

*What Is Water Pollution?

*Any physical, biological or chemical change in water quality that adversely affects living organisms or makes the water unsuitable for desired uses



Point Sources

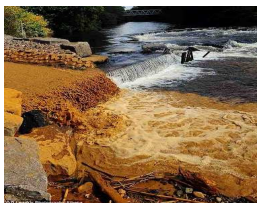
*Discharged from a specific point into the environment through pipes, sewers or ditches from specific factories



Non-point sources

*Land pollutants entering a body of water from large areas rather than a single point

- *Agricultural runoff
- *Mining wastes
- *All types of Urban runoff



*Water Pollution

*Nonpoint sources continued

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

* Types and Effects of Water Pollution

* Infectious Agents

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

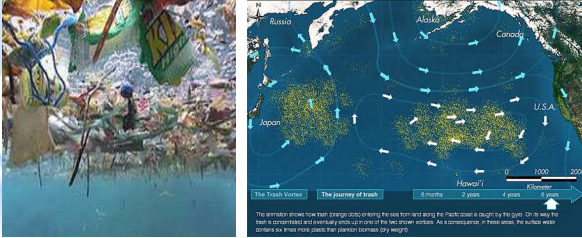
* Infectious Agents (cont.)

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



*Great Pacific Garbage Patch

- * An accumulation of plastic, garbage that are in the ocean.
- * Twice the size of Texas.



<https://www.youtube.com/watch?v=017bBeXhYz4>

Ocean Trash Video

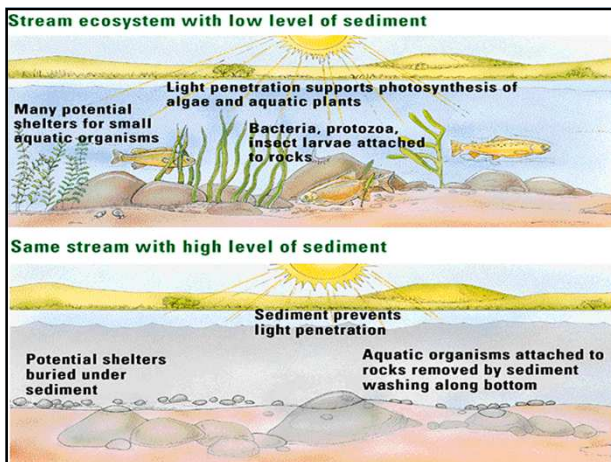
Turbidity (Sediment) Pollution

- * Largest pollutant by volume
- * Caused by Erosion
- * Reduces light penetration in aquatic systems
- * Fills waterways, reservoirs, wetlands



*Sediment

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



Pathogens = Disease-Causing Agents

(virus, bacteria, fungi, etc)

- Sewage from
 - Broken Sewer lines
 - Lack of Sanitation

- *25,000,000 deaths yearly
- *2/3 of child deaths
- *80% of sickness in developing countries



***Sewage is the most serious water pollutant in terms of health effects**

Pathogens Carried by Sewage	
Disease	Infectious Agent
Typhoid fever	<i>Salmonella typhi</i> (bacterium)
Cholera	<i>Vibrio cholerae</i> (bacterium)
Salmonellosis	<i>Salmonella</i> species (bacteria)
Diarrhea	<i>Escherichia coli</i> , <i>Campylobacter</i> species (bacteria)
Infectious hepatitis	Hepatitis A virus
Polioyelitis	Poliovirus
Dysentery	<i>Shigella</i> species (bacteria) <i>Entamoeba histolytica</i> (protozoan)
Giardiasis	<i>Giardia intestinalis</i> (protozoan)
Numerous parasitic diseases	(Roundworms, flatworms)

***Detecting Sewage in Drinking Water**

***E. coli* is used as an indicator species to detect contaminated water supplies because it grows only in human and animal feces**

Septic effluent percolates to the water table

Well, Septic tank, Drain field, Water table, Percolation, Evaporation, Well point

One colony of bacteria per 100ml is considered unsafe to drink

***Inorganic Chemicals**

***Heavy metals:**

- *Mercury, Cadmium, Nickel, Selenium
- *Sources: Lead pipes, gold mining waste, industrial processes, naturally occurring in soil.
- *Neurotoxins
- *Persist in the environment.

