Water Pollution

Chapter 14

VI. Pollution (25 -30%)

A. Pollution Types
B. Impacts on the Environment and Human Health
C. Economic Impacts

Module 41: Wastewater from Humans and Livestock

After this module you will be able to……

1) Discuss the three major problems caused by wastewater pollution
2) Explain the modern technologies used to treat wastewater

Water Pollution

Water pollution is the contamination of streams, rivers, lakes, oceans, or groundwater with substances produced through human activity.

Water pollution occurs from a wide range of substances from various sources. The broad range of pollutants that can be found in water includes human and animal waste, inorganic substances, organic compounds, synthetic organic compounds, and non chemical pollutants.

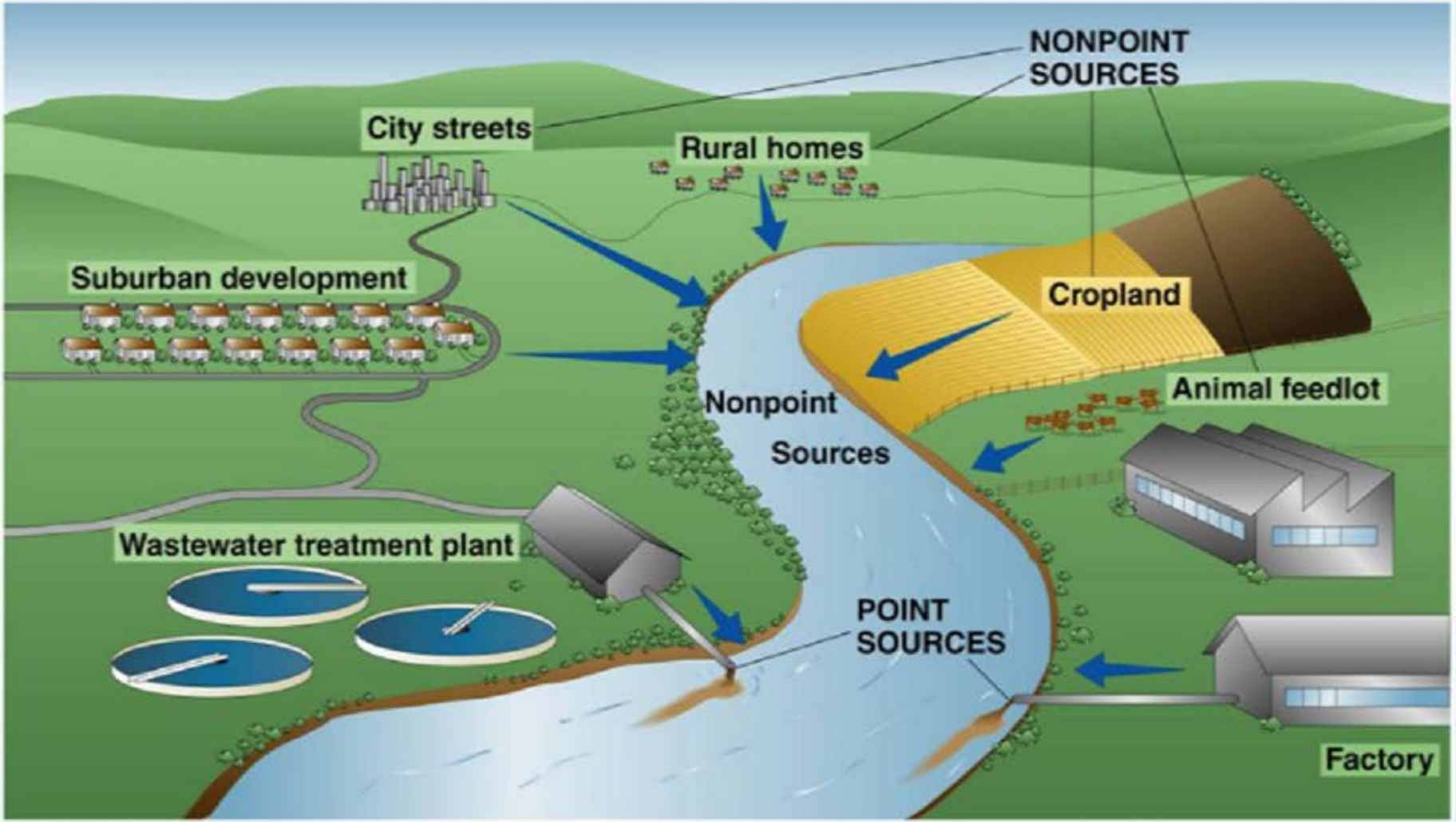
Wastewater from Humans and Livestock

Wastewater is water produced by livestock operations and human activities, including human sewage from toilets and gray water from bathing and washing of clothes and dishes.

Pollution can come from *point sources* or *nonpoint sources*.

A **point source** is a distinct location from which pollution is directly produced. This can be factories that pumps waste into a nearby stream, a sewage treatment plant that discharges wastewater from its pipes into the ocean.

A **nonpoint source** is a more diffuse area that produces pollution. This can be a farming region, a suburban community with many lawns and septic systems, or storm runoff from parking lots.



Wastewater from Humans and Livestock

Environmental scientists are concerned about wastewater as a pollutant for three major reasons…

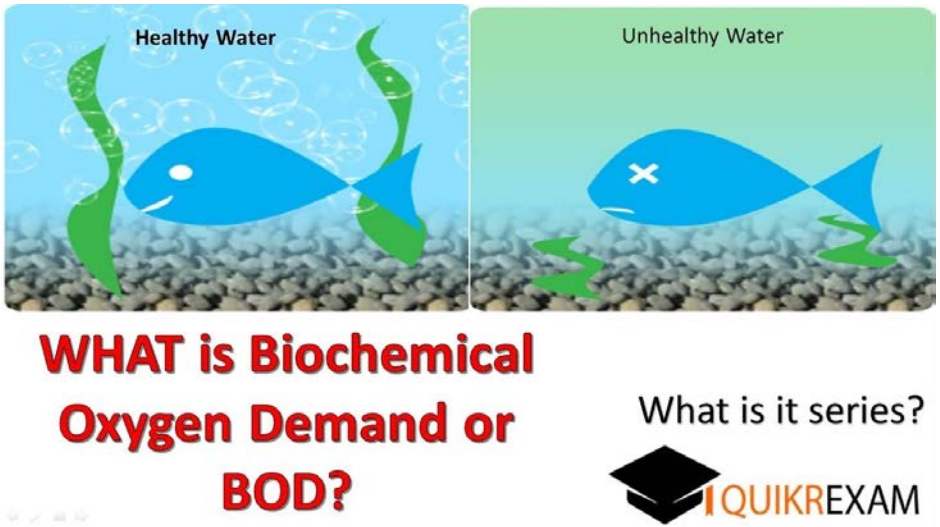
1. Wastewater dumped into bodies of water naturally undergoes decomposition by bacteria, which creates a large demand for oxygen in the water
2. Nutrients that are released from wastewater decomposition can make water more fertile
3. Wastewater can carry a wide variety of disease-causing organisms

Oxygen Demand

Biochemical oxygen demand (BOD)is the amount of oxygen a quantity of water uses over a period of time at specific temperatures.

