8

Pollution

According to ETS, about 25–30 percent of the questions you'll see on this exam will be on pollution. That means that there will be more questions about topics that fall under the broad category of pollution than there will be questions about any of the other major topics. This just goes to show the environmental importance of how we create waste and what we do with it.

We'll begin the chapter with a discussion of what it means for something to be toxic. We'll move on to discuss toxins in air pollution, and then review the major aspects of thermal pollution, water pollution, and the problems that arise as a result of solid waste. As we go through each type of pollution, we'll also discuss the impact of pollution on the environment and human health, as well as some economic impacts. Let's begin!

TOXICITY AND HEALTH

A **toxin** is any substance that is inhaled, ingested, or absorbed at sufficient dosages that it damages a living organism, and the **toxicity** of a toxin is the degree to which it is biologically harmful. Almost any substance that is inhaled, ingested or absorbed by a living organism can be harmful when it is present in large enough quantities—even water! In order for a substance to be harmful, all of the following must be considered:

- Dosage amount over a period of time
- Number of times of exposure
- Size and/or age of the organism that is exposed
- Ability of the body to detoxify that substance
- Organism's sensitivity to that substance (due, for example, to genetic predisposition, or previous exposure)
- Synergistic effect (more than one substance combines to cause a toxic effect that's greater than any one component)

Substances are usually tested for toxicity using a **dose-response analysis.** In a dose-response analysis, organisms are exposed to a toxin at different concentrations, and the dosage that causes the death of the organism is recorded. The information from a set of organisms is graphed and the resulting curve referred to as a **dose-response curve.** The dosage of toxin it takes to kill 50 percent of the test animals is termed **LD_{50}**, and this value can be determined from the graph. A high LD_{50} indicates that a substance has a low toxicity; a low one indicates high toxicity. A **poison** is any substance that has an LD_{50} of 50 mg or less per kg of body weight.

If just the negative health effects are plotted, instead of the level of the toxin at which death occurs, the resulting graph indicates the dosage that causes a change in the state of health. In this case, the **ED_{50}** is the point at which 50 percent of the test organisms show a negative effect from the toxin. The dosage at which a negative effect occurs is referred to as the **threshold dose.** Two more terms you should know for the test are **acute effect** and **chronic effect.** An acute effect is an effect caused by a short exposure to a high level of toxin; a snakebite, for example, causes an acute effect. A **chronic effect** is what results from long-term exposure to low levels of toxin; an example of this would be long-term exposure to lead paint in a house.

An **infection** is the result of a pathogen invading our body, and **disease** occurs when the infection causes a change in the state of health. For example, HIV, the virus that causes the disease AIDS, infects the body and typically has a long residence time. When it causes a change in a person's state of health, it has morphed into a disease called AIDS.

There are five main categories of pathogens.

- Viruses (and other subcellular infectious particles, such as prions)
- Bacteria
- Fungi
- Protozoa
- Parasitic worms

Pathogens are bacteria, viruses, or other microorganisms that can cause disease. Pathogens can attack directly or via a carrier organism (called a **vector**). One example of a pathogen that relies on a vector is the bacteria that causes Rocky Mountain spotted fever; it lives in the bodies of ticks, and when ticks bite humans, they inject the bacteria and cause the disease.

As you're probably well aware, other things besides pathogens can make people ill, including environmental factors such as tobacco smoke, UV radiation, or asbestos. Also, although you may be exposed to a toxin or an infectious agent and not experience a change in the state of your health, someone else who's exposed to the toxic agent or pathogen could become very ill.

The degree of likelihood that a person will become ill after exposure to a toxin or pathogen is called **risk.** Many environmental, medical, and public health decisions are based on potential risk. Calculating risk is referred to as **risk assessment,** and **risk management** means using strategies to reduce the amount of risk. The U.S. Department of Public Health and Public Services is an organization that makes use of risk assessment and management; for example, they decide who can receive the flu shot each year. If the risk of getting the flu is high for a particular year, most of the population is encouraged to get the shot; however, if the risk seems small or the predicted flu strains are mild, only older people and the immunocompromised are advised to get the flu shot.