"Mad as a hatter"

* Inorganic Pollutants

* Metals

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

* Other Metal Contaminants in Water

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

* Inorganic Pollutants

* Nonmetallic Salts

- * Many salts (including those selenium and arsenic-based) that are non-toxic at low concentrations can be mobilized by irrigation and concentrated by evaporation, reaching levels toxic to plants and animals.
- * Leaching of road salts has had detrimental effect on many ecosystems.
- * Arsenic in northeastern India and western Bangladesh groundwater

* Acids

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

* Acids and Bases

* Produced during leather tanning, metal smelting, plating, petroleum distillation.

Acid Mine Drainage - HNO_3 and H_2SO_4 coming from abandoned mine sites.



* Organic Compounds

- * Pesticides, oils, plastics, pharmaceuticals, pigments, detergents, cleaning solutions, and paints
- * Persist in water.



* Organic Chemicals

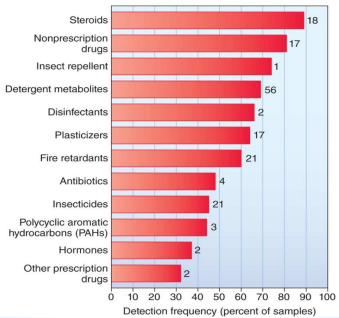
*Thousands of natural and synthetic organic chemicals are used to make pesticides, plastics, pharmaceuticals, pigments, and many other day-to-day products.

*Two most important sources of toxic organic chemicals in water are:

- *Improper disposal of industrial and household wastes
- *Runoff of pesticides from fields, roadsides, golf courses, and lawns.

* Detection Frequency of Organic Contaminants

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* Oil Pollution

*Few coastlines in the world remain uncontaminated by oil pollution.

*3 to 6 million tons of oil are released into ocean each year, about half of which is due to maritime transport.

*Major oil spills from transport, military conflict, & oil drilling in risky locations such as the North Sea

*There are plans to drill in seismically active California and Alaskan coasts.

*Oil Spill Clean-up



The image is split into two parts. The left part shows a dark, polluted body of water with a person in a yellow safety vest and a boat. The right part shows a person's hands washing a bird in a metal tub.

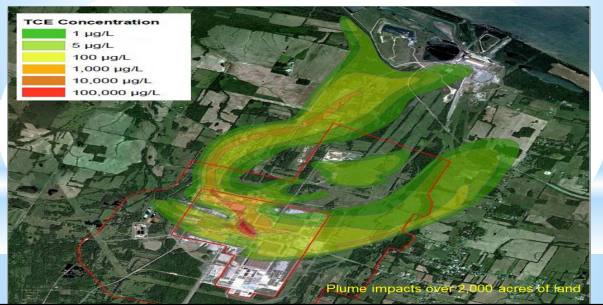
Largest environmental disaster in US history.

- BP Deepwater Horizon spill in Gulf of Mexico.

*Groundwater Pollution

* A MTBE (gasoline additive) spill contaminated 50% of ground water supplies of Santa Monica. City had to purchase replacement water.

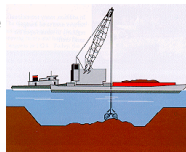
* Groundwater flowing toward the ocean.



*Minimata Japan

* 1956: **Minimata Disease** = loss of motor control resulted in partly paralyzed and contorted bodies.