A ↓ BOD value indicates less pollution by wastewater.

When microbial decomposition uses a large amount of oxygen in a body of water, the remaining oxygen is limited for other organisms. This can createdead zoneswhich is a body of water with extremely low oxygen and little-to-no life.



Marine Life Dead Zones

Dead zones where marine life cannot survive, cover more than **245,000 km²** globally.

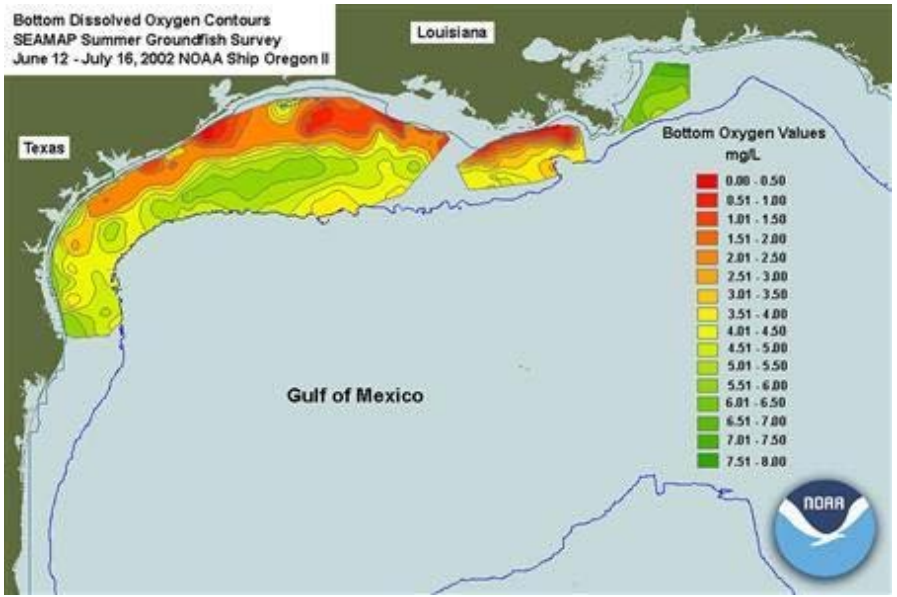
Source: nasa.gov

Nutrient Release

Decomposition of wastewater releases nitrogen and phosphorous, which are the two most important elements for limiting the abundance of producers in aquatic systems. This abundance of nutrients increases the fertility to a water body, a process known as **eutrophication** . When a body of water experiences an increase in fertility due to anthropogenic inputs of nutrients, it is called **cultural eutrophication.**

Nutrient Release

One of the most impressive dead zones in the world occurs where the Mississippi River dumps into the Gulf of Mexico. The Mississippi River receives water from more than 41% of the land of the continental United States.



Most dead zones are caused by human activities. In 1910, four dead zones were known around the world. This number increased to 87 in the 1980’s and more than 400 by 2008.

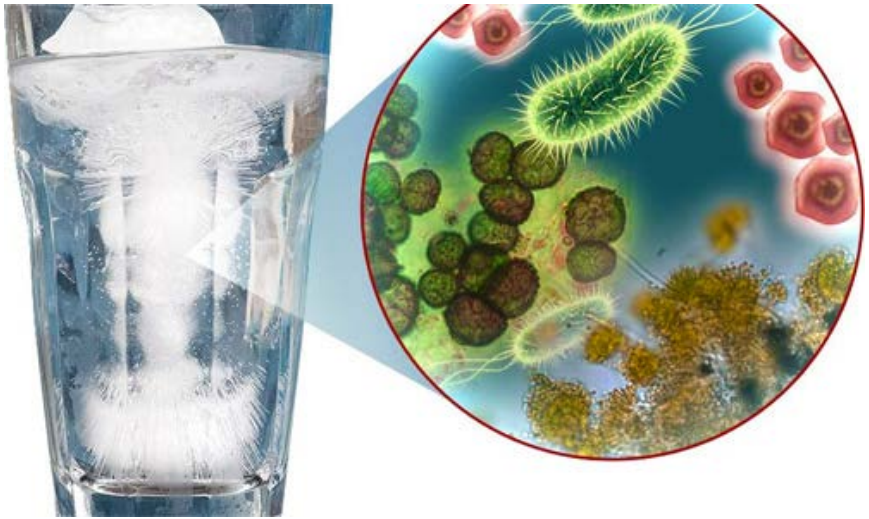
Disease-Causing Organisms

Various pathogens cause different diseases such as cholera, typhoid fever, stomach flu, and diarrhea. Worldwide, the major waterborne diseases are cholera and hepatitis. In the United States, hepatitis A appears more frequently in restaurants that lack adequate sanitation practices.

The WHO estimates that 1.1 billion people (nearly⅙ of the world's population) do not have access to safe drinking water.

Approximately 42% of the world's population do not have access to proper sanitation and hygiene. Over half of these people live in China and India.

Disease-Causing Organisms



Since many pathogens exist that can contaminate water scientists have settled on using an **indicator species**. This is a species that exists whether or not disease-causing pathogens are likely to be present. The best indicators for water that is potentially harmful are **fecal coliform bacteria**, a group of generally harmless microorganisms that live in the intestines of human beings and other animals.

Disease-Causing Organisms

E. coli is a common strain of bacteria that is naturally found in human and animal intestines without being harmful. Using *E. coli* as an indicator can be a reliable way to see if human waste has entered the water. For safe swimming and fishing, the acceptable level of *E. coli* is less than 500-10,000 colonies per 100 megaliters of water.

Technologies to Treat Wastewater

There are various ways for treating wastewater, however, all solutions have the same basic approach. Bacteria are used to break down the organic matter into CO_2 and inorganic compounds, including N_2 and P_2, and the harmful pathogens are outnumbered by the nonharmful pathogens.

The two most widespread systems for treating human sewage are *septic systems* and *sewage treatment plants*.

Septic Systems

In rural areas, houses often treat their own sewage with a septic system, a relatively small and simple sewage treatment system, made up of a *septic tank* and a *leach field*. The septic tank is a large container that receives wastewater from a house, usually buried underground. After some time of operation, three layers develop inside the septic tank. Whatever floats to the top is known as the scrum layer. Anything heavier than water sinks and forms the sludge layer. The middle layer is known as septage.

