic sediment, sewage, runoff of pesticides, manure, fertilizers, and red tides from excess nitrogen.
5. Reduction or prevention of water pollution can be achieved through reduction of use of toxic pollutants, banning of ocean dumping of sludge, protection of sensitive areas from oil drilling and oil transport, regulation of coastal development, and regulation of sewage treatment.
6. The U.S. Safe Drinking Water Act of 1974 requires that drinking water contain less than the maximum contaminant levels for any pollutants that may have adverse effects on human health. Restructuring of water treatment systems, enforcing current regulations, banning the use of lead in new structures, and chemical tests and biological indicators can be used to make drinking water safer.