CHAPTER 18

Pollution Types

IN THIS CHAPTER

Summary: The Earth's atmosphere and water make up a delicately balanced system that functions well until disrupted by outside forces or contaminants. Some natural contaminants are naturally cleared, while others from human activities take much more effort to eliminate.

KEY IDEA

Keywords

✪ Ozone, troposphere, volatile organic compounds (VOCs), point source, nonpoint source, smog, heat island, dissolved oxygen, dead zones, Superfund, fecal coliform bacteria, total organic carbon (TOC), thermal pollution, sick building syndrome

Atmosphere

Our atmosphere contains oxygen from algae and plants, but the primeval atmosphere was mostly volcanic gases with little oxygen. Today, there are four distinct layers (i.e., troposphere, stratosphere, mesosphere, and thermosphere) divided by temperature, chemical properties, and gaseous mixing. Atmospheric gases include 80% nitrogen (by volume), 20% oxygen, 0.036% carbon dioxide, and trace amounts of other gases. Refer back to Figure 6.1 for these layers.

Virtually all living organisms and human activities occur in the troposphere, which is protected from harmful incoming radiation. Rising and falling temperatures, as well as circulating air masses, keep things lively. When compared to the other layers, however, the troposphere is thin.

Air Pollution

Urban *smog* is a major air pollutant regulated by the EPA, but it is not emitted directly from specific sources. It's formed in the atmosphere from nitrogen oxides and *volatile organic compounds (VOCs)*. Sources of VOCs include: (1) combustion products from motor vehicles and machinery that burns fossil fuels, (2) gasoline vapors from cars and fueling stations, (3) refineries and petroleum storage tanks, (4) chemical solvent vapors from dry-cleaning processes, (5) solid waste facilities, and (6) metal-surface paints. Internal combustion engine fumes contain many VOCs that, when released into the atmosphere, interact with other gases and sunlight to create the ozone part of smog. The EPA has targeted VOC reduction as an important control mechanism for reducing high-ozone-containing smog in cities.

TIP

Since reactions forming ozone are affected by sunlight, high ozone levels usually occur in the summer months when the air is hot and slow moving. In the summer, more people are also traveling in addition to their daily commute, so vehicle emissions rise.

Topography and Heat

When a stable layer of warm air rolls over the top of cooler air, a *temperature inversion* occurs. Instead of it getting colder higher in the atmosphere, it gets warmer. This is particularly true in cities rimmed by mountains (e.g., Los Angeles). At night the land cools, but because pollutants hold the day's heat, cool air slips below and causes an inversion. During the day, air currents mix in more pollutants and by late afternoon a brown haze (i.e., smog) makes eyes water and sinuses burn. At this point, the air is a health hazard.

Smog irritation of the mucous membranes of the nose, throat, and lungs depends on ozone levels, as well as the frequency and duration of exposure. In fact, when urban ozone concentrations are high, illness and hospital admissions go up.

Huge cities with tall buildings and miles of concrete and glass add to this problem. With little plant life to absorb the heat, cities produce high heat gradients during the day and release heat at night. They are often 3–5°C higher than surrounding areas.

These city *heat islands* collect pollutants so that areas downwind have much less visibility and greater rainfall due to condensation characteristics than their neighbors with cleaner air. City aerosols and dust also trigger lightning strikes. In fact, Houston, Texas, which has many oil refineries and chemical plants, has a relatively high number of lightning strikes compared to most other areas in the United States.

Indoor Air

Industry has developed amazing products (e.g., complex carpet fibers, composite wood, linoleum, plastics, paints, and solvents) in the past 60 years. These products make our lives easier, but often contain toxic compounds (e.g., formaldehyde, a known *carcinogen*).

When homes are well ventilated, it isn't a problem, but energy-efficient homes are airtight. Toxic pollutants are trapped indoors where we spend the majority of our time. In the workplace, bad air mixed with mold spores has led to *sick building syndrome*. People suffer headaches, allergies, fatigue, nausea, and respiratory problems leading to greater medical costs, days off, and low productivity.

STRATEGY

When the Clean Air Act named sulfur dioxide, carbon monoxide, nitrogen oxides, photochemical oxidants, particulates, volatile hydrocarbons, and lead as health threats in 1970, it opened the door for stricter regulation of polluting industries. For example, the *Energy Policy and Conservation Act* of 1975 allowed the U.S. Department of Transportation to set the Corporate Average Fuel Economy (CAFE) for motor vehicles. To reduce fuel consumption and emissions, the standard requires vehicles to have an average fuel efficiency of

27.5 mi/gal, with larger vehicles (e.g., SUVs and minivans) at 22.5 mi/gal. Tier 2 standards of 2007 require light trucks to meet the stricter passenger car standard.

CAFE Tier 2 standards also reduced nitrous oxide emissions to 0.07 grams per mile (i.e., 90% reduction) for cars, and targeted gasoline sulfur emissions to drop from 300 to 30 parts per million (ppm).

STRATEGY

In 2005, President George W. Bush announced the *Clean Air Interstate Rule* (CAIR), which set sulfur dioxide, nitrogen oxides, and particulate emissions limits. By 2018, this will decrease these chemicals by 70%.

In addition to removing particulates and limiting industrial production, citizens can also help by conserving energy, using nonpolluting four-cycle gasoline engines, planting trees, writing Congressional representatives, installing high-efficiency fireplace inserts, using latex paints, and reducing dry cleaning.