- 1932 *Chisso Corp.* began releasing a effluent with **Mercury** into the bay.
- 1963: "disease" traced to mercury from Chisso which was forced to pay victims \$3.2 million
- Chisso had to *dredge bay* to remove mercury laden soil.
- 1997: bay declared safe for fishing



* Selenium at Kesterson National Wildlife Refuge

MAJOR ECOLOGICAL RISKS FROM SELENIUM

The diagram illustrates the flow of selenium from sources like rocks and soil into water and food chains, leading to ecological risks for raptors, waterbirds, fish, and mammals. It includes photographs of dead birds with selenium levels (S-313, S-9, S-35, S-302) and a map of the Kesterson National Wildlife Refuge area in Nebraska, showing locations like Patterson, Double T Acres, and Kesterson NWR.

* Toxic Tides

- *Red tides - dinoflagellate blooms - have become increasingly common in slow-moving and shallow waters.
- *Dinoflagellates are single-celled organisms that swim with 2 whip-like flagella.
- **Pfiesteria piscicida* is a toxic dinoflagellate recently recognized.
- *Found in marine zones that are polluted due to eutrophication

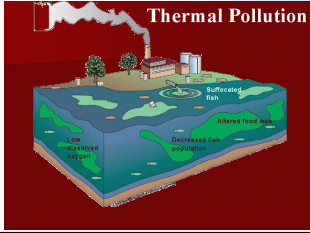
* Radioactive Waste

- *Sources -
 - *high level nuclear waste,
 - *natural uranium and radium
- *Effects -
 - *Increases the risk of developing cancer and kidney disease.
- *Control -
 - *can be removed through reverse osmosis
 - *The Safe Drinking Water Act requires testing.

6 Tanks leaking at nuclear site in Washington - 2/23/2013 - 150 to 300 gallons a year

*** Thermal Pollution**

- * Source -
 - * Effluent from industrial plants.
- * Effect -
 - * Warmer water holds less dissolved oxygen
 - * Lack of oxygen can effect food web - how?



Temperature (°C)	Oxygen Solubility (mg/L)
0	14.6
5	12.8
10	11.3
15	10.2
20	9.2
25	8.6
100	0

*** Thermal Pollution**

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

*** Thermal Pollution (cont.)**

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

* Oxygen-demanding Wastes

- * Major human sources—sewage, animal feed lots, paper mills
- * Effects—depletion of dissolved oxygen leading to death of aquatic organisms
- * **BOD: Biological Oxygen Demand**
 - * Biological Oxygen Demand (BOD)—amount of dissolved oxygen needed by aerobic decomposers to break down the organic matter in a certain volume of water in a 5-day incubation period at 20 degrees C

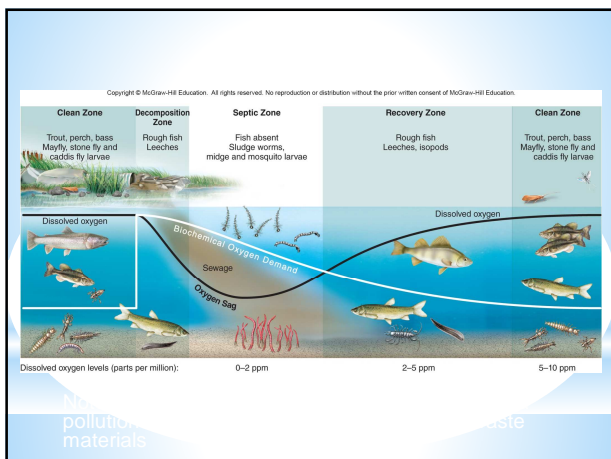
Water Quality	ppm of DO at 20°C
Good	8-9
Slightly polluted	6.7-8
Moderately polluted	4.5-6.7
Heavily polluted	below 4.5
Gravely polluted	below 4