AIR POLLUTION

Substances that are considered contributors to air pollution have two sources; they can be natural releases from the environment or they can be created by humans. The effects of air pollution on humans can range in severity from lethal to simply aggravating. Some natural pollutants include pollen, dust particles, mold spores, forest fires, and volcanic gases. One of the more recently described air pollutants from nature is produced by dinoflagellates, which, you might recall from Chapter 3, are the organisms that cause red tide. The toxins that are produced by these algae are caught in sea spray in which they can be aerosolized and inhaled by humans, causing respiratory distress.

Although you may think that human-caused pollution is a relatively new phenomenon, people have added pollutants to the air throughout the history of humankind. Early man's fire created pollutants, and the Roman's smelting of lead resulted in air pollution that drifted thousands of miles from the source—and has even been discovered trapped in the ice of Greenland! It is true, however, that the large-scale production of pollutants began with the Industrial Revolution; and this is especially true of air pollution. The beginning of the Industrial Revolution marked the entrance of pollutants from fossil fuel into the atmosphere, for example, and this has been environmentally disastrous.

Let's go over some terms used to describe pollution before we get into more specific details. **Primary pollutants** are those that are released directly into the lower atmosphere (remember the troposphere?) and are toxic; one example of a primary pollutant is carbon monoxide (CO). **Secondary pollutants** are those that are formed by the combination of primary pollutants in the atmosphere; an example of a secondary pollutant is acid rain. Acid rain is produced from the combination of **sulfur oxides** (such as SO_2 and SO_3) and water vapor.

Pollutants can be released by **stationary sources,** such as factories or power plants, or they can be released by **moving sources,** like cars. **Point source pollution** describes a specific location from which pollution is released; an example of a point source location might be a factory or a site where wood is being burned. Pollution that does not have a specific point of release—for example, a combination of many sources, such as a number of cows releasing methane gas within a few square miles—is known as **non-point source pollution.**

The Major Culprits

The Environmental Protection Agency has determined that there are six pollutants (familiarly referred to as the dirty half dozen) that do the most harm to human health and welfare; the Environmental Proection Agency (EPA) refers to them as **criteria pollutants.** They are

- carbon monoxide, CO
- lead, Pb
- ozone, O_3
- nitrogen dioxide, NO_2
- sulfur dioxide, SO_2
- particulates

In general, gases in the atmosphere are measured in units of parts per million, or ppm, when they are in relative abundance; when they are present in trace (very small) amounts, they are measured in parts per billion (ppb). For example, if in a certain geographic area, the carbon dioxide content of the air is 10 ppm, this would mean that there are ten molecules of CO_2 per one million molecules of air.

Let's go back through the list above. Carbon monoxide (CO) is an odorless, colorless gas that's typically released as a by-product of incompletely burned organic material, such as fossil fuels. CO is hazardous to human health because it binds irreversibly to hemoglobin in the blood. Hemoglobin is the molecule that is responsible for transporting oxygen around the body from the lungs. Hemoglobin has a higher affinity for CO than it does for oxygen, which means that in the presence of both CO and O_2, CO will bind more readily than O_2. In our normal oxygen-rich environments this competition is not a problem, but in areas where CO is present in large concentrations, it can be deadly. More than 60 percent of the CO released into the atmosphere comes from vehicles that burn fossil fuels.

Lead is an air pollutant that, as you now know, has been around since the time of the Roman smelters. It is generally released into the atmosphere as a particulate (a very small solid particle that can be suspended in the air), but then settles on land and water, where it is incorporated into the food chain. If it enters the human body, it can cause numerous nervous system disorders, including mental retardation in children. At one time, lead entered the atmosphere primarily as a result of the burning of leaded gasoline. However, lead gas has been phased out, and now the primary source of lead is industrial smelting. Incidentally, the "lead" in your pencils is not the element lead; in fact, it's the mineral graphite. The graphite in pencils received the name "lead" because of its lead-like color when it's transferred to paper.

We began our discussion of ozone in Chapter 3 and have mentioned it several times since. Notice that the ozone the EPA calls one of the dirty half dozen is specifically—and only—the ozone that's formed as a result of human activity. This **tropospheric ozone** is very different from the ozone in the stratosphere, which shields us from UV radiation. Up high, ozone helps us; down low, it hurts us. O_3 is a secondary pollutant; it is formed in the troposphere as a result of the interaction of **nitrogen oxides,** heat, sunlight, and volatile organic compounds (VOCs). Tropospheric ozone is a major component of what we think of as smog (more on this later).