Water

Pure water (H_2O), completely free from any dissolved substances, is found only in the laboratory. Natural water contains dissolved gases and salts. For example, water must contain enough dissolved oxygen for fish to survive or they die. Drinking water, without dissolved oxygen or dissolved mineral salts, tastes bad. Salts give water its taste.

TIP

A *total organic carbon* (*TOC*) level is measured by hydrologists when checking the health of freshwater. As we have seen, organic matter plays a big role in aquatic systems. It affects biogeochemical processes, nutrient cycling, biological availability, chemical transport, and interactions. It also directly affects municipal choices for wastewater and drinking water treatments. Organic content is commonly measured as total organic carbon and dissolved organic carbon, which are essential components of the carbon cycle.

Pollution

Water pollution is caused by the sudden or ongoing, accidental or deliberate, discharge of a polluting material. Increasing human populations put pressure on the oceans and marine environment. More and more people on the planet lead to more

- Sewage produced
- Fertilizers, herbicides, and pesticides used for crops, lawns, golf courses, and parks
- Fossil fuels extracted and burned
- Oil leaked and spilled
- Land deforested and developed
- Various by-products of manufacturing and shipping generated

Cultural, political, and economic forces affect the types, amounts, and management of waste produced. Increasing population is just one contributor to increasing pollution. As with everything in the environment, the causes and effects are complex.

KEY IDEA

> *Water pollution* comes from the loss of any real or potential water uses caused by a change in the water's composition due to human activity.

Water is used for everything from drinking and household needs to watering livestock and the irrigation of crops. Fisheries, industry, food production, bathing, recreation, and other services all use water to a large extent. When water becomes unusable for any of these purposes, it is polluted to a greater or lesser degree depending on the extent of the damage caused.

Groundwater has been contaminated by leaking underground storage tanks, fertilizers and pesticides, unregulated hazardous waste sites, septic tanks, drainage wells, and other sources, threatening the drinking water of 50% of the U.S. population.

The three major sources of water pollution are *municipal, industrial,* and *agricultural.* Municipal water pollution comes from residential and commercial wastewater. In the past, municipal wastewater was treated by reducing suspended solids, oxygen-demanding materials, dissolved inorganic compounds, and harmful bacteria. Today, the focus is on improving solid residue disposal from municipal treatment processes.

Agricultural areas in the United States have also developed water pollution problems. For example, in Iowa where chemical fertilizers are used across 60% of the state, private and public drinking water wells have exceeded safety standards for nitrates. Towns in Nebraska have also shown high nitrate levels and require monthly well testing.

Runoff

Pollution of marine ecosystems includes runoff from land, rivers, and streams; direct sewage discharge; air pollution; and discharge from manufacturing, oil operations, shipping, and mining.

Although coastal cities have the greatest impact on ocean ecosystems, pollution from runoff is not limited to coastal regions. Runoff from over 90% of the Earth's land surface (inland and coastal) eventually drains into the sea, carrying sewage, fertilizers, and toxic chemicals. Similarly, air pollution from inland as well as coastal cities, including by-products of fossil fuel consumption, polychlorinated biphenyls (PCBs), metals, pesticides, and dioxins, eventually finds its way into the oceans after rain or snow.

Oil Spills

Increased oil demand has increased offshore oil drilling operations and oil transport. These activities have resulted in many oil spills. The number of oil spills worldwide of between 7 and greater than 700 tons has varied in the past 30 years, with some years better than others. Table 18.1 lists the top 15 oil spills (excluding acts of war) recorded by the *International Oil Tanker Owners Pollution Federation* (*IOTPF*). The IOTPF measures all oil lost to the environment, including oil burned and released into the atmosphere or still in sunken ships. Relatively speaking, the well-known *Valdez* spill of 1989 off the coast of Alaska, and thought by many to be a particularly bad spill, was not as extensive as many others (it rates 35th in largest spills), but had a huge impact on the delicate and pristine arctic environment.

Spills account for only 10% of marine oil pollution. About 50% of oil pollution in marine waters comes from ongoing low-level sources such as marine terminal leaks, dumping of offshore oil drilling mud, land runoff, and atmospheric pollution from incompletely burned fuels.

Dead Zones

Cumulative pollution effects on ocean ecosystems are very serious. For example, in the Gulf of Mexico, scientists have identified *dead zones* in once highly productive waters. These zones have been traced to excessive nutrients from farms, lawns, and inadequately treated sewage. This stimulates rapid plankton growth that in turn leads to oxygen depletion in the water.

Blooms of toxic *phytoplanktons* and red tides have increased in frequency over the last two decades and may be linked to coastal pollution. For example, storm water runoff contains suspended particulates, nutrients, heavy metals, and toxin. The effects of storm water runoff often cause *dinoflagellate* (red tide) blooms following storms. These tides cause high numbers of fish and marine mammal deaths and can be a serious threat to human health.

Table 18.1 Oil spill impacts are as related to spill location as total volume lost.