Septic Systems

The septage will move out from the septic tank into several pipes which make up the leach field. These pipes contain small perforations that allow water to slowly seep out and spread across the leach field to become absorbed by the soil. This allows the harmful bacteria to either be outcompeted or degraded by other microorganisms. The organic matter is broken down into carbon dioxide and inorganic nutrients.

Usually these systems run on gravity and no electricity is needed, however, sludge from the septic tank must be pumped out periodically (5 to 10 years) and taken to a sewage treatment plant.

Sewage Treatment Plants

In areas with greater population density in developed countries a centralized treatment plant is used that receive the wastewater from hundreds of thousands of households via a network of underground pipes.

Sewage Treatment Plants

The primary treatment allows solid waste material to settle into a sludge layer. The remaining wastewater undergoes a secondary treatment that uses bacteria to break down 85-90% of the organic matter and convert it into carbon dioxide and inorganic nutrients such as nitrogen and phosphorous.

The secondary treatment typically aerates the water to add oxygen which promotes the growth of aerobic bacteria (emits less offensive odors). This treated water sits for several days to allow particles to settle out. These particles are then added to the sludge from the primary treatment while the remaining water is disinfected with chlorine, ozone, or ultraviolet light, then ultimately released into a nearby river or lake.

Sewage Treatment Plants

The combined sludge from the primary and secondary treatments are taken away from the plant. This sludge is exposed to bacteria that can digest it to help reduce the volume prior to the move, then most of the water is removed to reduce the volume and weight further. This is the final form that can be placed into a landfill, burned, or converted to fertilizer pellets.

Even though these plants are effective breaking down organic matter into carbon dioxide, the inorganic nutrients can still have negative effects on the waterways in which they are released. Too much nitrogen and phosphorous can increase the fertility of the water. This has led to a tertiary treatment that helps remove nitrogen and phosphorous from the wastewater.

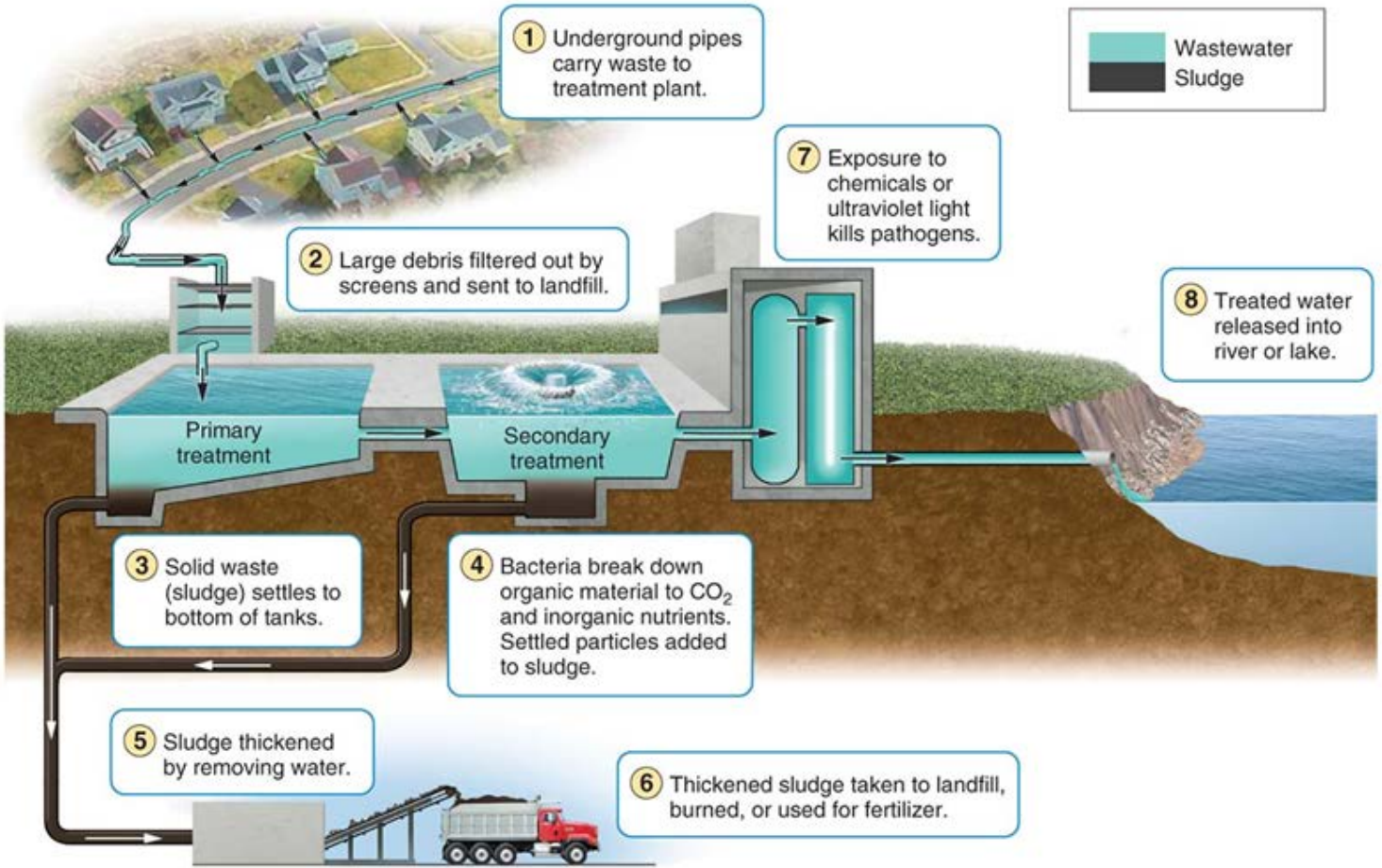


Figure 41.6
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Legal Sewage Dumping

Some treatment plants receive water from stormwater drainage systems. During period of heavy rain, the combined volume of stormwater and wastewater overwhelms the capacity of the plants. When this happens the treatment plants are allowed to bypass their normal treatment protocol and pump vast amounts of water directly into an adjacent body of water.

According to the U.S. Environmental Protection Agency, overflows of raw sewage occur approximately 40,000 times per year in the United States.

Animal Feed Lots and Manure Lagoons

A manure lagoon is a large, human-made pond lined with rubber to prevent the manure from leaking into the groundwater. After bacteria has broken down the manure, the manure can be spread onto farm fields to serve as fertilizer.

Risks associated with manure lagoons are the possibility of developing a leak in the liner or overflow of animal waste into rivers which can lead to disease outbreaks in humans and wildlife.