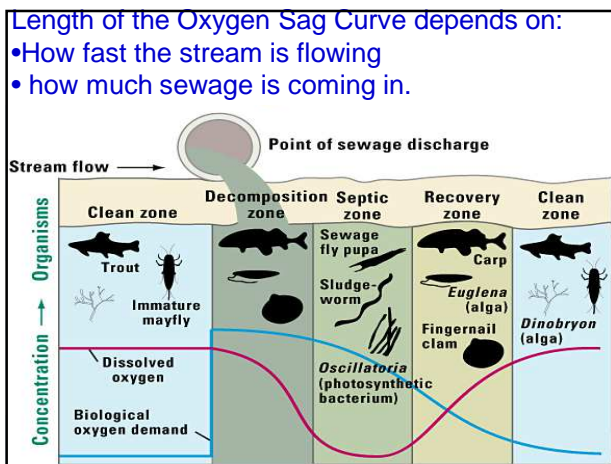
* Oxygen-Demanding Wastes

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

* Oxygen-Demanding Wastes

- * **Biochemical Oxygen Demand** - amount of dissolved oxygen consumed by aquatic microorganisms. Used as a test for organic waste contamination from sewage, paper pulp, and food waste.
- * **Dissolved Oxygen Content** - measure of dissolved oxygen in the water
- * Effects of oxygen-demanding wastes on rivers depend on volume, flow, and temperature of river water.



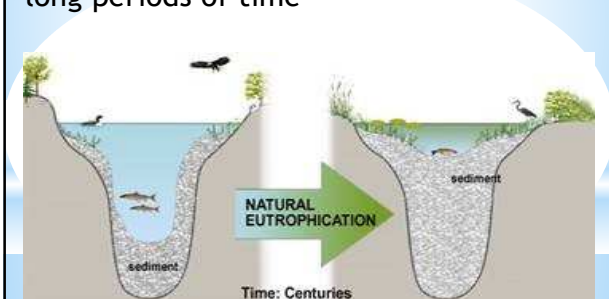


*** Plant Nutrients and Eutrophication**

- * **Oligotrophic** - bodies of water that have clear water and low biological productivity
- * **Eutrophic** - bodies of water that are rich in organisms and organic material
- * **Eutrophication** - process of increasing nutrient levels and biological productivity, a normal part of successional change in most lakes
- * **Cultural Eutrophication** - increase in biological productivity caused by human activities
- * Algal “blooms” often result and the decomposition of the algae depletes oxygen in the water.

* Natural Eutrophication

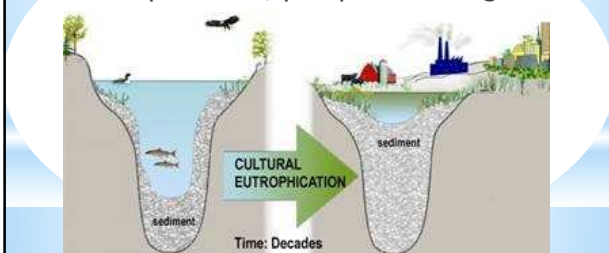
* Natural eutrophication is a slow process that leads to marshes and wetlands over long periods of time



* Cultural Eutrophication

* Humans speed up eutrophication by adding inorganic nitrates, phosphates, etc.

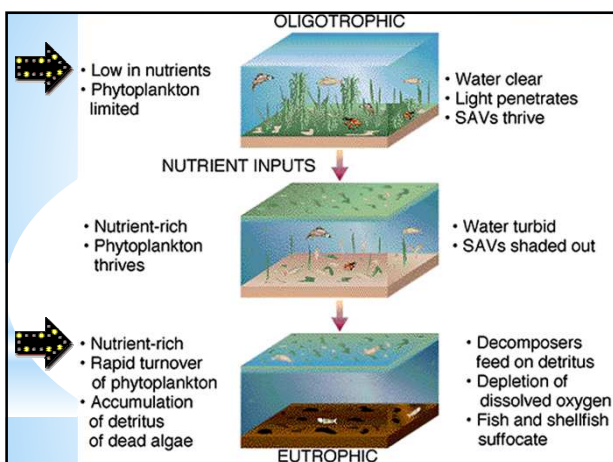
* Source: fertilizer runoff from farms and industrial processes, phosphate detergents.