SHIP	YEAR	LOCATION	VOLUME (gallons)
Rena (cargo ship)	2011	Off coast of New Zealand	91,636
Horizon British Petroleum (well blow out oil spill)	2010	Gulf of Mexico	21 million
M/V Selendang	2004	Aleutian Islands, Alaska	337,000
Hurricane Ike (oil platforms, tanks, pipelines)	2008	Gulf of Mexico	500,000
Solar 1	2006	Guimaras Island, Philippines	530,000
Westchester	2000	Port Sulphur, Louisiana	567,000
Hebel Spirit	2007	South Korea	2.8 million
Erika	1999	Coast of Brittany, France	3 million
Hurricane Katrina (oil platforms, tanks, pipelines)	2007	Gulf of Mexico	7 million
Exxon *Valdez*	1989	Prince William Sound, Alaska, USA	11 million
Prestige (sunk with oil inside)	2004	Spain	20 million
Odyssey	1988	St. John's, Newfoundland	43 million
Fergana Valley	1992	Uzbekistan	88 million

pH

Measurement of the *pH* of wastewater is an important factor used in decisions related to its treatment and eventual release into natural water ecosystems.

KEY IDEA

> The measurement of the number of hydrogen ions in water, on a scale from 0 to 14, is called the water's *pH*.

A solution with a pH value of 7 is neutral, while a solution with a pH value less than 7 is acidic and a solution with a pH value greater than 7 is basic. Natural waters usually have a pH between 6 and 9. The scale is negatively logarithmic, so each whole number (reading downward) is 10 times the preceding one (for example, pH 5.5 is 100 times as acidic as pH 7.5).

$$\text{pH} = -\log [\text{H}+] = \text{hydrogen ion concentration}$$

TIP

The pH of natural waters becomes acidic or basic as a result of human activities such as acid mine drainage, emissions from coal burning power plants, and heavy automobile traffic.

Dissolved Oxygen

Oxygen enters water by direct atmospheric absorption or by aquatic plant and algal photosynthesis. Oxygen is removed from water by respiration and the decomposition of organic material.

KEY IDEA

Dissolved oxygen is the amount of oxygen measured in a stream, river, or lake.

Dissolved oxygen is also an important marker of a river or lake's ability to support aquatic life. Fish need oxygen to survive and absorb dissolved oxygen through their gills. Dissolved oxygen present in even the cleanest water is extremely small and depends on several factors, including temperature (e.g., the colder the water, the more oxygen that can be dissolved), water flow volume and velocity, and the number of organisms using oxygen for respiration.

KEY IDEA

Oxygen solubility in water at a temperature of 20°C is 9.2 milligrams oxygen per liter of water (about 9 parts per million).

Dissolved oxygen in water is expressed as a concentration in milligrams per liter (mg/L) of water. Metropolitan activities affecting dissolved oxygen levels include removal of native vegetation, runoff, and sewage discharge. Many of these pollutants are nontoxic, so how do they cause pollution problems?

The answer comes back to the oxygen levels. A rapidly flowing stream reaches 100% saturation of around 9 ppm, which allows healthy growth of natural flora and fauna (e.g., animals and bacteria). The bacteria are mostly aerobic (they require oxygen), and their numbers are controlled by the availability of food (digestible organic matter). Bacterial growth is greatly stimulated when there is a big discharge of organic materials (e.g., sewage, milk, or agricultural waste). Bacteria populations grow rapidly, consuming and depleting water oxygen levels.

The amount of oxygen depletion over time depends on the speed with which the stream takes up oxygen from the atmosphere (*reaeration capacity*). Fast-flowing streams reoxygenate quickly, while deep, slow-flowing rivers take up oxygen slowly. Oxygen loss may be counteracted by plant photosynthesis, which produces oxygen during daylight. However, plant processes can't keep up in heavily polluted areas and oxygen levels drop quickly. In anaerobic conditions (i.e., complete lack of free oxygen), fish die.

Water Treatment

TIP

Whenever water is used for humans, it must be treated from two different angles. First, any surface water from rivers that is used in cities is treated for drinking; usually by chlorination. After water is used for drinking, washing, lawns, toilets, and so forth, it has to be treated at a wastewater treatment plant before it can be released back into the environment.

Most municipal water purification systems use several steps to treat water, from physical removal of surface impurities to chemical treatment. Figure 18.1 illustrates the path water takes from initial water treatment (*chlorination*) to urban use, and then to *wastewater treatment* before its release back into the environment.

Before raw water is treated, it passes through large screens used to remove sticks, leaves, and other large objects like plastic bottles. Sand and grit settle out or fall to the bottom of a tank during this stage. During *coagulation,* a chemical such as aluminum sulfate is added to the raw water, forming sticky blobs that snag small particles of bacteria, silt, and other impurities. *Flocculation* removes impurities by skimming the top of the tank. Water is then pumped slowly through a long basin called a *settling basin.* This is done to remove much of the remaining solid material, which collects at the bottom of the basin during *sedimentation* or *clarification.*

Next, microorganisms like viruses, bacteria, and protozoa, as well as any remaining small particles, are removed. This is done by water *filtration* through layers of sand, coal, and other granular materials. After the water is filtered, it is treated with chemical disinfectants to kill any organisms not collected during filtration.

Chlorine, often the only chemical treatment method used on surface water, is not without problems. When chlorine mixes with organic material, it creates potentially dangerous *trihalomethane* (THM). Big treatment plants remove THM to safe levels, but small towns often don't.

Ozone oxidation is another good disinfectant method, but unlike chlorine, ozone doesn't stay in water after it leaves the treatment plant. So bacteria lurking in municipal or residential water pipes aren't killed.

