Chapter 6

Pollution

The wide variety of human activities on the planet is accompanied by the unintended consequences of environmental pollution. Air, water, and soil all can become polluted. With an ever-increasing number of people being added to the planet, noise, light, and genetic pollution are becoming more common as well. Pollution can harm wildlife, ecosystems, and humans, and its presence requires efforts to reduce and eliminate it.

Pollution Types

Pollution comes in various forms and can adversely affect the biosphere's land, atmosphere, and water. Though the sources of pollution and the areas it affects are many, pollution is categorized two ways: **point-source pollution** or **non-point-source pollution.** Point-source pollution is emitted from a specific place, such as wastewater from a plant, acid drainage from a mine, noise from a jet plane, or oil from a tank. Identifying the main source of non-point-source pollution can be difficult, because it may come from a multitude of smaller sources. Examples of non-point-source pollution include emissions from vehicles, runoff from a group of farms, and emissions from widely dispersed factories.

Air, water, and soil are forms of pollution but are accompanied by noise, light, and genetic pollution as well.

Measuring units

To express pollutant amounts present in air, in water, on land, and in tissue, the term **parts per million (ppm)** is commonly used. Ppm is the concentration of a very dilute toxin or substance in relative proportion to another substance (in this case, meaning one part per million). For example, 2 ppm chlorine corresponds to 2 parts chlorine to 1,000,000 parts water. Parts per billion (ppb) and parts per trillion (ppt) also are used as measurements of concentration.

Air Pollution

Human-caused air pollution has been a problem since the Industrial Revolution, when combustion of fossil fuels became the world's primary source of energy. Air pollution is composed of unwanted gases and particulate matter and can be created through natural means or through human actions. Natural polluting events include wildfires, wind-blown debris and dust storms, and volcanic activity.

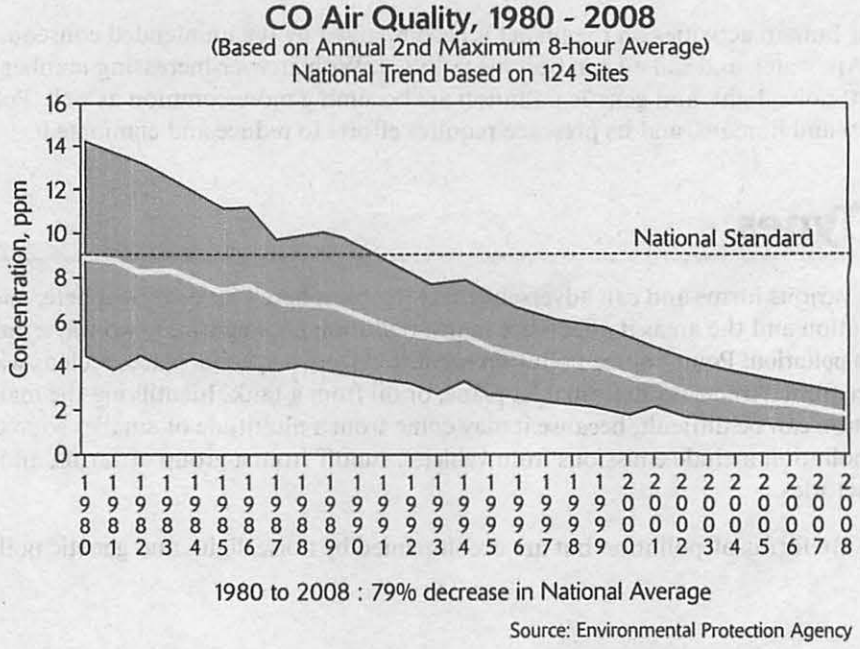
Airborne chemicals can travel far, so even though a pollutant is emitted from one source, it can affect an ecosystem hundreds or thousands of miles away, potentially in countries other than its source.

Major Air Pollutants

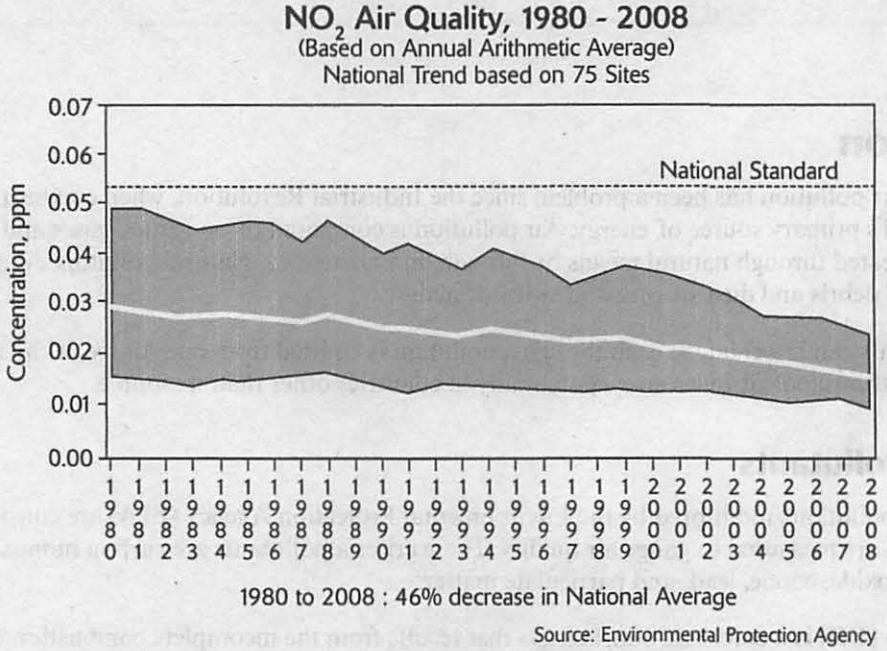
Six common air pollutants monitored by the Environmental Protection Agency (EPA) are considered to be **criteria pollutants** and are measured to gauge air quality. These criteria pollutants are carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, lead, and particulate matter.

Carbon monoxide (CO) is a colorless, odorless gas that results from the incomplete combustion of organic matter, especially fossil fuels. The use of fossil fuels in the internal combustion engines of vehicles accounts for the majority of CO emissions. Boats, lawn mowers, and construction equipment also contribute large amounts. Other

sources include industrial equipment, the burning of wood, cigarette smoke, forest fires, and volcanoes. Indoor sources of CO include gas stoves, wood-burning fireplaces, older furnaces and boilers, and gas and kerosene space heaters.

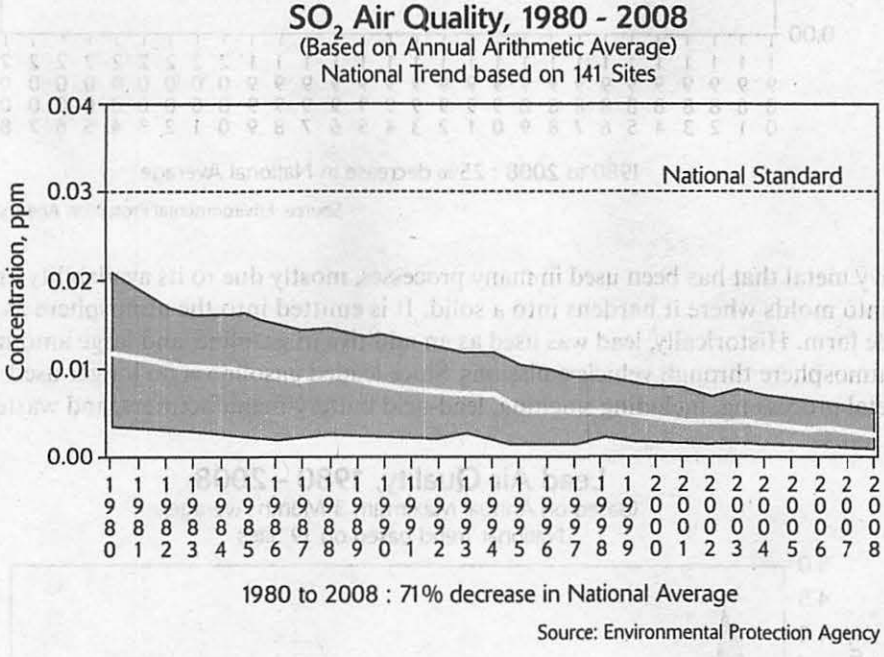


Nitrogen dioxide (NO_2) is a reddish-brown gas with a strong odor. It is created from combustion at high temperatures, most commonly in vehicles and electric utilities. Once in the atmosphere, NO_2 reacts to form nitrous acid and nitric acid, which are components of acid rain. NO_2 also reacts with the catalyst of the sun's heat in the form of UV radiation to form **photochemical smog.** This is especially common in the summers of warm, sunny regions with large volumes of automobile traffic, such as Los Angeles, California.