Module 42: Heavy Metals and Other Chemicals

After this module you will be able to……

1) Explain the sources of heavy metals and their effect on organisms
2) Discuss the sources and effects of acid deposition and acid mine drainage
3) Explain how synthetic organic compounds can affect aquatic organisms

Heavy Metals Are Highly Toxic

Heavy metals are a group of chemicals that can pose serious health threats to humans and other organisms. This section will focus on:

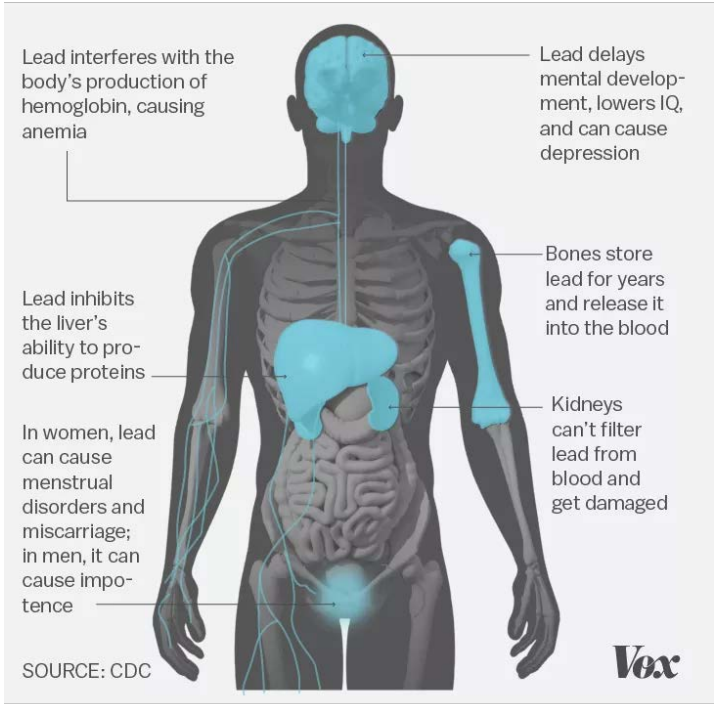
1. Lead
2. Arsenic
3. Mercury

Lead

Lead is rarely found in natural sources of drinking water, but it contaminates water through pipes and other materials such as brass fittings and solder used to fasten pipes together.

Fetuses and infants are the most sensitive to lead and exposure can damage the brain, nervous system, and kidneys.

Federal guidelines now require installation of lead-free pipes, pipe fittings, and pipe solders.



Arsenic

Arsenic is a compound that occurs naturally in Earth’s crust and can dissolve into groundwater. Human activity also contributes to higher arsenic concentrations in groundwater. For example, mining breaks up rocks deep underground and industrial uses of arsenic such as wood preservatives can add to the amount of arsenic found in drinking water.

Arsenic can be removed from water via fine membrane filtration, distillation, and reverse osmosis.

Arsenic

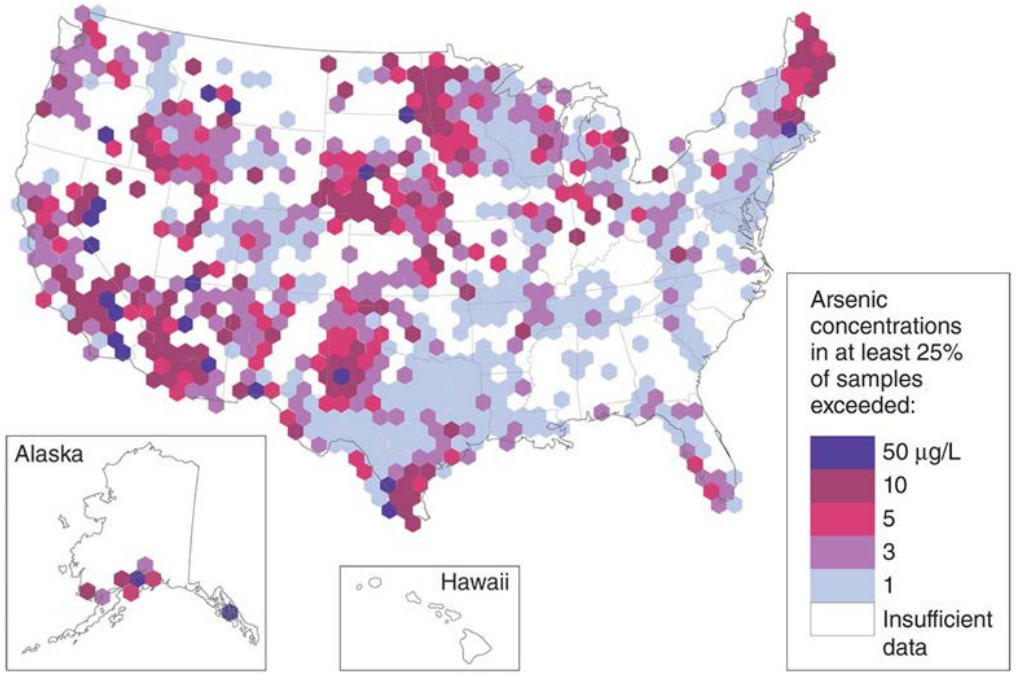
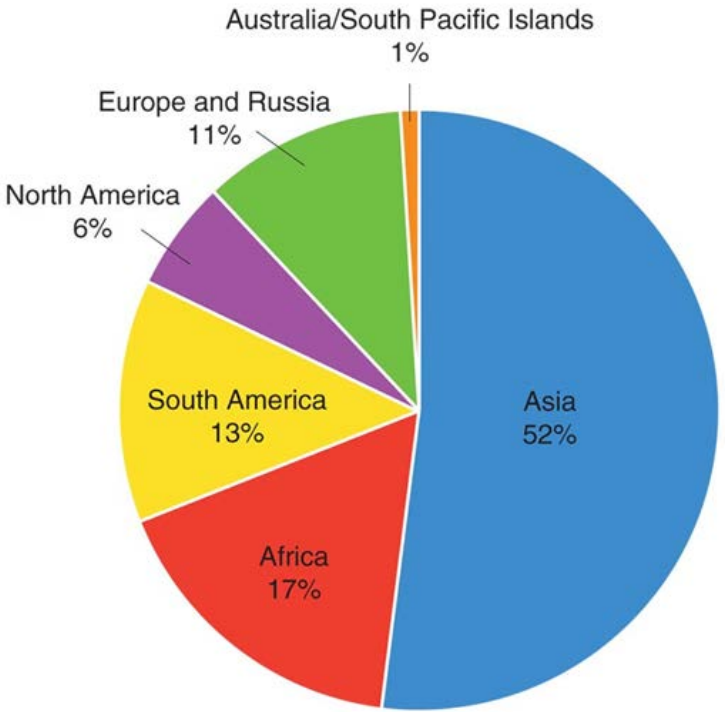


Figure 42.1
Environmental Science for AP®, Second Edition
Source: http://water.usgs.gov /nawqa/trace/pubs/geo_v46n11/fig3.html

Arsenic is associated with cancers of the skin, lungs, kidneys, and bladder, which can take 10 or more after exposure to develop.

Click here for information on arsenic safe drinking levels.