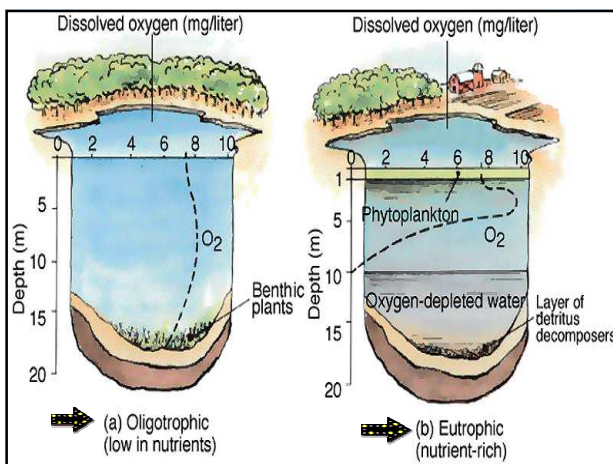


* Steps of Eutrophication

1. N/P are added to water
2. Cause an algae bloom
3. Algae begins to die and sink
4. Dead algae is food for bacterial decomposers - BOD increases
5. Oxygen decreases
6. Anaerobic bacteria increase and produce hydrogen sulfide and methane.







*Controlling Eutrophication

- * Reduce N and P flowing into waterways.
- * Biofiltration - sewage can flow through wetlands designed to remove N and P.
- * Detergents and fertilizers should be used sparingly and be **phosphate-free** when possible

PHOSPHATE FREE

Palmolive ECO

*Water Pollution Solutions

- *Control Industrial Runoff
 - *Reduce runoff from farms, logging
 - *Reclaim, clean up water
- *Control Urban Runoff
 - *Golf courses, lawns, pets
 - *Reduce use
- *Control Acids From Mines
 - *Revegetation and sediment ponds
- *Protect Wetlands
 - *Protect and revegetate
- *Ban or Regulate Phosphate Detergents



*Process This

1. Make a list of possible water pollution solutions.
2. List the steps of cultural eutrophication.
3. How have you personally benefitted from the Clean Water Act?

*Water Quality Today

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

* Areas of Progress

*In 1998, EPA switched regulatory approaches. Rather than issue standards on a site by site basis, the focus is now on watershed-level monitoring and protection.

*States are required to identify waters not meeting water quality goals and develop **total maximum daily loads** for each pollutant and each listed water body.

* Remaining Problems

*Some of the greatest impediments to achieving national goals in water quality are sediment, nutrients, and pathogens, especially from non-point discharges.

*About three-quarters of water pollution in the U.S. comes from soil erosion, air pollution fallout, and agricultural and urban runoff.

*Cattle in feedlots produce 144 million tons of manure

*Pet waste does not go through sewage treatment

* Other Countries Also Have Water Pollution

*Sewage treatment in wealthier countries of Europe generally equals or surpasses the U.S.

*In Russia, only about half of the tap water supply is safe to drink and in China 70% of surface waters are unfit for consumption.

*The poorest countries of South America, Africa, and Asia have disastrous water quality due to poverty, population growth, and shift of polluting industries from countries where laws are strict to where they are lax.

*The Yamuna River and 2/3 of the other surface waters in India are so polluted that it is dangerous to even have contact with the water.

* Is Bottled Water Safer?

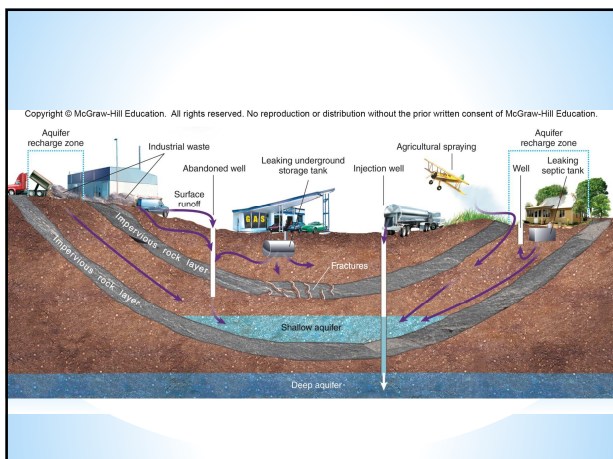
- * Americans buy 28 billion bottles of water annually
 - * Adds up to around \$15 billion
- * Worldwide = 42 billion gallons
- * Municipal water is often safer than bottled because most large cities test their water supplies every hour for up to 25 different chemicals
- * 80% of water bottles purchased in the United States end up in landfills