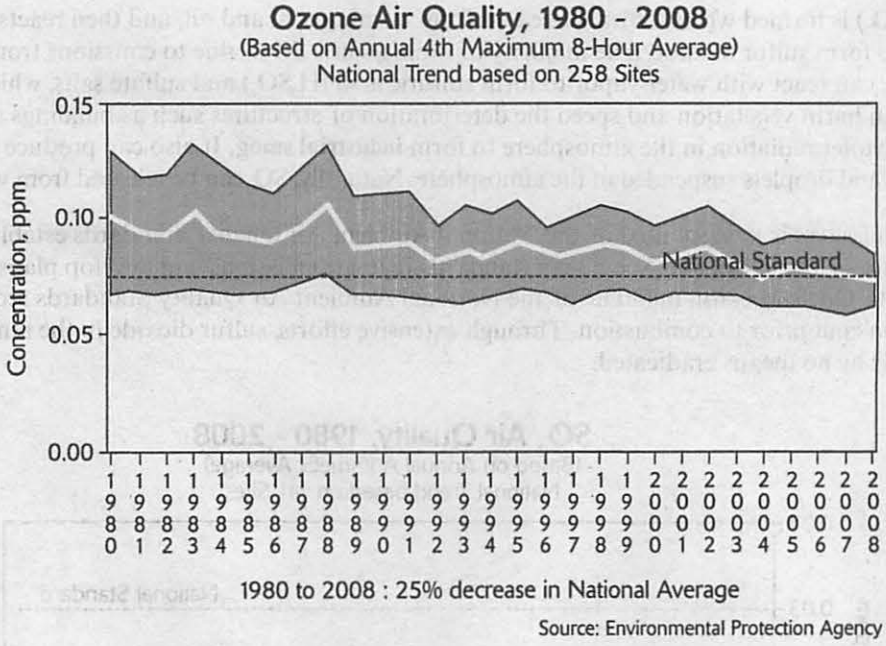


Sulfur dioxide (SO_2) is formed when sulfur is released from burning coal and oil, and then reacts with oxygen in the atmosphere to form sulfur dioxide. The majority of atmospheric SO_2 is due to emissions from coal-fired power plants. SO_2 can react with water vapor to form sulfuric acid (H_2SO_4) and sulfate salts, which can cause acid rain. Acid rain can harm vegetation and speed the deterioration of structures such as buildings and statues. Also, SO_2 absorbs ultraviolet radiation in the atmosphere to form **industrial smog.** It also can produce **aerosols,** which are solid particles and droplets suspended in the atmosphere. Naturally, SO_2 can be released from volcanic activity.

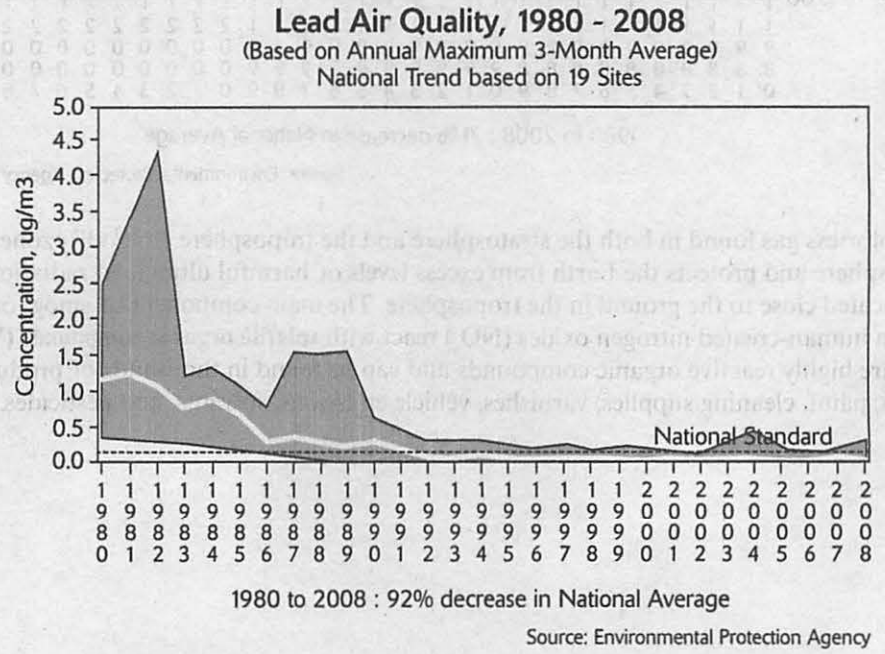
Control of SO_2 emissions is a major goal of the National Ambient Air Quality Standards established by the EPA under the authority of the Clean Air Act. These standards regulate emissions and develop plans to reduce and monitor pollutants. One successful mandate of the National Ambient Air Quality Standards required the extraction of sulfur from coal prior to combustion. Through extensive efforts, sulfur dioxide in the atmosphere has decreased, but it is by no means eradicated.



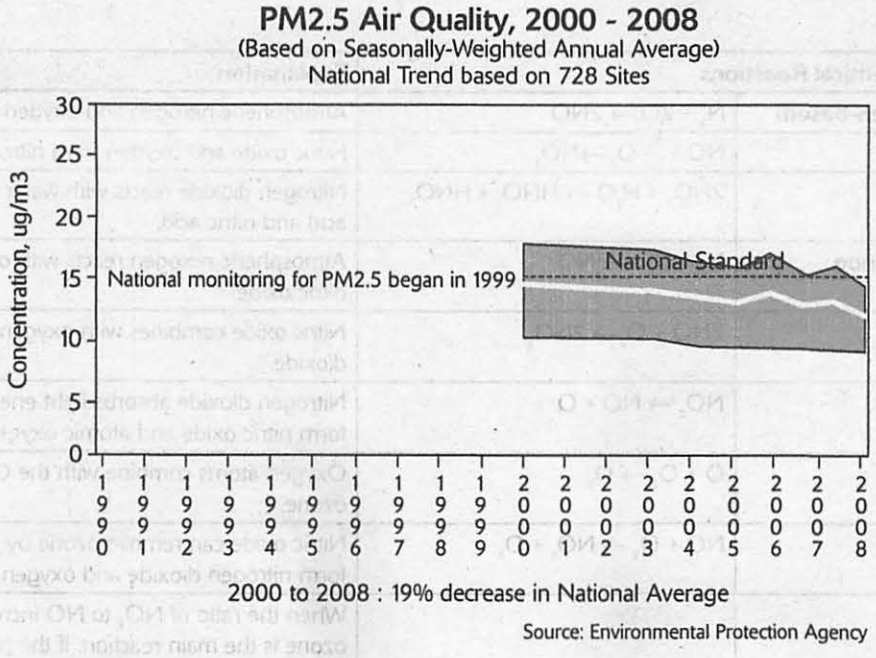
Ozone (O_3) is a colorless gas found in both the stratosphere and the troposphere. "Good" ozone is located naturally in the stratosphere and protects the Earth from excess levels of harmful ultraviolet radiation from the sun. "Bad" ozone is located close to the ground in the troposphere. The main component of smog, ozone is created at ground level when human-created nitrogen oxides (NO_x) react with **volatile organic compounds (VOCs),** sunlight, and heat. VOCs are highly reactive organic compounds and can be found in thousands of products including dry-cleaning products, paint, cleaning supplies, varnishes, vehicle emissions, solvents, and pesticides.



Lead (Pb) is a heavy metal that has been used in many processes, mostly due to its availability and the fact that it can be poured into molds where it hardens into a solid. It is emitted into the atmosphere as a **particulate,** meaning in particle form. Historically, lead was used as an additive in gasoline, and large amounts of lead were released into the atmosphere through vehicle emissions. Since leaded gasoline is no longer used, the main source of lead is from metal processing, including smelting, lead-acid battery manufacturers, and waste incinerators.



Particulate matter (PM) includes solid or liquid particles in the atmosphere and can be either a primary pollutant from direct emissions, or a secondary pollutant formed from the chemical reactions of substances such as SO_2 and NO_x. Dust, soot, smoke, dirt, metals, and liquid particles are all examples of particulate matter. Particle size tends to vary depending on the source. As a primary pollutant, PM can come from wood burning, trucks, factories, buses, stone crushing, construction sites, unpaved roads, and bare fields. Secondary or indirect forms of PM can come from vehicle, factory, or power plant emissions.



Smog

The two common types of smog—photochemical smog and industrial smog—are formed from the interactions of pollutants with the atmosphere, catalyzed by solar radiation. For example, to form photochemical smog, nitrogen dioxide, NO_2, reacts with the heat of UV radiation from the sun. To form industrial smog, sulfur dioxide, SO_2, absorbs ultraviolet radiation in the atmosphere. Sulfur dioxide can also produce aerosols, which are solid particles and droplets suspended in the atmosphere.

Acid Deposition

Acid deposition, also known as acid precipitation or (most commonly) acid rain, occurs when chemical reactions occur in the atmosphere between pollutant emissions and atmospheric components. Ultimately, acidic (below 7 on the pH scale) particulate matter falls to Earth's surface as either as precipitation, particulate, or gas. The main contributors to acid deposition are sulfur dioxide and nitrogen dioxide. In the atmosphere, NO_2 reacts to form nitrous and nitric acids, which can fall as acid rain. In addition, sulfur dioxide can react with water vapor to form sulfuric acid (H_2SO_4) and sulfate salts, resulting in acid precipitation.