Ultraviolet light has also been used to treat wastewater by killing microorganisms, but like oxidation, it is a one-time treatment at the plant. There is no continuing protection like that provided by chlorine, but people who oppose water chlorination prefer it.

Turbidity is a measure of water's cloudiness; the cloudier the water, the higher the turbidity. Water turbidity, caused by suspended matter such as clay, silt, and organic matter, can also result from microscopic organisms blocking light through water. Though not a major health concern, turbidity blocks disinfection and augments microbial growth. High turbidity can also be caused by soil erosion, urban runoff, and high flow rates.

Wastewater Treatment

Wastewater treatment starts with screening for large particles, followed by an aerobic system with activated sludge to remove organics. Next, sedimentation and removal of organic biomass takes place, often recycling more than once. Biomass sludge is removed from wastewater before the filtration step. Wastewater filtration, followed by disinfection with chlorine and its removal, takes place before clean water is finally discharged into the environment.

Contaminants

Pollution is bad news. It poisons drinking water and land and marine animals (through bioaccumulation), upsets aquatic ecosystems, and causes deforestation through acid rain.

TIP

In general, four main water contaminants exist: *organic, inorganic, radioactive,* and *acid-base.* Released into the environment in different ways, most pollutants enter the hydrologic cycle as direct (*point source*) and indirect (*nonpoint source*) contamination.

Point sources (e.g., water from factories, refineries, and waste treatment plants) are released directly into urban water supplies. In the United States and elsewhere, these releases are regulated, but some pollutants are still found in these waters.

Nonpoint sources include contaminants entering the water supply from soils and groundwater systems runoff and rainfall. Soils and groundwater contain fertilizer and pesticide residues, as well as industrial wastes. Atmospheric contaminants also come from gaseous emissions from automobiles, factories, and even restaurants.

In 1987, the U.S. Environmental Protection Agency (EPA) issued the *Clean Water Act,* Section 319, calling for federal cooperation, leadership, and funding to help state and local governments tackle nonpoint-source pollution.

Chemicals

Many pollution sources contain high nutrient levels, which affect the photosynthetic cycle of water plants and organisms. This hurts fish and shellfish living in the water.

Nitrogen

Nitrogen, needed by all organisms to grow and reproduce is very common, and found as *nitrate* (NO_3), *nitrite* (NO_2), *ammonia* (NH_3), and *nitrogen gas* (N_2). Organic nitrogen in the cells of living things makes up proteins, peptides, and amino acids. Nitrogen enters waterways from lawn fertilizer runoff, leaking septic tanks, animal wastes, industrial wastewaters, sanitary landfills, and car exhausts.

Phosphorus

Phosphorus is a nutrient needed by all organisms for basic biological processes. It is found in mineral deposits, soils, and organic material, and in very low concentrations in fresh water. However, phosphorus used widely in detergents, fertilizer, and other products is often found in higher concentrations (e.g., phosphate) in the surface waters of populated areas.

Hazardous Waste

TIP

When hazardous waste sites are discovered years after they have been abandoned, it is often individuals or communities who have experienced most of the ill effects (e.g., polluted water, increased birth defects). Sometimes contaminants were dumped illegally or land was purchased for waste disposal and then years later, homes and schools were built on the toxic sites. This is what happened in 1978 at Love Canal, New York. It wasn't until residents noticed dying trees, barrels leaking toxic liquids, and smelly sludge in their basements that the EPA was called.

The land's past use was investigated and families had to be moved away. The entire Love Canal area was closed and cleaned up, costing millions of dollars. This resulted in federal legislation in 1980 called the *Comprehensive Environmental Response Compensation and Liability Act* (CERCLA) or, as it is commonly called, the *Superfund.*

The Superfund established a federal tax on chemical and oil industries and created rules on how abandoned hazardous sites are handled. The Superfund also made it possible to go after polluting offenders and create a trust fund for cleanup when no offender could be found.

Organic Matter

Pollution occurs when silt and other suspended solids (e.g., soil) run off newly plowed fields, construction and logging sites, residential areas, and river banks after a rain or snow melt. In the presence of excess phosphates, lakes and slow-moving rivers go through *eutrophication,* gradually filling them in with sediment and organic matter. When extra sediments enter a lake, fish respiration is impacted, plant growth and water depth are limited, and aquatic organisms asphyxiate. Early phosphate removal helps prevent eutrophication.

Organic pollution enters waterways as sewage, leaves and grass clippings, or as runoff from livestock feedlots and pastures. When bacteria break down this organic material, measured as *biochemical oxygen demand* (*BOD*), they use oxygen dissolved in the water. Most fish can't live when dissolved oxygen levels drop below 2 to 5 parts per million. So, when this happens, fish and other water organisms die in huge numbers and the food web is hit hard. Pollution of rivers and streams is one of the most critical environmental problems of the past 100 years causing a domino effect of destruction.

Measuring Toxicity

TIP

Subtle differences in the human genome may explain why what affects some individuals greatly has little or no affect on others. For this reason when measuring toxicity and setting safety limits, individual and species variations must be taken into account. Some species are more susceptible to specific chemicals than others. For example, of the 226 known cancer-causing chemicals in rats and mice, 95 cause cancer in one species, but not the other.