* Groundwater Is Hard To Monitor and Clean

- * About half the U.S. population and 95% of rural residents depend on underground aquifers for drinking water.
- * For decades, groundwater was assumed impervious to pollution, and artesian well water was considered the definitive standard for water quality, but that is no longer true.

* Groundwater and Drinking Water

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

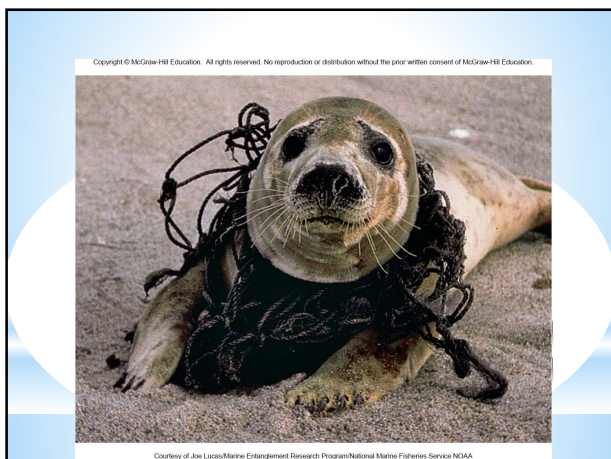


*** Groundwater and Drinking Water**

- * In addition to groundwater, contaminated surface waters can make drinking water unsafe.
- * 2008 EPA data show that 30 million people in the U.S. get water from community systems that don't meet all health-based drinking water standards
- * An estimated 1.5 million Americans fall ill from fecal contamination annually
 - * *Cryptosporidium* outbreaks
 - * Milwaukee - in 1993, 400,000 became ill and 100 died

*** There Are Few Controls On Ocean Pollution**

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



* Source Reduction Can Reduce Water Pollution

- Cheapest and most effective way to reduce pollution is avoid producing it or releasing it into the environment.
- * Studies show as much as 90% less road salt can be used without significantly affecting safety.
- * Carefully dispose of oil
- * Recover metals from industrial waste and sell them
- * Elimination of the use of lead in gasoline led to a significant decline of lead in US surface waters

* Land Management Controls Nonpoint Sources

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

* Signs Can Remind People Where Wastes Can End Up



* Human Waste Disposal

*More than 500 pathogenic bacteria, viruses, and parasites can travel from human or animal excrement through water.

* Natural Processes

*In many poor countries, outdoor urination and defecation is the norm.

*When population densities are low, natural processes can quickly eliminate waste, but in cities this is unworkable.

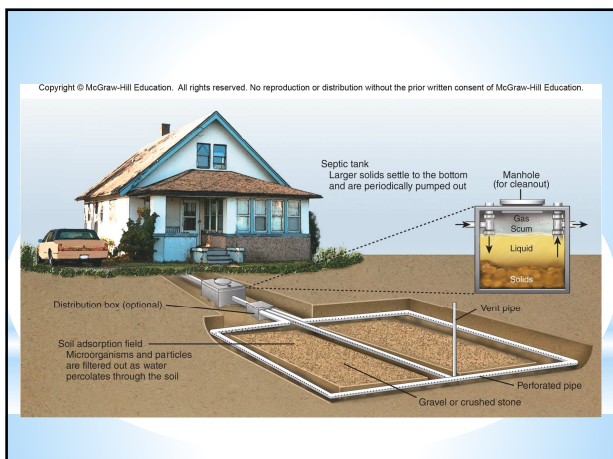
*A significant proportion of dust in Mexico City is actually dried feces.