The following table shows basic chemical reactions of pollutants in the atmosphere and their production of smog and acid precipitation.

Atmospheric Chemical Reactions		Explanation
Acid rain (sulfur-based)	$S + O_2 \rightarrow SO_2$	Sulfur and oxygen form sulfur dioxide.
	$2SO_2 + O_2 \rightarrow 2SO_3$	Sulfur dioxide reacts with oxygen to form sulfur trioxide.
	$SO_3 + H_2O \rightarrow H_2SO_4$	Sulfur trioxide and water react to form sulfuric acid, which can produce acid precipitation.

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Atmospheric Chemical Reactions		Explanation
Acid rain (nitrogen-based)	$N_2 + 2O \rightarrow 2NO$	Atmospheric nitrogen and oxygen form nitric oxide.
	$NO + ½\ O_2 \rightarrow NO_2$	Nitric oxide and oxygen form nitrogen dioxide.
	$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$	Nitrogen dioxide reacts with water to create nitrous acid and nitric acid.
Photochemical smog	$N_2 + O_2 \rightarrow 2NO$	Atmospheric nitrogen reacts with oxygen to produce nitric oxide.
	$2NO + O_2 \rightarrow 2NO_2$	Nitric oxide combines with oxygen to form nitrogen dioxide.
	$NO_2 \rightarrow NO + O$	Nitrogen dioxide absorbs light energy and splits to form nitric oxide and atomic oxygen.
	$O + O_2 \rightarrow O_3$	Oxygen atoms combine with the O_2 in air to produce ozone.
	$NO + O_3 \rightarrow NO_2 + O_2$	Nitric oxide can remove ozone by reacting with it to form nitrogen dioxide and oxygen.
		When the ratio of NO_2 to NO increases, formation of ozone is the main reaction. If the ratio is on the lower side, then the nitric oxide reaction destroys ozone at almost the same rate as it is formed, keeping ozone concentration below harmful levels.
*Note: The mixture of nitric oxide (NO) and nitrogen dioxide (NO_2) is sometimes referred to as NO_x.		
Industrial smog	$C + O_2 \rightarrow CO_2$	Coal (mostly carbon) is burned, and carbon dioxide, carbon monoxide, and soot are produced (soot is uncombusted carbon).
	$2C + O_2 \rightarrow 2CO$	
	$S + O_2 \rightarrow SO_2$	Coal containing sulfur produces sulfur dioxide.
	$2SO_2 + O_2 \rightarrow 2SO_3$	Sulfur dioxide is further oxidized to sulfur trioxide.
	$SO_3 + H_2O \rightarrow H_2SO_4$	Sulfur trioxide can then react with water, forming sulfuric acid.

It should also be noted that **peroxyacetyl nitrate** ($CH_3CO_3NO_2$), known as **PAN**, can be produced by the reaction of some volatile organic hydrocarbons with oxygen and nitrogen dioxide. PAN, ozone, and organic compounds called aldehydes are responsible for many of the harmful effects of smog.

Heat Islands

A problematic phenomenon, but one much less discussed than many other pollutants, is the phenomenon of **heat islands**, which are urban areas with long-term increased temperatures due to human activity. They result from the heat released from activities such as vehicle use, air conditioning, lights, and appliances. Pavement and building materials also may absorb more heat than would a natural ecosystem, therefore the heat island effect can be especially strong in summertime. Unfortunately, higher summertime temperatures encourage additional use of air conditioning, which, in turn, increases the effect of the heat island. Not only does this increased air-conditioning usage contribute to heat islands by producing heat as a by-product of the operation of the units, but it also increases electrical usage, and therefore increases air pollutants.

Indoor Air Pollution

Not only are air pollutants found in the atmosphere, but they also can be a threat indoors. Indoor air pollutants are found in most buildings and can become a problem in large concentrations or when there is poor ventilation.

Indoor air pollutants can include, but are not limited to, tobacco smoke, radon, asbestos, lead and other heavy metals, mold, carbon monoxide, and emissions from burning wood. Indoors, people may also be exposed to harmful chemicals including those in cleaning products, volatile organic compounds (VOCs), and polybrominated biphenyl ether (PBDEs).

Here is a brief description of each of the main indoor air pollutants:

- **Tobacco smoke** produced from cigarettes, pipes, and cigars is a known carcinogen. The inhalation of tobacco smoke can lead to respiratory issues and potentially harmful or fatal cancers.
- **Radon** is an extremely toxic, naturally occurring radioactive gas. It is produced from the decay of radium, which is, in turn, produced from the decay of uranium and can seep into basements from the bedrock. Like installing a smoke alarm, a radon detector can help people recognize the danger before becoming affected.
- **Asbestos** is a naturally occurring mineral. At one time it was used as insulation for pipes, soundproofing, roof tiles, and as a fire retardant. Asbestos fibers can float in the air and if inhaled can cause respiratory problems. Though no longer widely used, it is still found in older buildings.
- **Lead and mercury** can sometimes be found indoors in the form of dust particles or fumes. Lead is mainly found indoors in lead pipes and lead paint. While lead is no longer widely used, it can still be found in older buildings and furniture. Mercury also can become airborne indoors, and mercury fumes can occur from the use of latex paints.
- **Biological threats,** such as mold, dust mites, and pet dander, are often found indoors. They are not universally toxic, but some people are sensitive to these allergens.
- **Carbon monoxide (CO)** is a colorless, odorless gas that is emitted from broken or incorrectly used heating appliances such as clothes driers and water heaters. It is also emitted in vehicle exhaust and the combustion of wood.
- **Wood-burning** emits particulate matter and carbon monoxide.
- **Volatile organic compounds (VOCs)** can be released as gases from a wide variety of products including carpeting, paints, aerosol sprays, cleaning products, building supplies, pesticides, printers, glues, wood preservatives, mothballs, and air fresheners. Some VOCs are also used in dry cleaning processes.
- **Polybrominated biphenyl ether (PBDEs)** are chemicals that are used as flame-retardants in household items such as televisions, furniture, fabrics, wire insulation, drapes, small appliances, and other electronics. During manufacture, PBDEs are mixed with materials in order to raise the temperature at which they burn, but unfortunately they are released into the air in small quantities throughout the life of the product. Some forms of PCDEs have been banned in places such as the United States and the United Kingdom, but others are still in use.

Noise Pollution

Noise pollution encompasses all human activities that produce enough sound to be considered a nuisance. Common sources of noise pollution consist of vehicle traffic, railways, aircraft, car alarms, machinery, barking dogs, yard equipment, loud motorcycles, and music. Poor urban planning can result in an increased amount of aggravating noise for the people who reside or work in these locations.

This issue is serious enough that federal laws have been enacted in response to noise pollution. Such laws include the Noise Pollution and Abatement Act of 1970 and the Noise Control Act of 1972.

Light Pollution

Light pollution results from the excessive use of artificial light and can cause glare, over-illumination, sky glow, and decreased night visibility, and can consume excessive amounts of energy. In addition to being a distraction and an annoyance, light pollution can block terrestrial views of the night sky, interfering with organisms that depend on this view. Reducing light pollution requires conscious conservation efforts by all.

Genetic Pollution

Genetic pollution is a new concern that refers to the unintended spread of altered genetic information from genetically engineered organisms to natural organisms. **Genetically engineered organisms** are organisms that have had their DNA intentionally altered by combining their genetic material with that of another, most commonly in hopes of creating traits that are commercially desirable, including size, growth, or disease resistance. The use of these genetically engineered organisms is quickly increasing, especially in industrialized agriculture, in which genetically modified seeds are used to grow crops. This process has proponents and opponents and is seen to have both positive and negative impacts. Benefits of genetically engineered foods can include increased yield and crop efficiency. Dangers of these organisms include their potential to leak into the wild due to pollination or wind, where they may out-compete native species. Another concern is that only a few companies may have access to certain types of genetically modified products, allowing these few companies to control markets, restricting the freedom of competition.

Economic impacts of genetic engineering (both positive and negative) are dramatic and far-reaching, affecting farmers, fishermen, ranchers, markets, and nations.

Water Pollution

Water pollution can be very harmful to the environment as well as to people and wildlife. This section addresses freshwater and marine water.

Cultural Eutrophication

Eutrophication is the addition of excess nutrients to water. If these excess nutrients are due to human activity, it is called **cultural eutrophication.** Nutrients are added to an ecosystem through runoff, including excess nitrogen and phosphorus from fertilizers, untreated sewage, detergents, animal waste, or fossil fuel combustion. Nitrogen has a greater impact on marine ecosystems, and phosphorus has a larger impact on freshwater ecosystems.

Groundwater Pollution

Groundwater and surface water can be polluted by anthropogenic sources such as leaking oil tanks, agricultural runoff, chemical spills, untreated sewage, storm runoff, development, and mining operations.