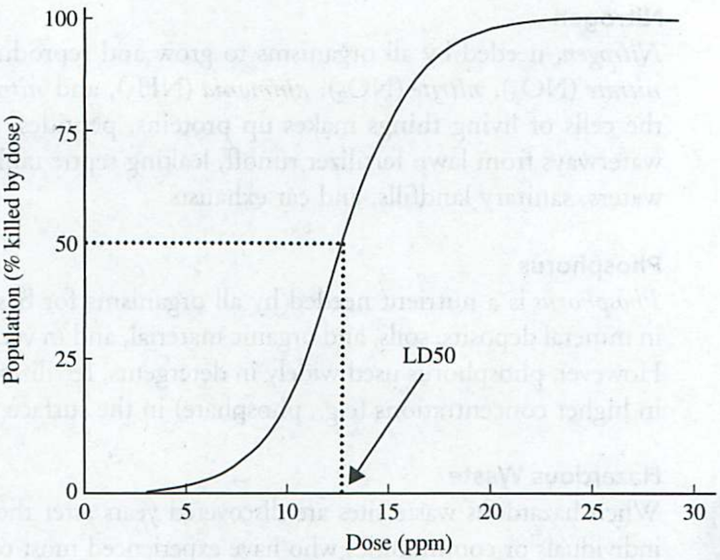

Figure 18.1 Scientists use dose response curves to set acceptable limits for pollutants/carcinogens.

When setting acceptable limits for different pollutants, scientists use *dose response curves.* A chemical's toxicity dose is equal to that amount at which 50% of a test population is sensitive. A lethal dose is written as *LD50.* Figure 18.1 shows a hypothetical chemical's LD50 and dose response curve.

Pathogens

Fecal coliform bacteria, present in the feces and intestinal tracts of humans and warm-blooded animals, enter rivers and lakes from human and animal waste. When fecal coliform bacteria are present, it is an indication of pathogenic microorganisms.

TIP

Pathogens or disease-causing microorganisms cause everything from typhoid fever and dysentery to respiratory and skin diseases. Microscopic pathogens (e.g., bacteria, viruses, and protozoa) enter waterways through untreated urban sewage, storm drains, pet waste, septic tanks, farm runoff, and bilge water, causing sickness and/or death.

Protecting human health is the key concern in water treatment. Removal of potential pathogens, turbidity, hazardous chemicals, and nitrates are all important factors in keeping water safe. Poor and war-torn countries around the world have no clean drinking water. The vast majority of disease in these countries is directly related to polluted water supplies.

Acid Rain

Rain is naturally acidic (pH of 5.6 to 5.7) because water reacts with carbon dioxide in the atmosphere to form carbonic acid. Acid rain is formed when elevated levels of atmospheric chemicals (i.e., nitrogen, sulfur, and carbon) react with water and turn to the Earth in acidic raindrops.

When acid rain falls on limestone statues, monuments, and gravestones, it dissolves, discolors, and/or disfigures the surfaces by reacting with the rock. This is known as *dissolution.* Statues and buildings, hundreds to thousands of years old, suffer this kind of weathering.

As early as the 17th and 18th centuries, acid rain affected plants and people. Angus Smith published a book called *Acid Rain* in 1872. However, it wasn't until fishermen saw fish numbers and diversity declining throughout North American lakes and Europe that it became globally recognized. The eastern North American coast has precipitation pH levels near 2.3 or about 1,000 times more acidic than pure water.

KEY IDEA

> *Acid rain* refers to all types of precipitation (rain, snow, sleet, hail, fog) that are acidic (pH lower than the 5.6 average of rainwater) in nature.

Sulfur and nitrogen oxides in acid rain are released from industrial smokestacks, vehicle exhausts, and wood burning. In the atmosphere, oxides mix with moisture becoming sulfuric and nitric acid and fall to the ground as rain and snow.

TIP

Acid rain has been measured in the United States, Germany, the Czech Republic, the Netherlands, Switzerland, and Australia. It is also becoming serious in Japan, China, and Southeast Asia. Acid rain affects lakes, streams, rivers, bays, ponds, and other bodies of water by increasing acidity until aquatic creatures can no longer live. Aquatic plants grow best between pH 7.0 and 9.0. As acidity increases, submerged plants die and waterfowl lose a basic food source. At pH 6, freshwater shrimp cannot survive. At pH 5.5, bacterial decomposers die, organic debris stops getting broken down and builds up on the bottom, and plankton die off. Below 4.5 pH, all fish die.

Acid rain also harms surface vegetation. Forests in western Europe are thought to be dying from acid rain. Scientists think acid rain damages leaves' protective coating, allowing acids to penetrate. This disrupts water evaporation and gas exchange to the point that the plant can no longer breathe, convert nutrients, or take up water.

A big acid rain effect on forests is nutrient leaching from the soil and toxic metal concentration. Nutrients leach out when acid rain adds hydrogen ions to the soil and reacts with local minerals (e.g., calcium, magnesium, and potassium), robbing trees of nutrients. Toxic metals such as lead, zinc, copper, chromium, and aluminum are deposited in the forest by the atmosphere. When acid rain interacts with these metals, it stunts tree and plant growth, along with mosses, algae, nitrogen-fixing bacteria, and fungi.