Mercury



Mercury is another naturally occurring heavy metal found in increased concentrations in water as a result of human activities. This graph shows mercury releases from different regions of the world as the result of activities such as burning coal.

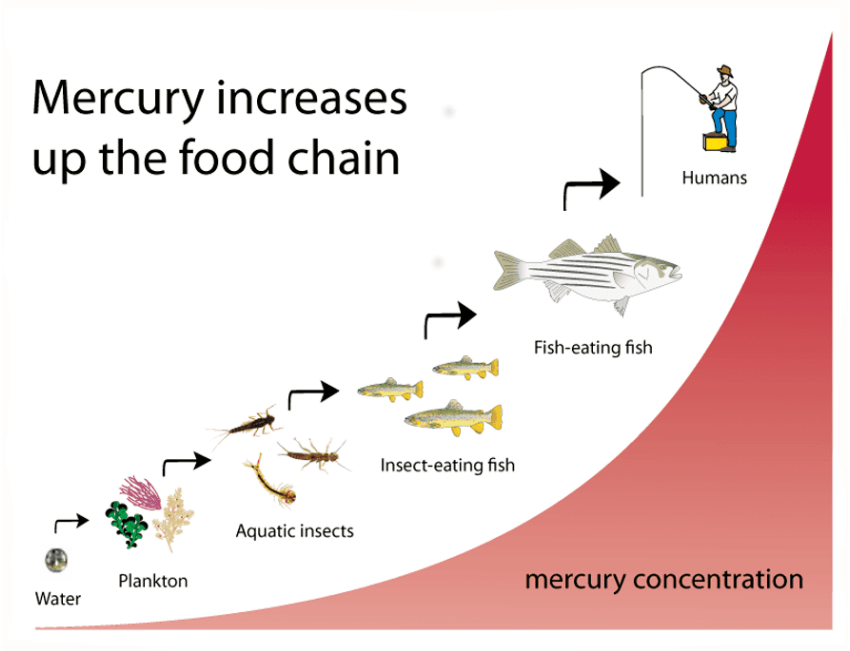
Approximately ⅔ of all mercury produced anthropogenically comes from burning of fossil fuels.

Other sources are incineration of garbage, hazardous waste, medical and dental supplies, and the making of cement.

Mercury

Methylmercury occurs mostly through eating fish and shellfish. In aquatic systems the top consumers contain the highest concentrations of mercury in their bodies.

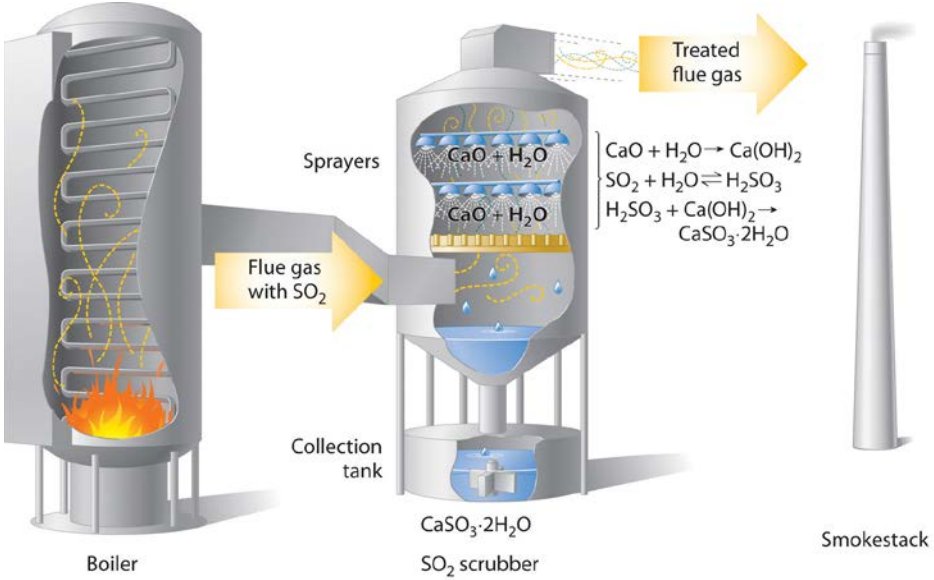
In 2013 the United States announced a new agreement with more than 140 other countries to reduce global mercury pollution. The EPA has proposed that cement-manufacturing plants reduce mercury emissions by 92 percent as well as reduce mercury emissions from other major sources, such as coal-burning power plants.



Acid Deposition and Acid Mine Drainage

Around 40 years ago, people began to notice that the forests, soils, lakes, and streams were becoming more acidic. Scientists were able to determine that tall smokestacks of industrial plants were burning coal and releasing sulfur dioxide and nitrogen dioxide into the air. In the atmosphere, these chemicals were converted into sulfuric acid and nitric acid that would return to Earth through rain and snow.**Acid deposition** is when acids deposit on Earth as rain or snow and gases and particles attach to the surface of plants, soil, and water.

Acid Deposition and Acid Mine Drainage



To help combat acids being released into the atmosphere, many coal burning facilities have installed coal scrubbers. Coal scrubbers pass the hot gases produced through combustion through a limestone slurry. The limestone removes the gases before they can leave through the smokestack.

Acid Deposition and Acid Mine Drainage

Low pH in water bodies also occurs when acidic water comes from below ground. This issue begins with the development of underground mines that, once abandoned, flood with groundwater. The combination of water and air allows pyrite to break down and produce iron and hydrogen ions. The increase in hydrogen ions produces acidic water.

Many of these companies that are responsible for these issues are no longer in business and can no longer be held accountable for the environmental damage they caused.

Synthetic Organic Compounds

Synthetic, or human-made, compounds can enter the water supply from industrial point sources where they are manufactured or from nonpoint sources where they are applied over very large areas. These carbon-containing compounds include pesticides, pharmaceuticals, military compounds, and industrial compounds. They can be toxic, cause genetic defects, and interfere with growth and sexual development.

Pesticides and Inert Ingredients

The first generation of synthetic pesticides was developed during WWII. Most pesticides do not target particular species of organisms, but generally kill a wide variety of related organisms. Pesticides can also alter physiological functions of non targeted species. DDT (dichloridephenyltrichloroethane) is designed to alter the nerve transmissions in insects, however, the chemical can also move up an aquatic food chain all the way to eagles that consume fish. Eagles that consume DDT produce eggs with thinner shells that would prematurely break during incubation.

Pesticides and Inert Ingredients

Inert ingredients are added to commercial formulations that make pesticides more effective. E.g. allow pesticide to dissolve in water

Inert ingredients are legally classified as trade secrets and are not required to be tested for safety. Roundup has an inert ingredient that is highly toxic to amphibians. The property that allows for the penetration of leaves also allow for the penetration of tadpole gill cells, thus causing the gills to burst and suffocating the tadpoles.