Pollutants that affect freshwater sources are:

- **Toxic chemicals:** These can run off or leak into waterways. Toxic chemicals include pesticides; volatile organic compounds; petroleum products; heavy metals such as arsenic, chromium, mercury, and lead; and other dangerous substances.
- **Nutrient pollution:** This results from nutrient runoff from agricultural practices, sewage, lawns, golf courses, and fields. Excess nutrients can cause eutrophication in both freshwater and marine environments, resulting in an alteration of the balance of the ecosystem.
- **Temperature pollution:** This results from the release of water that is either warmer or colder than normal for the specific environment. This temperature change can affect individual species as well as the balance of an entire ecosystem. Thermal (heat) pollution occurs when water is used in factories and manufacturing processes. The water becomes heated as it cycles through the manufacturing processes and is then discharged into the local water source. Heating of water also can occur when vegetation is removed from the banks of a river, allowing more sunlight to hit the water's surface. Cold water pollution can occur when a dam releases cold water from the bottom of a reservoir into a river, as in the case of most hydroelectric power stations. Both extremes affect ecosystem balance.
- **Sediment** can become excessive in freshwater systems. Although it is a natural part of aquatic ecosystems, sediment in disproportionate amounts can change the aquatic balance. Excess sediment suspended in the water causes cloudiness that is called **turbidity.** Turbidity affects some fish that cannot adjust to changes in

sediment levels and leads to a lack of sunlight and, thus, available energy in deeper waters. Once sediment settles it also can impact the benthic environment and alter the flow of water. Contaminants, such as heavy metals, can accumulate in sediment as well, ultimately settling on the bottom where they can be ingested by benthic organisms.

- **Pathogens and waterborne diseases** exist in surface waters and can enter the drinking water supply if water is untreated. Protists, bacteria, and pathogenic viruses can cause serious health effects in humans, entering the water supply through runoff from sewage and animal manure.

Marine Ecosystems

Marine environments also suffer from the impacts of pollution. For many decades, the oceans were thought to be endless, so waste was dumped into them without thought of repercussion. Now the issues of polluting marine environments are being addressed and understood. Forms of pollution include oil pollution, excess nutrients, sewage, and trash such as plastics, debris, and fishing equipment.

Most oil pollution reaches the oceans through runoff from hard surfaces on the land, especially roads. Other sources include maintenance of ships, natural seepage from the ocean floor, and spills such as the *Exxon Valdez* supertanker rupture and the *Deepwater Horizon* (BP) drilling rig explosion. Oil spills can drastically impact the economy, most directly through the loss of fisheries and decreased tourism. Losses to these industries ripple through a local economy. Additionally, spilled oil carried in currents can reach sites far from the original disaster.

Trash reaches the ocean from the occupants of boats, damaged or sunken boats, barges dumping the refuse of coastal cities, offshore winds, and water runoff. To exacerbate the problem, trash is then carried by ocean currents, waves, and gyres, sometimes traveling hundreds of miles from the original source of the trash. One especially visible effect of trash on the marine ecosystem is to sea turtles, which frequently eat and are killed by floating plastic bags, which look much like their natural prey, jellyfish.

Maintaining Water Quality

The United States government has put in place water quality standards to maintain water quality in both freshwater and marine ecosystems. Drinking, ground, and surface water quality is tested for potential threatening levels of nutrient concentrations, fecal coliform bacteria (from sewage), hardness, pH, turbidity (suspended particles), and dissolved oxygen content. Additionally, during the past few decades, The Environmental Protection Agency (EPA) and other organizations have made efforts to reduce sources of water pollution. These sources include leaking underground storage tanks, illegal dumping of toxic chemicals, and proper management of landfills, runoff, and other waste. The EPA also has set standards for concentrations of over 80 contaminants likely to be found in drinking water. The Clean Water Act also has reduced water contamination, helping to maintain safer water quality for both humans and ecosystems.

Clean Water Act

The Clean Water Act was created in 1972 and amended in 1977 to protect the America's freshwater sources. Specifically, it was established to regulate the discharge of pollutants into waterways while also establishing quality standards for surface waters, including wastewater standards for industries.

Wastewater Purification and Sewage Treatment

Wastewater is generated by humans. After water is used and before it is released back into the environment, it is put through a cleaning process, commonly using a septic system or a municipal sewer system.

Septic systems are constructed directly on the property where they are used. Wastewater travels from the house to a septic tank buried underground, where solids, oils, and water naturally separate by density. The wastewater then travels to an empty field, or lawn area, where the waste products continue to be decomposed by microbes. The remnants left in the tank undergo decomposition as well. If the tank gets full, it is pumped and the contents taken to a landfill for disposal. Septic systems are usually found in rural areas, although as more remote locations have been developed, septic systems can now be found in areas considered to be urban or suburban.

In a **municipal sewer system,** wastewater is taken by pipes from local homes and businesses and sent to a central treatment plant where it undergoes clarification processes. During **primary treatment** suspended solids are physically removed in settling tanks. The wastewater then goes through **secondary treatment** where oxygen enters the water from continual mixing and movement, encouraging aerobic decomposition. By the end of this process, the majority of suspended solids have been removed. Some treatment facilities also use a third step, or a **tertiary treatment,** where there is additional filtration of the water. The final step is the treatment of the clarified water with UV light treatment or chlorine to kill bacteria. The water is then discharged into a river or an ocean. The solids (sludge) that were extracted are placed in large tanks where decomposition occurs. When the solids dry, the remainder is incinerated, sent to a landfill, or used as fertilizer for crops. Unfortunately, in many developing countries, the bulk of domestic and industrial wastewater is discharged without any treatment, or with only limited primary treatment. Without adequate sanitation systems, ecosystems can be destroyed and human populations threatened.

Solid Waste

Soil can be polluted through industrial waste, agricultural runoff, acid precipitation, underground storage tanks, and radioactive fallout. The most prominent contaminants are heavy metals, petroleum hydrocarbons, solvents, and pesticides. For management purposes, solid waste is considered one of four types:

- **Hazardous waste** is flammable, corrosive, toxic, or reactive.
- **Industrial waste** is created during industrial processes such as agriculture, mining, consumer goods production, and the extraction and refining of petroleum products.
- **Municipal solid waste** comes from homes, business, schools, hospitals, and other types of institutions.
- Also classified as waste is **wastewater,** which is post-consumer water that is flushed or goes down the drain, or water that runs into sewers from streets.

Disposal

Waste material from industry, municipalities, mining, agriculture, and medical operations requires disposal in a way that does not contaminate the soil. These solid wastes include, but are certainly not limited to, tailings and overburden from mining processes, agricultural remnants, medical wastes (biohazards), and radioactive and toxic substances, each of which requires its own protocol for disposal. Landfills, open dumps, or incineration facilities are often the final destination for these materials.

Landfills are areas where solid waste is disposed of by being buried in the ground or piled in a mound. Once a landfill is full, it is capped, or covered. In the United States, landfill regulations help to protect human health, wildlife, and ecosystems. For example, landfills must be located away from wetlands and cannot be built on an earthquake fault. Also, the bottoms of landfills are lined with plastic and clay to prevent leakage into the environment. Waste in a landfill experiences aerobic and anaerobic decomposition, allowing some of the waste to break down.

In some locations, solid waste is incinerated, or burned, at high temperatures in facilities built for this purpose. Prior to incineration, metals are removed for recycling. The ash that remains after incineration is then sent to a landfill.

This process reduces the mass and volume of waste being placed in a landfill. Unfortunately, incineration is likely to produce some quantity of hazardous waste, which requires specialized handling. Most likely, this special handling includes disposal in a hazardous waste landfill. In the United States, incineration plants have air emission guidelines aimed at the reduction of the amount of acid-causing chemicals, heavy metals, and other toxic and harmful substances released during incineration.

Most incineration plants operating in the United States are considered to be **waste-to-energy** facilities, where the heat that is generated during combustion is captured and used to heat water, which creates steam at high temperatures. Just as in a coal-fired power plant, this steam is then used to turn turbines, generating electricity.

Reduction

Certainly the most energy efficient and environmentally friendly way to address waste is by producing less of it. While recycling is becoming more common and economical, not all products are recycled. Even products that are recycled must be disposed. Composting of organic substances is also becoming more widely accepted and used, but it still requires time, effort, and space to conduct it properly. By reducing what we purchase and use, reusing existing products, recycling used products, and composting people can reduce the amount of waste entering landfills or being incinerated.

Many efforts have been made at the international, federal, state, and local levels to control pollution, both at the source and in the areas where it concentrates. Subsidies, green taxes, and permit trading have been used to help lessen pollution. For more information on these efforts refer to Chapter 4. Innovative technological advancements also have helped to reduce pollution from a range of sources. To protect human health and the environment, the **Clean Air Act** set standards governing the release of criteria pollutants. The act was created in 1970 and most recently amended in 1990, with the goal of protecting public health and welfare. The **Clean Air Act** regulates emissions from mobile and stationary sources, as well as hazardous emissions. It focuses on reducing air emissions, reducing concentrations of air pollutants, and ultimately reducing the production of destructive chemicals. National Ambient Air Quality Standards (NAAQS) were set by this act.