Treating Acid Rain Deposition

A number of methods reduce acid deposition problems (e.g., liming) and aid in normalizing pH. Large amounts of hydrated lime or soda ash, added to lake waters, raise alkalinity and pH. However, some lakes are unreachable, too large and costly to treat, or have a high flow rate and become acidic soon after liming. The best way to slow or stop acid deposition is to limit chemical emissions at their source.

Legislation

STRATEGY

In some countries, regulations limit atmospheric sulfur and nitrogen oxide emissions. Acidic pollutants from industry are reduced by (1) switching to fuels that have zero or low sulfur content, and (2) using smokestack scrubbers to reduce sulfur dioxide released. Requiring catalytic converters on vehicles limits these emissions from automobiles and trucks.

In 1991, Canada and the United States established the *Air Quality Accord,* which controls cross-border air pollution. This agreement established a permanent limit on acid emissions (i.e., 13.3 million tons in the United States and 3.2 million tons in Canada).

Oil Slicks, Radioactivity, and Thermal Problems

Large oil spills (e.g., the Exxon *Valdez*) cause tons of pollution along shorelines. One estimate suggests that one ton of oil is spilled for every million tons of transported oil.

Oil pollution is devastating to coastal wildlife, since even small oil amounts spread quickly across long distances to form deadly oil slicks. Once spilled, oil is hard to remove or contain, washing up along miles of shoreline. Efforts to chemically treat or sink spilled oil often disrupt marine ecosystems even more than the original spill.

Radioactivity

Large amounts of radioactive waste materials are created by nuclear power plants, industry, and mining. Dust and rock from uranium mining and refining contain radioactive contaminants, which cause problems due to runoff from mining sites.

Medical *radioactive tracers,* which include phosphorus (^{32}P), iron (^{59}Fe), and iodine (^{131}I), are used to detect and treat early-stage diseases (e.g., thyroid, breast cancer). Thallium (^{201}Tl) is used to detect heart disease since it binds tightly to well-oxygenated heart muscle. However, no matter how helpful they are, radioactive elements can enter sewage if not disposed of properly.

Thermal Pollution

Heat or *thermal pollution* has far-reaching and damaging ecological effects. It pollutes water by impacting aquatic organisms and animal populations.

KEY IDEA

> The release of a liquid or gas, which increases heat in a surrounding area, is known as *thermal pollution.*

Water temperature controls metabolic and reproductive activities in aquatic life. Most marine organisms are cold-blooded, and their body temperatures are controlled by the water temperature around them. Cold-blooded organisms have adapted to specific temperature ranges. If water temperatures change too much, metabolic processes break down. Unlike humans, who can adapt to wide temperature ranges, most organisms live in narrow temperature niches. When these niches change, marine organisms die.

TIP

Industries (e.g., electric power plants, refineries, metal smelters, paper mills, food processing, and chemical manufacturing) produce thermal pollution and often release high-temperature wastewater directly into rivers and lakes. This heated water disrupts ecosystems at the discharge site and downstream.

Noise Pollution

Noise pollution seems more subjective than other pollution types, since what affects one person may not bother someone else, but very loud noises like jack hammers and jet engines actually damage the inner ear. The Environmental Protection Agency created the *Noise Control Act* of 1972 to set limits on major sources of noise (e.g., construction, equipment and vehicles).

TIP

In the United States, the *Occupational Safety and Health Agency* (OSHA) regulates workplace noise pollution and safety. It sets limits for worker exposure to noise, as well as requiring protective safety equipment.

Looking to the Future

Science provides modern methods to reduce and treat pollutants before they enter the environment. However, it's important to consider how our activities affect the environment and what can be done to minimize the impact. Table 18.2 lists the many sources and types of pollution to monitor.

Table 18.2 There are many different sources of pollution.

POLLUTION SOURCE	COMPOSITION OF POLLUTANT
Automobiles	Burning of oil and gas produces carbon monoxide, VOCs, hydrocarbons, nitrogen oxides, peroxyacetyl nitrate, benzene, and lead.
Utility power plants	Burning of coal, oil, and gas produces nitrogen oxides, heavy metals, sulfur dioxide, and particulates.
Industry	Particulates, sulfur dioxide, nitrogen oxides, heavy metals, fluoride, CFCs, and dioxins are emitted by smoke stacks.
Incineration	Carbon monoxide, nitrogen oxides, particulates, dioxins, and heavy metals are produced by burning.
Biomass burning	Burning of grasslands, crop stubble, agricultural waste, organic fuel, and forests produces sulfur, methane, radon, carbon dioxide, nitrogen oxides, carbon monoxides, and particulates.
Small engines	Mowers, blowers, trimmers, chain saws, and other machines produce nitrogen oxides and hydrocarbons.
Disasters	Radiation leaks, chemical leaks, and burning of oil wells produce radiation, nitrogen oxides, carbon monoxide, sulfur, heavy metals, and particulates.
Mining	Rock breakdown and processing produces nitrogen oxides, heavy metals, radiation particles, and particulates.
Erosion	Road work and farm work produce dust, particulates, dried pesticides, and fertilizers.
Indoor air pollution	Carpeting, cooking, and other indoor products and activities produce formaldehyde, lead and asbestos dust, radon, and other incorporated chemicals.
Nature	Volcanic eruptions and forest fires produce dust and particles, sulfur dioxide, carbon monoxide, carbon dioxide, chlorine, nitrogen oxides, heavy metals, radon, and particulates.