Pharmaceuticals and Hormones

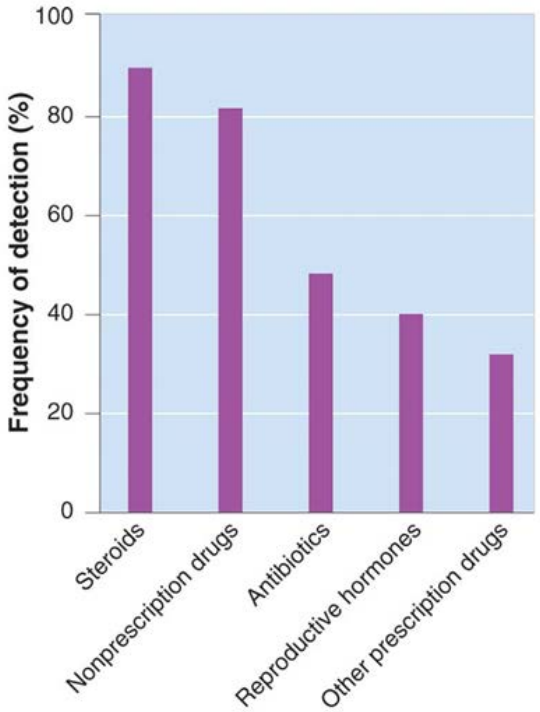
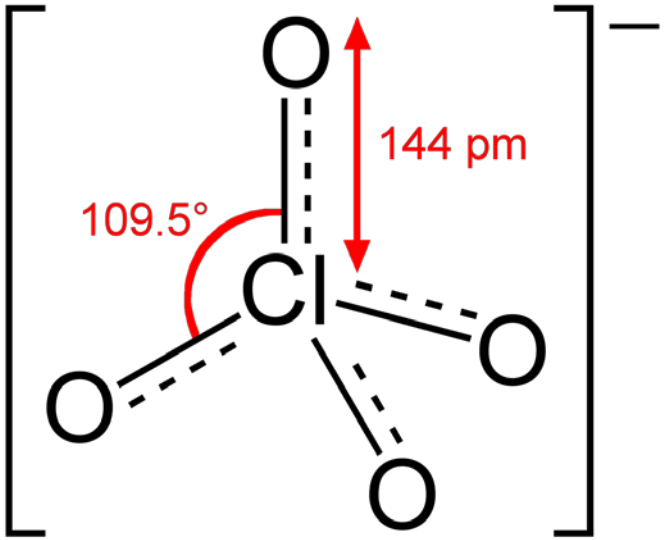


Figure 42.5
Environmental Science for AP®, Second Edition
After D. W. Kolpin et al. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999–2000: A national reconnaissance. Environmental Science & Technology 36: 1202–1211

Pharmaceutical drugs are commonly found in the environment. In most cases, however, the concentrations are low enough to not pose a risk to the environment or human health. Some chemicals, such as hormones, operate at very low concentrations inside the tissues of organisms and we have a poor understanding of their effects.

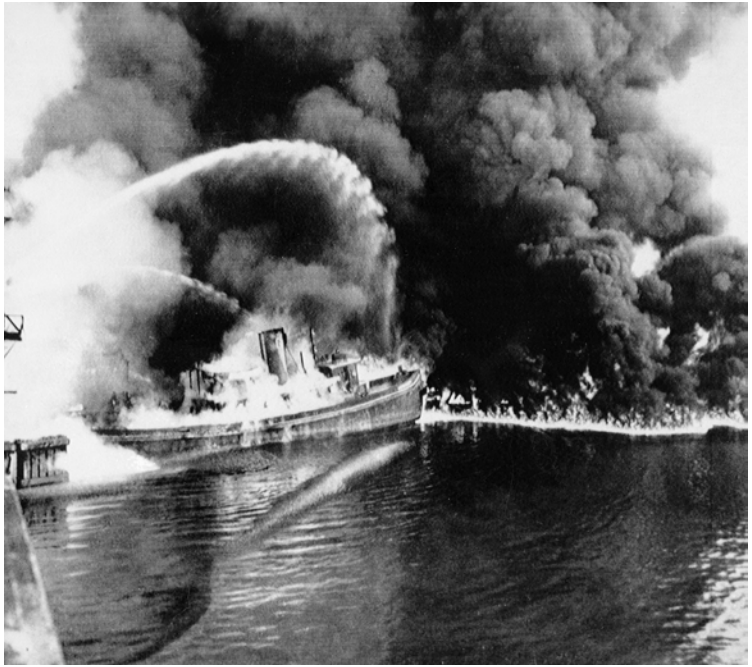
Military Compounds



Perchlorates are a group of harmful chemicals used for rocket fuel that sometimes contaminate the soil in regions of the world where military rockets are manufactured, tested, or dismantled. Perchlorates easily leach from contaminated soil into groundwater. Humans then consume food and water that contains perchlorates which negatively affects the thyroid gland and reduces the production of hormones.

Industrial Compounds

It used to be common for manufactures in the U.S. to dispose of industrial compounds into bodies of water. For more than 100 years, the Cuyahoga Riverin Ohio was a victim of this practice. The pollution virtually killed all animal life. The river often caught fire over the decades. The river today is much cleaner because of legislation that substantially reduced the amount of industrial and other waste that can be legally dumped into waterways.



Industrial Compounds

Polychlorinated biphenyls (PCBs) are a group of industrial compounds that were once used to manufacture plastics and insulate electrical transformers. Ingesting PCBs are lethal and carcinogenic. The manufacturing of PCBs ended in 1979, but they are still present in the environment.

One high-profile case involves two General Electric manufacturing plants in New York that dumped 1.3 million pounds of PCBs into the Hudson River from 1947-1977. In 2002 the EPA ruled that GE must pay for the removal of 2.03 million cubic meters of PCB contaminated sediment. The dredging begin in 2009.

Module 43: Oil Pollution

After this module you will be able to……

1) Identify the major sources of oil pollution
2) Explain some of the current methods to remediate oil pollution

Sources of Oil Pollution

Oil tankers can spill into the ocean, such as the tanker *Exxon Valdez* that ran aground off the coast of Alaska in 1989. This ship spilled 11 million gallons of crude oil, killing 250,000 seabirds, 2,800 sea otters, 300 harbor seals, and 22 killer whales. Cleanup efforts have been going on for two decades.

In 2009, scientists concluded that many harmed species have roubounded, including bald eagles and salmon, but many have not, such as killer whales and sea otters. It's suggested that approximately 14,500 gallons of oil remain and it will take more than 100 years to break down completely.

Sources of Oil Pollution

Exxon has paid $1 billion for the cleanup and $500 million in damages. The company also changed the ship’s name, even though it has been banned from carrying oil in North America. The disaster also sparked a new rule forcing tankers to have a doublehull design with two steel walls to contain leaking oil.