U.S. Laws and Treaties

- ❑ National Environmental Policy Act (NEPA)
- ❑ Clean Air Act (CAA)
- ❑ Clean Water Act (CWA)
- ❑ Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- ❑ Toxic Substances Control Act (TSCA)
- ❑ Resource Conservation and Recovery Act (RCRA)
- ❑ Emergency Planning and Community Right-to-Know Act (EPCRA)
- ❑ Oil Pollution Prevention Act (OPP)
- ❑ Pollution Prevention Act (PPA)

International Laws and Treaties

- ❑ The 2001 Stockholm Convention on Persistent Organic Pollutants (POPs)
- ❑ United Nations Framework Convention on Climate Change
- ❑ Kyoto Protocol
- ❑ Convention on Long-Range Transboundary Air Pollution
- ❑ United Nations Convention on the Law of the Sea
- ❑ Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade
- ❑ International Convention on Oil Pollution Preparedness, Response, and Cooperation
- ❑ International Atomic Energy Agency Convention on Nuclear Safety
- ❑ Protection of the Arctic Marine Environment (PAME)

Impacts on the Environment and Human Health

Pollution can break down quickly in the environment and cause relatively little harm, or it can persist for years, decades, centuries, or millennia depending on the pollution type and quantity. Detrimental affects of pollution can impact human, wildlife, and ecosystem health.

Hazards to Human Health

Exposure

Exposure to health hazards can be long-term or short-term, in high or low doses. **Acute exposure** occurs when someone is exposed to a high dose for a brief period of time, whereas **chronic exposure** occurs repeatedly over a long period of time but in small doses. Historic examples of chronic exposure include the many people who had frequent contact with lead, asbestos, or mercury, all of which were considered harmless at the time. In fact, low-dose, one-time exposure to these substances is unlikely to be harmful. However, chronic exposure to lead, mercury, or asbestos can lead to life-threatening conditions. There are many examples of acute exposure, including a one-time experience of high radiation or inhalation of toxic gas. Generally, it is easier to identify the source of acute exposure, since it is usually related to an event, as opposed to exposure over an extended period of time.

Environmental Risk Analysis

A **risk analysis** assesses the environmental risks potentially associated with an event or action. Any environmental risk is balanced against the associated monetary value, and recommendations are included for mitigating risk. A risk analysis also helps concerned parties better understand the toxins and pollutants involved in the event and their effects on humans and ecosystems, the potential for human exposure to the threat, and people's perceptions of the risk. A **dose-response analysis** can be used to determine the toxicity and threat to human and wildlife health, and a **cost-benefit analysis** provides the final overview of the proposed action.

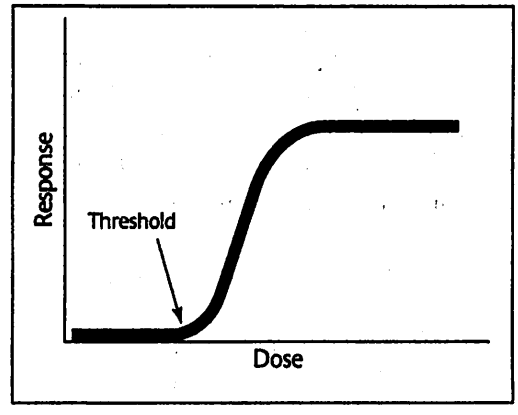
Despite research and testing, the effects of substances are not fully known until they are used; therefore, some countries and companies use the **precautionary principle** when evaluating a substance's toxicity. This means assuming the product is harmful until proven otherwise. In contrast to this is the **innocent-until-proven-guilty** approach, in which a product is assumed to be harmless until proven otherwise. Obviously, the latter approach is somewhat riskier (and usually less expensive) and can potentially lead to health problems or death. The United States often uses the innocent-until-proven-guilty approach, while Europe commonly uses the precautionary principle.

In the United States, some substances do not require Food and Drug Administration (FDA) approval prior to being released to the market, although many of these substances are then tracked and regulated through the FDA, EPA, and other agencies. Many substances that are not regulated through laws are monitored by the EPA. A key law that addresses the monitoring of toxic chemicals is the Toxic Substances Control Act (TSCA). Workplace hazards and safety, including exposure to toxins, are monitored through the Occupational Safety and Health Administration (OSHA).

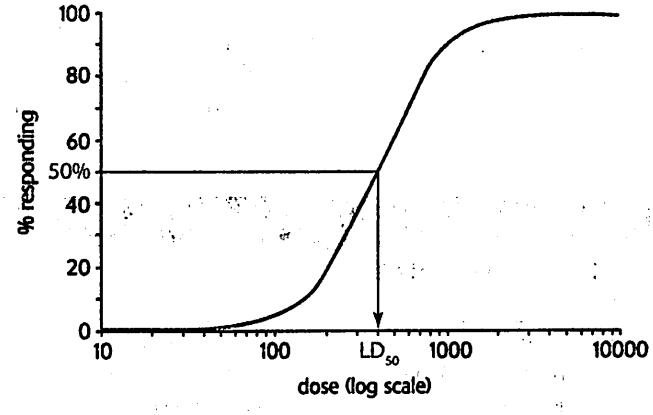
Dose-Response

A **dose-response relationship** is used to represent the effect of a toxin on an organism or population. A **dose** is the amount or concentration of a substance, while the **response** is an organism's reaction to a substance. Thus, dose-response describes the effects of certain levels of a toxin, illustrating the tipping point at which a safe level and exposure time becomes hazardous. In order to show this relationship, a **dose-response curve** can be used, as illustrated in the following figures. The term $\mathbf{LD_{50}}$ describes the lethal dose of a substance for 50 percent of the test population. When 50 percent of the population is affected (but not killed) by a certain dose of a substance, it is labeled $\mathbf{ED_{50}}$ or effective dose-50 percent. The **threshold** dose is the amount of a substance that has any effect on an organism or population.

Dose-Response Curve Showing Threshold



Dose-Response Curve Showing LD_{50}



Acute and Chronic Effects

The health and environmental effects of pollution vary depending on levels, the individual, the location, vegetation types, climate, and many other factors.

Indoor Air Pollutants

Indoor air pollution can have a wide range of health effects. Here are the major hazards:

- **Radon** is an extremely toxic radioactive gas that occurs naturally. Exposure generally occurs after it seeps into basements from the bedrock. Radon can be detected with the proper equipment, but without a detection kit it can build up in an enclosed space and eventually lead to lung cancer. Radon exposure is considered the second leading cause of lung cancer, next to tobacco smoke.
- **Asbestos** threats occur when a product containing asbestos is damaged, which releases the tiny asbestos particles into the air. When inhaled, these particles can lodge in the lungs, which produce acid to fight the invaders, ultimately scarring the lung tissue. Long-term exposure can lead to asbestosis, which is a decrease in lung function due to scarred lungs. Asbestos is also classified as a carcinogen. Mesothelioma is the result of asbestos damaging major organs of the human body. It is often a fatal condition. Before its impact on human health was discovered and acknowledged, asbestos was widely used to insulate pipes, for soundproofing, as vehicle brake shoes, as a fire retardant, among many other uses.
- **Tobacco smoke** is produced from cigarettes, pipes, and cigars and is the leading cause of lung cancer. There are many toxic chemicals found in tobacco smoke including butane, hydrogen cyanide, arsenic, lead, carbon monoxide, and ammonia. Both the smoking of tobacco and exposure to secondhand smoke are dangerous, and secondhand smoke actually contains higher concentrations of chemicals because it does not pass through cigarette filters before being inhaled.
- **Lead and mercury** can be toxic if buildup occurs in body tissue. Exposure to small amounts of lead can cause minor symptoms such as headaches, fatigue, and nausea, but larger exposure to lead can affect brain development of fetuses. Heavy metals contain neurotoxins, which can affect the nervous system.
- **Biological threats,** such as mold, dust mites, and pet dander, can create respiratory issues, congestion, headaches, and infections, especially in those who are allergic. Some molds are toxic and can be very harmful.
- **Carbon monoxide** is undetectable without a proper monitoring device and can lead to asphyxiation, as it disrupts blood oxygenation.
- **Wood-burning indoors** can lead to the exacerbation of asthma symptoms, respiratory problems, and respiratory illness.
- **Volatile organic compounds (VOCs)** have diverse effects depending on the product and amount of exposure. Less severe symptoms of exposure include headaches; nausea; and eye, nose, and throat irritation. More severe exposure can lead to liver, kidney, and central nervous system damage. Some VOCs are known carcinogens and can lead to potentially fatal cancers. VOCs such as those used in dry-cleaning processes can have negative impacts on the environment if leaked from a storage source into the soil, air, groundwater, or other water source.
- **Polybrominated biphenyl ethers (PBDEs)** can bioaccumulate in the tissues of organisms and biomagnify throughout a food web as organisms eat other organisms. They can cause neurological problems and are cancer-causing, especially affecting the thyroid and liver. PBDEs can enter the water, soil and air, and then make their way into wildlife.