Green Taxes

TIP

Income, land, and employment are taxed, while polluting processes have not historically been heavily taxed. However, policy makers are starting to set higher taxes on polluting activities and industries. *Green taxes* are gaining support, along with carbon taxes on fossil fuels; mining, energy, and forestry taxes; fishing and hunting licensing; garbage taxes; and effluent, emissions, and hazardous waste fees. These new and/or higher taxes are meant to clean up pollution problems and change behavior.

Since *Earth Day* was first established by President Richard Nixon on April 22, 1970, the public has awakened to resource limitations, endangered species, air and water pollutants, and environmental protection.

› Review Questions

Multiple-Choice Questions

1. The atmospheric layer largely responsible for absorbing the sun's ultraviolet (UV) radiation is the

(A) thermosphere
(B) cumulus cloud
(C) troposphere
(D) stratonimbus
(E) ozone

2. Precipitation is considered acidic (e.g., rain, snow, sleet, hail, fog) if it has a pH less than

(A) pH 5.6
(B) pH 6.2
(C) pH 7.0
(D) pH 8.2
(E) pH 9.0

3. The four main polluting contaminant types include all the following except

(A) inorganic
(B) organic
(C) acid-base
(D) drought
(E) radioactive

4. Atmospheric gases blanketing the Earth exist in a mixture. What percent of this mixture is nitrogen (by volume)?

(A) 8%
(B) 20%
(C) 36%
(D) 58%
(E) 80%

5. Taxes on fossil fuels, mining, energy, forestry, fishing and hunting licensing, garbage, effluent and emissions, and hazardous wastes are known as

(A) recreation taxes
(B) park taxes
(C) green taxes
(D) incentive taxes
(E) single use taxes

6. The atmospheric layer where all the local temperature, pressure, wind, and precipitation changes take place is the

(A) stratosphere
(B) ionosphere
(C) mesosphere
(D) troposphere
(E) thermosphere

7. Why is thermal pollution a problem for marine organisms?

(A) They are hot-blooded and overheat.
(B) Their metabolic processes break down.
(C) They are adapted to wide temperature ranges.
(D) They don't have a problem with it.
(E) They live in many temperature niches.

8. When acid rain falls on limestone statues, monuments, and gravestones, discoloring and disfiguring surfaces, the process is known as

(A) dispensation
(B) sedimentation
(C) dissolution
(D) suspension
(E) cementation

9. Brown urban smog is not emitted directly from specific sources, but formed in the atmosphere from nitrogen oxides and

(A) inorganic compounds
(B) volatile organic compounds
(C) potassium chloride
(D) fertilizer
(E) helium

10. In the workplace, bad air mixed with mold spores has led to

(A) shorter coffee breaks
(B) increased productivity
(C) sick building syndrome
(D) reduced medical costs
(E) greater appreciation of weekends

11. Looking at Figure 18.1, what dose would be lethal to 25% of the population?

(A) 4 ppm
(B) 7 ppm
(C) 9 ppm
(D) 11 ppm
(E) 14 ppm

12. City heat islands cause

(A) pollutants to collect
(B) residents to seek winter vacations
(C) less dust and lightning strikes
(D) reduced rainfall
(E) greater visibility

13. Total organic carbon (TOC) levels are used by hydrologists to check the health of freshwater as it affects biogeochemical processes and

(A) climate change
(B) nutrient cycling
(C) annual rainfall
(D) biological unavailability
(E) carbon nanotube levels

14. The Comprehensive Environmental Response Compensation and Liability Act (CERCLA) is commonly called the

(A) Superfund
(B) Clean Air Interstate Rule
(C) Liability Limitation Act
(D) Clean Water Act
(E) CAFE standards

15. The amount of dissolved oxygen in water depends on

(A) temperature
(B) water flow volume
(C) water flow velocity
(D) number of organisms using oxygen for respiration
(E) all of the above

16. Turbidity is a measure of water's

(A) transparency
(B) cloudiness
(C) chlorination
(D) coagulation
(E) flocculation

17. The amount of oxygen depletion in water depends on the speed at which a stream can take up atmospheric oxygen and replenish its

(A) color
(B) pathogens
(C) reaeration capacity
(D) turbidity
(E) minerals

18. The least likely way microscopic pathogens (e.g., bacteria, viruses, and protozoa) enter waterways is through

(A) untreated urban sewage
(B) farm runoff
(C) bilge water
(D) mining runoff
(E) family pet waste

› Answers and Explanations

1. C—The atmospheric layer closest to the Earth where life is protected from harmful cosmic radiation showers is the troposphere.

2. A—Natural rain has a pH of 5.6, so anything with a pH below that is considered acid rain.

3. D—Drought is a climatic condition not a contaminant.

4. E—Nitrogen makes up the largest component of the atmosphere.

5. C

6. D—The troposphere is the most active of the atmospheric layers.

7. B—Unlike humans, who can adapt to wide temperature ranges, most organisms live in narrow temperature niches and their metabolism breaks down at higher temperatures.

8. C

9. B—Urban smog, regulated by the EPA, is not emitted directly from specific sources, but formed in the atmosphere from nitrogen oxides and volatile organic compounds.

10. C—People suffer headaches, allergies, fatigue, nausea, and respiratory problems leading to greater medical costs, sick days off, and low productivity.