Offshore drilling is another source of oil pollution. There are approximately 5,000 offshore oil platforms in North America and another 3,000 worldwide. The best estimate for the amount of petroleum leaking into North American waters is 322,000 pounds per year.

Sources of Oil Pollution

One of the most famous oil leaks from an offshore platform occured in 2010 on a BP operation in the Gulf of Mexico. An explosion on the *Deepwater Horizon* platform caused a pipe to break on the ocean floor nearly 1 mile below the surface of the ocean. The explosion occurred in April and was not sealed until August 2010, allowing the release of 206 million gallons of crude oil. This spill contaminated beaches, wildlife, and estuaries that serve as habitats for the reproduction of commercially important fish and shellfish. The magnitude was nearly 20 times larger than the *Exxon Valdez* accident.

Sources of Oil Pollution

In addition to human activities, oil spills occur naturally in the ocean. The U.S. National Academy of Sciences recently estimated that the natural releases of oil from seeps in the bottom of the ocean account for 60 percent of all oil in the waters surrounding North America and 45 percent of all oil in water worldwide.

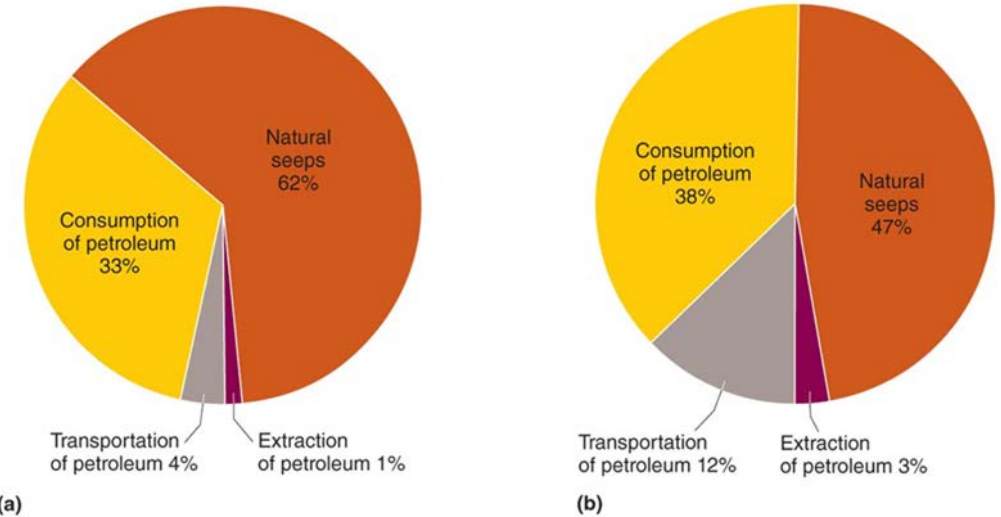
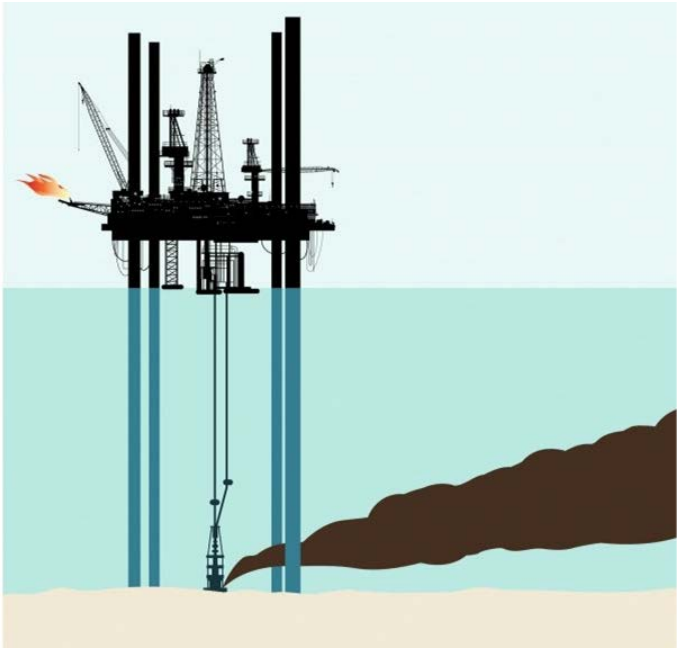


Figure 43.2
Environmental Science for AP®, Second Edition
After http:// oceanworld.tamu.edu/resources/oceanography-book/contents.htm

Remediating Oil Pollution

The *Exxon Valdez* disaster prompted researchers to investigate how to best remediate oil spills. To clean oil floating on the surface of the ocean a common approach is is to contain the oil within an area then suck it off the surface of the water. A second approach is to apply chemicals that help break up and disperse the oil before it hits the shoreline, however, this can be toxic to marine life. A third approach uses genetically engineered bacteria from genes of naturally occurring bacteria.

Remediating Oil Pollution



Oil in underwater plumes persists as a mixture of water and oil. The plume from the BP oil spill was approximately 3,000 feet below the surface and more than 1520 miles long and 5 miles wide. There is currently no agreed-upon method for removing underwater plumes from the water.

Remediating Oil Pollution

When spilled oil comes to the shore, the best solutions are not always clear. High-pressure hot water can help remove the oil, but it also removes most of the marine life and, in some cases, the finegrained sediments containing nutrients. This gives certain organisms trouble recolonizing.

Some parts of the coastline are treated while others receive no human intervention.

Module 44: Nonchemical Water Pollution

After this module you will be able to……

1) Identify the major sources of solid waste pollution
2) Explain the harmful effects of sediment pollution
3) Discuss the sources and consequences of thermal pollution
4) Understand the causes of noise pollution

Solid Waste Pollution

Solid wastes consists of discarded materials that do not pose a toxic hazard to humans and other organisms, such as garbage and sludge from sewage treatment plants. In 1997 scientists discovered a large area of solid waste in the North Pacific known as the Great Pacific Garbage Patch. Current estimates range in hundreds of millions of kilograms of solid waste.

Coal ash and coal slag remain behind as solid waste when coal is burned. In the United States, the Environmental Protection Agency considers this waste as “special waste” that is exempt from federal regulations for the disposal of hazardous waste.

Sediment Pollution

Sediments are particles of sand, silt, and clay carried by moving water in streams and rivers that eventually settle out in another location where water movement is slowed.

Human activities, such as constructing buildings, require the digging of soil to produce this sediment. Plowed agricultural fields are susceptible to soil erosion. Around 30 percent of all sediments in our waterways come from natural sources while 70 percent comes from human activities.

Sediment Pollution

Sediment pollution causes waterways to become brown and cloudy. This reduces infiltration from the sunlight, which can reduce the productivity of aquatic plants and algae. Sediments can also clog gills and hinder the ability of fish and other aquatic organisms to obtain oxygen.