Effects of Major Outdoor Air Pollutants

Environmental Air Pollutant	Health and Environmental Effects	Major Sources of Environmental Pollution
Carbon monoxide (CO)	Carbon monoxide inhibits the blood's ability to carry oxygen to body tissues including vital organs such as the brain and heart. CO can cause headaches and dizziness with continuous exposure. Higher concentrations can cause nausea, impaired vision, confusion, fatigue, seizures, respiratory failure, and death.	Motor vehicle exhaust
Nitrogen dioxide (NO_2)	NO_2 can irritate eyes, nose, and lungs and lower resistance to respiratory infection. Sensitivity increases for people with asthma and bronchitis. Environmental effects include eutrophication in aquatic systems, acid rain, and photochemical smog.	Motor vehicle exhaust, heat and power generation, explosives, fertilizer

Environmental Air Pollutant	Health and Environmental Effects	Major Sources of Environmental Pollution
Sulfur dioxide (SO_2)	SO_2 can cause respiratory and cardiovascular health problems. It is a precursor of fine particulate soot. Sulfur dioxide is a major component of acid rain, which accelerates corrosion of buildings and can disturb water and soil pH levels and can produce industrial smog.	Industry (heat and power) that uses oil or coal containing sulfur
Ozone (O_3)	Ozone can lead to respiratory problems, especially in people with existing respiratory ailments. Environmental effects include destroying vegetation (crops and forests) and, thus, ecosystems. It is a foundation of smog.	Formed from a reaction of NO_2 and VOCs (nitrogen oxides, hydrocarbons, and sunlight)
Lead (Pb)	Lead damages the nervous system by accumulating in the bloodstream over time. It is not easily removed and can bioaccumulate in organisms and is a neurotoxin. Lead can kill fish and animals and, thus, affect ecosystems.	Motor vehicles (burning leaded gasoline) and battery plants
Particulate matter (PM)	Particles can enter the bloodstream through the lungs. Health effects include lung and heart problems, chronic bronchitis, asthma, and other respiratory system issues. It can contribute to acid precipitation and smog. When it settles in land or in water, it depletes the soil of nutrients, causes groundwater sources to become acidic, changes the nutrient content of groundwater, and damages vegetation and crops. Particulates also decrease visibility.	Soot from motor vehicles industry

Water Pollutants

The contamination of freshwater can have harmful effects on human and ecosystem health. As discussed earlier, pollution can occur from excessive nutrients, excessive heat, pathogens and waterborne disease, toxic chemicals, and sediment. Since all life depends on water, when sources become polluted, there are far-reaching effects. Effects of water pollution on ecosystems include poisoning of organisms, loss of biodiversity, and potentially ecosystem death. Groundwater and surface water are used for drinking, crop irrigation, cleaning, recreation, and other human activities.

Coral reefs are especially fragile and sensitive to pollutants. Eutrophication, excess sediment, and oil spills can smother coral. Temperature changes can be lethal, because coral needs a consistent water temperature. Acid precipitation and other forms of pollution can kill coral as well.

Soil Contaminants in Water

When soils are contaminated, the contaminant can percolate down through the soil, transported by water, and ending up in a groundwater source. Contaminated groundwater and aquifers can be a serious issue in areas of dense human population. With population density comes the threat of accidents, leaks, and human carelessness. Contaminated soil and water may result in the inability to support life and the degradation of an ecosystem. Humans can be at risk from direct contact with the soil, inhalation of fumes, or consumption of contaminated water. Health effects vary from mild to extreme, depending on the substance and concentration.

Oil Spills

The effects of an oil spill can be destructive, far-reaching, and long-term. Once oil is released in water, it can float on the surface, partially submerge and stay suspended in midlevel waters, or sink to the bottom, depending on the density of the oil. In an ecosystem, oil spills can:

- Poison or suffocate life
- Affect breeding cycles and locations

- Damage nesting sites
- Weaken egg shells and harm or kill larvae
- Damage coastlines
- Contaminate algae and phytoplankton, which serve as the basis of food webs
- Coat organisms with oil, potentially leading to loss of body heat, smothering, drowning, and starvation
- Get trapped between rocks, gravel, and sand particles and persist for many years

The amount of oil released by the *Deepwater Horizon* spill is one of the largest oil spills in history. The devastation of wildlife and ecosystems, combined with the economic losses to people such as fishermen and the tourism industry, is dramatically higher than that of most spills due to the proximity to the coastline and barrier islands, and to the biologically productive nature of the Gulf of Mexico.

Waterborne Diseases and Pathogens

Health effects from pathogens and waterborne diseases are more immediately devastating than those from any other form of water pollution. These waterborne diseases include cholera, typhoid, hepatitis A, *E. coli,* dysentery, SARS, giardiasis, and many others. An increasing number of people worldwide have access to safe and clean drinking water, but an unreasonably high number of people still do not, mainly in developing countries.

Nutrients

Nutrient overload from fertilizers and sewage runoff can create eutrophication, hypoxia, and dead zones in both marine and freshwater ecosystems, affecting wildlife, ecosystems, and humans. **Eutrophication** occurs when excess nitrogen or phosphorous enters an aquatic system, leading to an excessive growth of phytoplankton, algae, and other plants. As organisms die off and decompose, the bacteria consuming them use large amounts of oxygen, which ultimately can deprive an ecosystem of oxygen. A **hypoxic** environment, lacking oxygen, can form, and much of the ecosystem life cannot survive or will leave the area. An extreme hypoxic environment can become devoid of any life and become a **dead zone.**

Trash

Trash that ends up in oceans can end up in organisms, as some fish and marine organisms consume small pieces in the assumption that it is food. Some items, such as plastics, do not break down in the organisms' digestive tracts and if it cannot be passed, will remain inside the organism for its lifespan. This can shorten an organism's life span through a slow release of synthetic chemicals or through the lodging of the trash inside their bodies. Organisms also can become tangled in fishing gear and other debris, trapping them and ultimately leading to starvation and death.

Noise

Noise pollution can cause immediate irreversible hearing loss in the event of an extremely loud instantaneous burst, or it can gradually impact hearing through long-term repeated exposure. Other effects include increased stress levels, hypertension, aggression, sleep deprivation, short-term hearing loss, and tinnitus. Organisms in ecosystems are also impacted by noise pollution and may lead to a decline in biodiversity in some areas.

Light

Anthropogenic light can affect organisms by causing distractions or by altering their natural cycles. Light can alter feeding cycles, prompt unnatural periods of attraction that lead to disruptions in reproductive cycles, disorient migratory birds, and interfere with intraspecies communication. Thus, bright lights are a form of habitat destruction, altering behaviors, with effects that can be passed throughout an ecosystem.

Also, using more light requires more electricity, which uses more energy and leads to increased emissions.

Genetic

Since genetic pollution is still relatively new, we are still discovering its long-term effects, both good and bad. Known adverse effects of genetically modifying crops and organisms include the following:

- Decrease in crop diversity
- Increase in pest and disease resilience
- Abnormalities and mutations occurring that would not occur naturally
- Possible species extinctions due to natural species being out-competed by modified ones

Hazardous Chemicals in the Environment

When substances are considered to be **toxins**, or poisonous substance, they are classified based on their potential health impacts.

Types of Hazardous Waste	
Neurotoxins	Neurotoxins target the nervous system, affecting motor control and brain function. Heavy metals such as lead, cadmium, and mercury are classified as neurotoxins.
Carcinogens	Carcinogens are cancer-causing toxins, such as asbestos, formaldehyde, radioactive substances, and some organic compounds like benzene.
Teratogens	Teratogens can affect embryo development, harming or killing the fetus. Known teratogens include alcohol and thalidomide.
Mutagens	Mutagens create mutations in the DNA of organisms and include radiation, nitrous oxide, and UV light. Many mutagens including benzene are also carcinogens.
Endocrine disruptors	Endocrine disruptors alter the hormone (endocrine) system, usually by binding to hormone receptors in place of the existing, desired hormone or by otherwise blocking hormone effects. DDT, the pesticide once used in the United States, is an endocrine disruptor.
Allergens	Allergens overactivate the immune system, stimulating a disproportionate response in those who are allergic. Examples range from pollen and dust mites to peanuts.