11. D—Starting at 25% of the population killed (vertical axis), intersect the dose response curve and then read the dose level (horizontal axis).

12. A—City heat islands collect pollutants such as dust and particulates.

13. B—Total organic carbon (TOC) levels are used by hydrologists to check the health of freshwater as it affects biogeochemical processes, bioavailability, and nutrient cycling.

14. A

15. E

16. B

17. C—Fast-flowing streams reoxygenate quickly, while deep, slow-flowing rivers take up oxygen much more slowly.

18. D—Mining runoff is often the source of heavy metal and chemical contaminants rather than pathogens.

Free-Response Questions

1. Sometimes when trying to help the environment, we create other problems. For example, methyl tertiary-butyl ether (MTBE), a by-product of natural gas, increases octane levels and burns cleaner than gasoline. In 1990, the Clean Air Act mandated MTBE be added to gasoline in areas with ozone problems. Unfortunately, MTBE was a serious groundwater pollutant. Like benzene, the most hazardous gasoline-related groundwater pollutant in the United States, MTBE (less toxic) changes groundwater color and causes it to smell and taste like turpentine in the smallest quantities. Because of this, California and 11 other states are phasing MTBE out and looking for alternatives to reduce pollution and fossil fuel emissions.

   (a) Provide examples and descriptions of the three main water pollutants.
   (b) Long-term environmental effects from the use of MTBE must be prevented by cessation of MTBE as a fuel additive. Groundwater changes that occur with MTBE-related reactions foul water use for public consumption or recreational use as well as environmentally by marine species in the polluted area. Other fuel methods or chemicals to increase octane levels must be found.

2. The Federal Centers for Disease Control estimate that 82% of all Americans have the widely used insecticide Dursban (now banned) in their bodies. To limit the use of this chemical and others, control pests, and protect waterways from pollution, people can (1) use pesticides sparingly, (2) focus on early identification of pests, (3) use natural controls (e.g., ladybugs eat aphids), and (4) plant naturally resistant native plants.
   (a) What are other practical ways in which we can keep our air and water clean?
   (b) What other pollutants have an impact on human health? Why?

Free-Response Answers and Explanations

1.
   a. Municipal: Sewage is an example of municipal water pollution. Greater population growth and heavily populated urban centers produce vast quantities of wastewater, which if untreated can find its way into the groundwater and other freshwater supplies.
      Industrial: MTBE is an example of an industrial water pollutant. Produced on a mass scale and mandated for use in gasoline by the government, MTBE rendered sources of water in California hazardous to the environment and undrinkable.
      Agricultural: Fertilizers and pesticides are major contributors to agricultural water pollution due to runoff and poor irrigation practices.
   b. Individuals can get MTBE information from California and then check MTBE use in their own state. With this information in hand, they can approach their state representatives about discontinuing the additive.

2.
   a. We can keep our air and water clean by encouraging the food industry to use recycled packaging and natural dyes where possible and to keep toxic dyes out of landfills and groundwater. Walking or biking, instead of driving everywhere, also cuts down on acid, hydrocarbon, and nitrogen oxide emissions to the atmosphere and therefore to worldwide freshwater supplies.
   b. Oil spills, acid rain, radioactivity, and noise pollution all impact human health. For example, very loud work environments can damage the inner ear and cause hearing loss.

› Rapid Review

- In general, four main categories of contaminants exist: organic, inorganic, radioactive, and acid-base.
- Green and carbon taxes are being assessed on fossil fuels, mining, energy, forestry, fishing and hunting licensing, garbage, effluent, emissions, and hazardous wastes.
- Thermal pollution, the release of liquid or gas that increases heat in a surrounding area, has far-reaching and damaging ecological effects by impacting aquatic organisms and animal populations.
- Cold-blooded organisms adapted to specific temperature ranges. If water temperatures change too much, metabolic processes break down. Unlike humans, who can adapt to wide temperature ranges, most organisms live in narrow temperature niches.
- In the workplace, sick building syndrome has caused workers to suffer headaches, allergies, fatigue, nausea, and respiratory problems.

- City heat islands collect pollutants so that areas downwind have much less visibility and greater rainfall due to condensation than their neighbors with cleaner air.
- Total organic carbon (TOC) levels are used by hydrologists to check the health of freshwater as it affects biogeochemical processes, nutrient cycling, biological availability, chemical transport and interactions.
- The amount of dissolved oxygen in water depends on temperature (the colder the water, the more oxygen that can be dissolved), water flow volume and velocity, and the number of organisms using oxygen for respiration.
- Microscopic pathogens (e.g., bacteria, viruses, and protozoa) enter waterways through untreated urban sewage, storm drains, pet waste, septic tanks, farm runoff, and bilge water causing sickness and/or death.
- Water turbidity, caused by suspended matter such as clay, silt, and organic matter, can also result from microscopic organisms blocking light through water and provide a medium for their growth.
- Ozone oxidation is a good water disinfectant method, but unlike chlorine, ozone doesn't stay in water after it leaves the treatment plant.
- Ultraviolet light is used to treat wastewater by killing microorganisms, but like oxidation, it is a one-time treatment at the plant.
- During coagulation, aluminum sulfate is added to raw sewage water, forming sticky blobs that snag small particles of bacteria, silt, and other impurities.