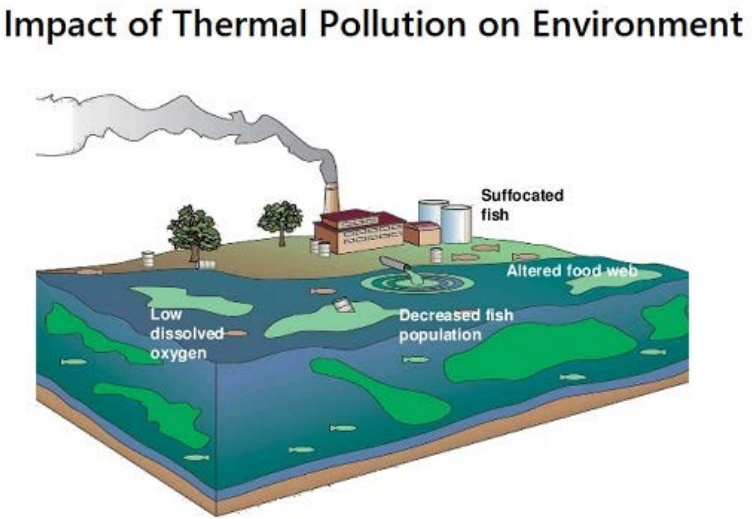
If water moves slowly, the sediments settle out and accumulate on the bottom of the water body which clogs the gills of bottom dwellers, such as oysters and clams.

The U.S. Environmental Protection Agency estimates that sediment pollution costs $16 billion annually in environmental damage.

Thermal Pollution

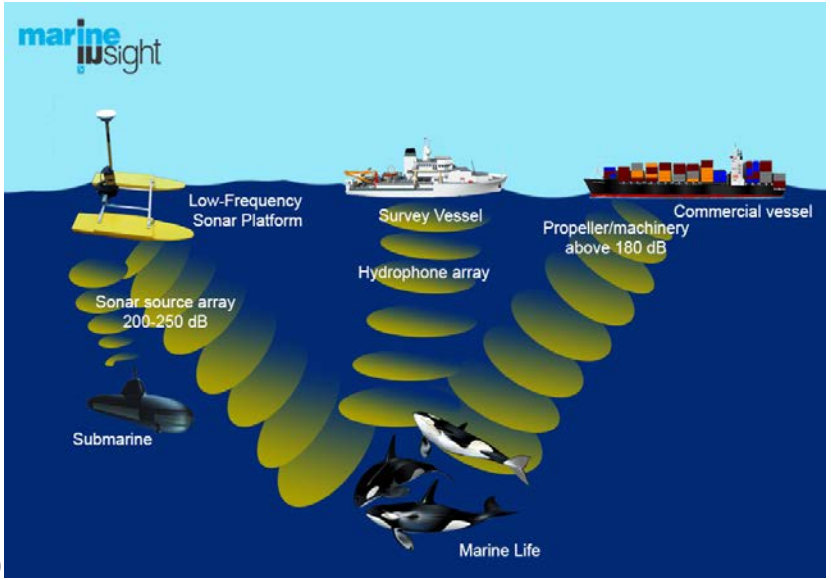
Thermal pollution occurs when human activities cause a substantial change in the temperature of the water. Thermal pollution is most common when an industry removes cold water from a natural supply in order to absorb heat during manufacturing before being returned back to its original location. This leads to thermal shock, a dramatic change in water temperature that can kill organisms.

The EPA regulates how much heated water can be returned to natural water bodies, but compliance becomes a challenge in the summer.



Noise Pollution

Noise pollution has received the least amount of attention of environmental scientists, and as a result, we know the least about it. Sounds emitted by ships and submarines interfere with animal communications.



In 2003, a federal judge rejected the U.S. Navy's request to install a network of long-range sonar systems across the ocean floor to detect incoming submarines. In 2012, the U.S. National Oceanic and Atmospheric Administration completed its first step in mapping the noises and inspired some shipbuilders to design ships equipped with quieter propellers.

Module 45: Water Pollution Laws

After this module you will be able to……

1) Explain how the Clean Water Act protects against water pollution
2) Discuss the goals of the Safe Drinking Water Act
3) Understand how water pollution legislation is changing in developing countries

The Clean Water Act

The Federal Water Pollution Control Act of 1948 was the first major piece of legislation affecting water quality. In 1972, the act was expanded into the Clean Water Act, which supports the "protection and propagation of fish, shellfish, and wildlife and recreation in and on the water" by maintaining and, when necessary, restoring the chemical, physical, and biological properties of surface waters. Note that this protection does **not** include the protection of groundwater.

The Clean Water Act

The Clean Water Act originally focused mostly on chemical properties of surface waters. More recently, there has been an increased focus on the abundance and diversity of various species and and defining acceptable limits of various pollutants.

The act also allowed the EPA and state governments to issue permits to control how much pollution industries can discharge into the water. Overtime, more and more categories of pollutants have been brought under the jurisdiction of the Clean Water Act, including animal feedlots and storm runoff from municipal sewer systems.

The Safe Drinking Water Act

TABLE 45.1 The maximum contaminant levels (MCL) for a variety of contaminants in drinking water as determined by the U.S. Environmental Protection Agency, in parts per billion (ppb)

Contaminant category	Contaminant	Maximum contaminant level (ppb)
Microorganism	Giardia	0
Microorganism	Fecal coliform	0
Inorganic chemical	Arsenic	10
Inorganic chemical	Mercury	2
Organic chemical	Benzene	5
Organic chemical	Atrazine	3

Table 45.1
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TABLE 45.2 The current leading causes and sources of impaired waterways in the United States

	Causes of impairment	Sources of impairment
Streams and rivers	Bacterial pathogens, habitat alteration, oxygen depletion	Agriculture, water diversions, dam construction
Lakes, ponds, and reservoirs	Mercury, PCBs, nutrients	Atmospheric deposition, agriculture
Bays and estuaries	Bacterial pathogens, oxygen depletion, mercury	Atmospheric deposition, municipal discharges including sewage

Table 45.2
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The Safe Drinking Water Act (1974, 1986, 1996) sets national standards for safe drinking water. Under this act, the EPA is responsible for establishing maximum contaminant levels (MCL) for 77 different elements or substances in both surface water and groundwater. In general, these laws have been very successful.

Water Pollution Legislation Worldwide

There is a clear difference between developed and developing countries with water pollution legislation. Developed countries have experienced tremendous industrialization many decades ago, thus polluting the air and water at that time. Developing countries are still in the process of industrializing and less able to afford water-quality improvements.

In some cases, contaminating industries move from developed countries to developing countries. This increases pollution, but also creates jobs and spending to help the economy.

Water pollution problems are prevalent in many nations of Africa, Asia, Latin America, and Eastern Europe.