Biomagnification and Bioaccumulation

Over time, toxins may build up, or **bioaccumulate**, in organisms' muscles, organs, and other tissues. Especially if a substance is fat- or oil-soluble, it can dissolve into fatty tissues and accumulate in the organism. This accumulation can magnify through the food chain as predators consume organisms, each with accumulated toxins, which then pass to the predator. Thus, toxin levels tend to increase dramatically with each step higher in the food chain. The buildup of toxins within an organism through the consumption of other organisms is called **biomagnification.**

Treatment and Disposal of Hazardous Waste

Disposal of hazardous chemicals poses a serious threat to human and environmental health. Some hazardous substances degrade over time until they are no longer dangerous, but some substances **persist**, or remain in the environment for an extended period of time. Heavy metals, many organic compounds, and radioactive waste all persist in the environment. Hazardous waste substances can be classified as:

- **Toxic:** Harmful to human health
- **Corrosive:** Can wear away and break down metals
- **Reactive:** Easily react with other substances and can cause a serious reaction such as explosions or toxic gases
- **Ignitable:** Easily combustible

Some hazardous waste is treated prior to disposal in order to neutralize it. Usually, treatment involves the incineration of the waste, which breaks down the toxic organic components and reduces the volume of the waste. As specified in the Clean Air Act, the emissions from these incineration facilities are monitored through the National Emissions Standards for Hazardous Air Pollutants (NESHAP), with levels established by the EPA.

Proper disposal of hazardous waste requires special facilities designed to hold these substances, often designed to permanently contain the waste. Most hazardous substances are placed into landfills, injection wells, land treatment units, or surface impoundments. Liquids are usually placed into injection wells deep within the earth. Hazardous waste disposal is monitored by the Resource Conservation and Recovery Act (RCRA) and the Safe Drinking Water Act (SDWA).

Remediation and Cleanup of Contaminated Sites

Polluted waters and soils can be **remediated,** or cleaned up, through extensive effort and at high costs. Remediation is the removal of contaminants from water or soil. Prior to the start of remediation, an environmental site assessment is created to determine what activities occurred on the site and in the area, what pollutants are present, and what can be done to remove and clean up the pollutants. Generally, the parties who contaminated the site are responsible for the remediation and removal of contaminated soils and water within the contaminated area. If the contamination is found on an abandoned site and cannot be traced to any person or company, funds are provided by the federal government through the EPA's Superfund program. Taxes imposed on polluting industries are placed into the Superfund to be used for the remediation of contaminated areas.

Remediation can involve either treating the contaminated area without removing any soil **(in situ),** or removing contaminated soil **(ex situ),** or a combination of both. Possible remediation techniques include excavation, extraction, pump and treat, bioremediation, aeration, phytoremediation, and thermal remediation, with the optimal treatment depending on the type of pollution, what is contaminated, and how much is affected.

Economic Impacts

Pollution affects many economic sectors, so it can be difficult to put an exact dollar amount on the effects of pollution. Because pollution can travel from the point of origin, it impacts both human health and ecosystem health, sometimes in locales widely removed from the original source of contamination. Effects may not be seen for years or decades, and not all effects are reported or known. Thus, the economic impact of pollution is estimated, including combinations of many factors including the following:

- Medical costs, loss of income, and loss of productivity due to pollution-related human illness
- Lost profits due to impacts on agriculture
- Loss of income due to impacts on resources, including fisheries and timber
- Potential decrease in tourism
- Costs related to cleanup and control of pollution
- Loss of revenues due to businesses moving from or refusing to move to polluted areas
- Lost income of all services that depend on monies generated in communities affected by pollution

However, it is beneficial for some businesses to move specifically to areas that allow higher levels of pollution, in which their emission and pollution standards may not be as tight and permitting for pollution may be simpler. Thus, allowing pollution can have beneficial effects on local economies.

Cost-Benefit Analysis

Many industries use **cost-benefit analysis (CBA)** to determine beneficial courses of action. For example, an office might ask if the ease and decreased cost over time is worth the purchase price of a new printer. Similar analysis applies when industries pollute or evaluate the remediation of a polluted area. Simply, do the benefits outweigh the costs?

For example, benefits of remediation may include improved air or water quality, species preservation, increased recreational opportunities, reduced wildlife mortality, increased job opportunities, and reduced pollution. Costs may include higher prices of goods passed on to the consumer; increased taxes, fees, or costs associated with the action; and lost opportunities to create marketable products. Aside from assessing the immediate economic gains and losses of an action, a cost-benefit analysis takes into account long-term effects and the impact on human well-being.

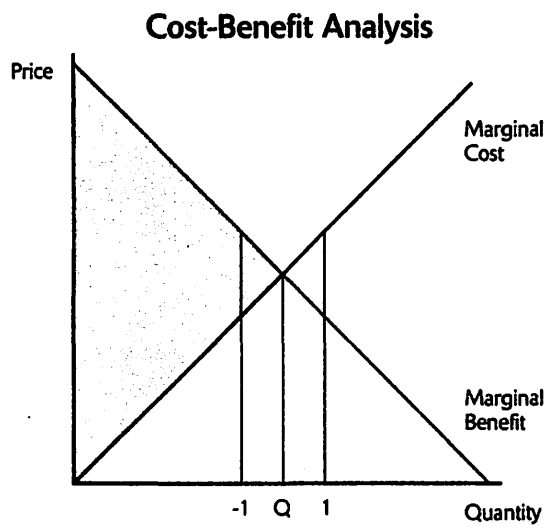
Market effects are the effects that can be expressed in dollars, whereas **nonmarket effects** do not necessarily have a fixed dollar amount but may have tangible and intangible benefits to ecosystem or human well-being. Sometimes, for the purpose of comparison in a cost-benefit analysis, these intangibles are represented as dollar amounts; however, some people argue that assigning dollar values to nature, ecosystems, and human lives is unethical.

Assessing the relative desirability of actions is a difficult and often subjective process, and one in which finite monetary resources must be allocated to the places in which they do the most good. Is preserving a unique forest ecosystem just as valuable as providing increased healthcare options to individuals? Also, how is the value of an ecosystem or a resource assessed? Therefore, CBA is used not only to define whether a single action should take place, but also to compare the benefits of many possible actions, allowing more informed decisions on where limited resources can be the most useful.

Marginal Costs

It isn't very difficult to clean up "grade F" air to "grade D" air, but it is much harder to make B+ air into A+ air. This is the idea of **marginal cost:** As more units are produced, as air gets cleaner, or as grades get higher, it is increasingly difficult to add the same amount as you did before. So, although the effort of cleaning very dirty air may be worthwhile, the effort of cleaning air that is already relatively clean may not be worthwhile. Add to this the idea of **marginal benefit**—the fact that making those first air-quality improvements can drastically increase quality of life, but making further improvements tends to have decreasing benefits. One piece of pizza is great, but 15 pieces are not so great—each subsequent piece has a decreasing marginal benefit. So, how much air should you clean or how much pizza should you eat? To create economic efficiency, you should clean or eat exactly until the marginal benefit becomes less than the marginal cost—you want to continue until the cost outweighs the gain. At this point of equilibrium, between marginal cost and marginal benefit, is economic efficiency.

The cost benefit analysis in the diagram below shows the optimal point of equilibrium (Q), between marginal cost and marginal benefit. To the right of equilibrium, items' production cost outweighs their gain; to the left of equilibrium, the relatively high combination of high marginal benefit and low marginal cost means that you should be producing more than you are to take advantage of these conditions (again, producing in exactly the quantity at which you reach equilibrium between these factors).



Cost of Pollution Control

There are costs associated with most efforts to limit and control pollution. Thus, rather than depending on businesses to police their own pollution control, pollution-control mechanisms often come in the form of laws and regulations. This approach is considered a **command-and-control strategy,** where the government sets and enforces legal limits. Although this method is very common and has led to success in some sectors, it is not always the most efficient and/or economical method. For example, emissions standards vary depending on the country, the state, the industry, the age of the factories, and a variety of other factors; the costs of new technologies and other adjustments needed to create compliance may simply be passed on to consumers. There are also costs to the government (and, thus, to taxpayers) for the enforcement of laws.

In addition to regulating pollution standards, there exist market-based strategies to pollution control. For example, making companies responsible for the cleanup of any pollution of their land creates incentives for companies to pollute the land less in the first place. Another way to create incentives for pollution reduction (used mainly in Europe) is to mandate that companies pay **pollution fees,** which are taxes levied on polluters relative to the amount of pollution discharged, frequently with a cap on the total amount of pollution allowed. This cap-and-trade system allows relatively clean companies to sell pollution permits to companies that exceed the cap (which buy the permits to avoid penalties). With **permit trading,** including **marketable emissions permits,** companies can buy, sell, and trade credits for the amount of pollution they are allotted to emit. Some companies will pollute more, while others will pollute less, but cap-and-trade ensures that all companies have an economic incentive to pollute less. This approach was used to successfully reduce sulfur-dioxide emissions in the United States.

In yet another approach, instead of creating laws and regulations to control pollution, federally funded programs provide grants to support local remediation programs. An example of this in the United States is the Superfund, which contributes federal dollars to clean up hazardous waste sites in situations in which a responsible party is not identified or is unable to pay.

Sustainability

In the long tem, economics is dependent on environmental sustainability. A situation of maximum pollution is one without the resources that businesses need. Thus, economics and the environment are interwoven, dependent on each other, and the concept of sustainability applies to both. Short-term economic success may come more easily by polluting and over-utilizing the environment, but businesses that operate in this way will eventually create excessive harm to humans and the environment. Therefore, economic goals must be aligned with environmental sustainability in order for both to continue indefinitely.