* Human Waste Disposal

*In many countries, especially in Asia, "night soil" (human and animal waste) is spread on fields as fertilizer, but it can cause disease.

*Until about 70 years ago, most rural areas in the U.S. depended on outhouses, which contaminated drinking water supplies.

*Development of septic fields which clean water by aeration and remove excess nutrients through bacterial action. Solids are pumped out and taken to a treatment plant.



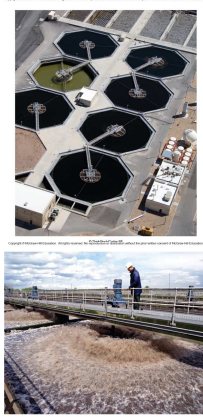
* Municipal Sewage Treatment

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

* Municipal Sewage Treatment (cont.)

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

Municipal Sewage Treatment



* Low-Cost Waste Treatment

* Effluent Sewerage

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

* Natural or Artificial Wetlands

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

* Water Remediation

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

* Ecological Engineering

***Ocean Arks International** designs vessels that combine living organisms with containment. In a machine, water flows through a series of containers, each with a distinctive biological community. Waste from one vessel becomes the food for the next vessel.

*Final effluent is technically drinkable, but more often used for irrigation or flushing toilets.

* Water Legislation

***U.S. Clean Water Act (1972)**

*Goal was to return all U.S. surface waters to “fishable and swimmable” conditions

*For point sources, discharge permits and **best practicable control technology (BPT)** are required.

*Set goals of **best available, economically achievable technology (BAT)** for zero discharge of 126 priority toxic pollutants

***Clean Water Act of 1972** (amended 1977)

***Goal:** Restore and maintain the

*Chemical, Physical, and Biological integrity of US waters

***Established national effluent standards** prohibits the discharge of a pollutant from a point source to waters of the U.S. without a permit.

*Set standards for wastewater and all surface water contaminants.



* Clean Water Act (1972)

* Areas of Contention

- * Draining or filling of wetlands is regulated by Section 404
- * Farmers and developers consider this the taking of private lands

* Unfunded Mandates

- * State or local governments must spend monies to comply with regulations but are not repaid by Congress.
- * Agricultural runoff and urban nonpoint pollution is the largest source of surface water degradation, but regulation remains a problem.

* Other Important Water Legislation

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

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Table 18.2 Some Important U.S. and International Water Quality Legislation	
1.	Federal Water Pollution Control Act (1972). Established uniform nationwide controls for each category of major polluting industries.
2.	Marine Protection Research and Sanctuaries Act (1972). Regulates ocean dumping and established sanctuaries for protection of endangered marine species.
3.	Ports and Waterways Safety Act (1972). Regulates oil transport and the operation of oil handling facilities.
4.	Safe Drinking Water Act (1974). Requires minimum safety standards for every community water supply. Among the contaminants regulated are bacteria, nitrates, arsenic, barium, cadmium, chromium, fluoride, lead, mercury, silver, pesticides, radioactivity and turbidity also are regulated. This act also contains provisions to protect groundwater aquifers.
5.	Resource Conservation and Recovery Act (RCRA) (1976). Regulates the storage, shipping, processing, and disposal of hazardous wastes and sets limits on the sewerage of toxic chemicals.
6.	Toxic Substances Control Act (TOSCA) (1976). Categorizes toxic and hazardous substances, establishes a research program, and regulates the use and disposal of poisonous chemicals.
7.	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (1980) and Superfund Amendments and Reauthorization Act (SARA) (1984). Provide for sealing, excavation, or remediation of toxic and hazardous waste dumps.
8.	Clean Water Act (1985) (amending the 1972 Water Pollution Control Act). Sets as a national goal the attainment of "fishable and swimmable" quality for all surface waters in the United States.
9.	London Dumping Convention (1990). Calls for an end to all ocean dumping of industrial wastes, tank washing effluents, and plastic trash. The United States is a signatory to this international convention.

*The End
Pasig River Manilla, Phillipines