Practice

Questions 1–4 refer to the following air pollutants.

A. Carbon monoxide
B. Sulfur dioxide
C. Nitrogen dioxide
D. Ozone
E. Particulate matter

1. Which criteria pollutant contributes to the creation of industrial smog?

2. Which criteria pollutant is a component of photochemical smog and acid precipitation?

3. Which criteria pollutant can lead to eutrophication in an aquatic system?

4. Which criteria pollutant helps to create smog when in the troposphere but protects life from UV radiation when in the stratosphere?

5. Which of the following best describes the way carbon monoxide interacts in the body to cause asphyxiation?

   A. Carbon monoxide binds with hemoglobin in the bloodstream, displacing oxygen and preventing it from binding with the hemoglobin.
   B. Carbox monoxide is inhaled into the lungs, where it replaces oxygen.
   C. The carbon and oxygen atoms in carbon monoxide separate, and the carbon bonds with hemoglobin.
   D. Excess carbon monoxide cannot cause asphyxiation.
   E. Carbon monoxide combines with oxygen and forms a toxic substance in the body.

6. Endocrine disruption occurs when

   A. Heavy metals bioaccumulate in the body.
   B. An ecosystem is disrupted by the removal of vegetation.
   C. Carbon monoxide replaces a hormone in a molecule within the body, impeding the necessary reaction process.
   D. A toxin replaces a hormone in a molecule within the body, impeding the necessary reaction process.
   E. Allergens over-activate the immune system.

7. Which of the following chemical reactions best represents the process of the creation of acid precipitation?

   A. $N_2 + O_2 \rightarrow 2NO$
      $2NO + O_2 \rightarrow 2NO_2$
      $NO_2 \rightarrow NO + O$
      $O + O_2 \rightarrow O_3$
      $NO + O_3 \rightarrow NO_2 + O_2$
   B. $H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$
   C. $S + O_2 \rightarrow SO_2$
      $2SO_2 + O_2 \rightarrow 2SO_3$
      $SO_3 + H_2O \rightarrow H_2SO_4$
   D. $C + O_2 \rightarrow CO_2$
      $2C + O_2 \rightarrow 2CO$
      $S + O_2 \rightarrow SO_2$
      $2SO_2 + O_2 \rightarrow 2SO_3$
      $SO_3 + H_2O \rightarrow H_2SO_4$
   E. $4FeS_2 + 11O_2 \rightarrow Fe_2O_3 + 8SO_2$

8. The most harmful form of water pollution affecting human health is

   A. An oil spill
   B. Heavy metals
   C. Waterborne diseases and pathogens
   D. Eutrophication
   E. Thermal pollution

9. Genetic pollution occurs when

   A. Speciation occurs.
   B. Mutations occur as cells replicate within an organism.
   C. Toxins are spread by wind.
   D. Artificial selection is used to select desired traits.
   E. There is an unintended spread of altered genetic information from genetically engineered organisms to natural organisms.

10. Which of the following toxins can produce birth defects and affect embryo development?

    A. Mutagens
    B. Teratogens
    C. Allergens
    D. Neurotoxins
    E. Carcinogens

11. Why can asbestos be lethal?

    A. Small inhaled fibers can get lodged in the lining of the lungs, which can cause the lungs to develop scar tissue and can ultimately lead to death.
    B. The gaseous form causes lungs to create acid to combat the invader, which causes the development of scar tissue and can ultimately lead to death.
    C. It is a mutagen.
    D. Asbestos fibers are inhaled and get lodged in the throat, causing asphyxiation.
    E. Asbestos is not lethal but can act as an allergen.

12. Which of the following is a common source of lead pollution today?

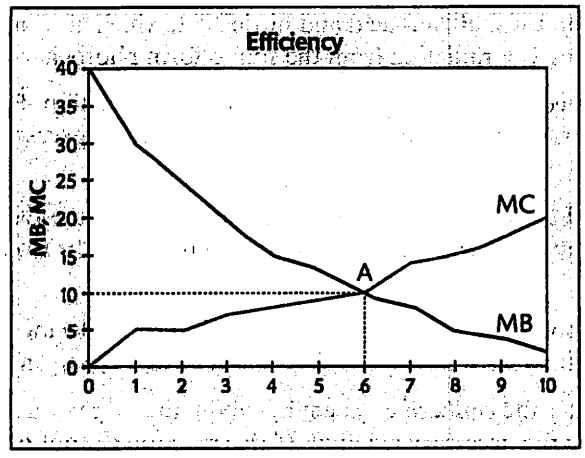
    A. The use of leaded gasoline
    B. Vehicle emissions
    C. Metal processing
    D. Acid precipitation
    E. Smog

13. When a factory uses water to help cool its operational processes and then releases this water into a local river, pollution can occur as which of the following?

    A. Carcinogens
    B. Pathogens
    C. Thermal pollution
    D. Heavy metal pollution
    E. Cold discharged water

Questions 14–15 refer to the following cost-benefit analysis curve.

Cost-Benefit Analysis Curve



MB = marginal benefits *MC = marginal costs*

14. Which is a valid reason why marginal costs exceeded marginal benefits?

- **A.** An increase occurred in the cost of production.
- **B.** There is potential for an increase in biodiversity.
- **C.** Profits are high.
- **D.** Prices are higher than marginal cost.
- **E.** It was pushed in this direction due to an increase in production.

15. At which point on the graph does maximal economic efficiency occur?

- **A.** On the line representing marginal costs
- **B.** On the line representing marginal benefits
- **C.** Where marginal costs exceed marginal benefits
- **D.** At point A
- **E.** Where marginal benefits exceed marginal costs

Answers

1. **B** Sulfur dioxide reacts with UV radiation from the sun to form industrial smog.
2. **C** Nitrogen dioxide reacts to form nitrous acid and nitric acid, which are components of acid precipitation. It also reacts with the heat of UV radiation from the sun to form photochemical smog.
3. **C** Excess nitrogen introduced into an ecosystem can cause eutrophication. Eutrophication occurs when excess nitrogen or phosphorus enters an aquatic system, leading to an excessive growth of phytoplankton, algae, and other plants.
4. **D** "Good" ozone is located naturally in the stratosphere and protects the Earth from harmful ultraviolet radiation from the sun. "Bad" ozone is located close to the ground in the troposphere and is the main component of smog.
5. **A** In the bloodstream, carbon monoxide binds with hemoglobin, displacing oxygen and inhibiting it from binding with the hemoglobin. This can result in suffocation, because oxygen is not circulating in the blood.
6. **D** Endocrine disruptors alter the endocrine system by taking the place of a hormone molecule, blocking the hormone, and impeding the necessary reaction. If this reaction cannot occur, the endocrine (hormone) system cannot function as necessary.
7. **C** Once sulfur is released into the atmosphere, it reacts with oxygen to form sulfur dioxide, which reacts with oxygen to form SO_3. Sulfur trioxide and water react to form sulfuric acid, which can fall as acid precipitation. The chemical reaction is as follows:

$$S + O_2 \rightarrow SO_2$$
$$2SO_2 + O_2 \rightarrow 2SO_3$$
$$SO_3 + H_2O \rightarrow H_2SO_4$$

8. **C** Waterborne diseases and pathogens bring health-related issues such as cholera, typhoid, hepatitis A, *E. coli,* dysentery, SARS, giardiasis, and many others. These diseases and pathogens are passed through water sources and are in higher abundance in unsanitary water. Often, fecal matter is the source of the contaminant. When consumed, or sometimes when a person comes in contact with the water, contamination occurs.
9. **E** When altered genetic material is unintentionally transported to neighboring areas via wind and pollination, the altered material can become part of the genetic makeup of local wildlife and other crops. This is genetic pollution.
10. **B** Teratogens are toxins that can affect embryo development, harm the fetus, or lead to death. When pregnant or breastfeeding, it is important for women to be aware of potential health threats from toxic substances.
11. **A** Small fibers of asbestos can get lodged in the lining of lungs. The lungs produce acid to try to get rid of the fibers, causing scarring of tissue and decreased lung function. This alteration of the lungs can lead to lung cancer.
12. **C** In the past, lead was used as an additive in gasoline, so it was emitted as a pollutant through car emissions. Due to its toxicity, leaded gasoline is no longer used, so the main source of lead is metal processing, including smelting, lead-acid battery manufacturers, and waste incinerators.
13. **C** When water is used as part of the cooling process in a factory, it gets heated due to the transfer of heat from the energy produced by the processes. This heat transfer increases the temperature of the water, so when the water is discharged into a local river, it creates thermal pollution, impacting the ecosystem and wildlife.
14. **A** The marginal costs curve continues to rise after equilibrium, meaning costs are increasing. Costs associated with the production process could be one reason why the overall costs increase. For example, the price of raw materials used in the production process could have increased or increased production could require specialized machinery.
15. **D** At point A, marginal costs and marginal benefits are at equilibrium, which is where economic efficiency is maximized.