The next major culprit on the list, nitrogen dioxide (NO_2), is one in a family of nitrogen and oxygen gases. NO_2 and the other nitrogen oxides are formed when atmospheric nitrogen and oxygen react as a result of exposure to high temperatures; this type of reaction occurs in combustion engines, for example. In fact, more than half of the nitrogen oxides in the atmosphere are released as a result of combustion engines. Other sources of nitrogen oxides are utilities and industrial combustion. Nitrogen dioxide is also commonly found as a secondary pollutant, and is a component of smog and acid precipitation.

Sulfur dioxide (SO_2) is a colorless gas with a penetrating and suffocating odor. It is a powerful respiratory irritant, and is typically released into the air through the combustion of coal. As we mentioned in Chapter 7, the use of scrubbers in coal-burning plants has helped reduce the amount of SO_2 released into the atmosphere. However, there are other sources of sulfur dioxide, including the processes of metal smelting, paper pulping, and the burning of fossil fuels. Sulfur dioxide can also be a component of indoor pollutant as a result of gas heaters, improperly vented gas ranges, and tobacco smoke. In the atmosphere, SO_2 reacts with water vapor to form acid precipitation. Here's one last note to help you with the test: Both nitrogen and sulfur can combine with oxygen to make several different molecules. Rather than a list of all the possible molecules, you might see the terms NO_X and SO_X. These terms (O_X) mean that there are several sulfur- and nitrogen-containing compounds mixed together.

Particulate matter is the last on the EPA's list of the dirty half dozen. Like lead, it is not a gas, but exists in the form of small particles of solid or liquid material. These particles are light enough to be carried on air currents, and when humans breathe them in, the particles act as irritants.

There have been significant decreases in the atmospheric content of both lead and carbon monoxide since the 1970s, mostly because of the phasing out of lead gasoline and the introduction of car engines that burn more cleanly. However, there are other air pollutants that are a growing concern to environmentalists, including the volatile organic compounds (VOCs), which are released as a result of various industrial processes including dry cleaning, the use of industrial solvents, and the use of propane. VOCs can react in the atmosphere with other gases to form O_3 and are a major contributor to smog in urban areas. Now, what exactly is smog?

Smog

As you might be aware, the setting for many of the Sherlock Holmes mysteries was the foggy, smoggy city of London. The smog that covered London throughout the nineteenth century and well into the middle of the twentieth was **industrial smog**—also known as **gray smog.** As deadly as any of Holmes's adversaries in Sir Arthur Conan Doyle's stories, gray smog killed more than 2,000 people in a prolonged smog incident in 1911. However, the worst pollution-related incident in London occurred in 1952 and led to the death of about 10,000 city dwellers from pneumonia, tuberculosis, heart failure, and bronchitis. It was this disaster, resulting from the burning of large amounts of low-quality coal to heat homes and combat a cold fog, that prompted the Clean Air Act of 1952 in England.

Industrial smog is formed from pollutants that are typically associated with the burning of oil or coal. When **CO and CO_2** are released in the process of combustion, they combine with particulate matter in the atmosphere and produce smog. The production of smog can also be aided by weather conditions—air inversions, for example, which trap the pollutants; or fog, which holds the pollutants. As we mentioned above, sulfur dioxide may be another component in gray smog, combining with water vapor to form sulfuric acid that is suspended in the cloud of smog.

Photochemical smog, a different type of smog, is usually formed on hot, sunny days in urban areas. In photochemical smog, NO_x compounds, VOCs, and ozone all combine to form smog with a brownish hue. The intensity of sunlight on these days also promotes the formation of ozone from the combination of NO_x compounds. Los Angeles, California and Athens, Greece are two cities that are particularly susceptible to photochemical smog. Athens has enacted mandates that have already reduced the number of cars driven each day in the city and improved the quality of the air. For example, in Athens, by law, cars with even numbered license plates can only be driven on even-numbered days—and cars with odd-numbered license plates can only be driven on odd-numbered days!

Ozone Depletion

While harmful in the troposphere, as you know, ozone in the stratosphere provides us with a much-needed defense against ultraviolet radiation. The ozone layer is responsible for blocking about 95% of the sun's ultraviolet radiation (UV), thus protecting surface-dwelling organisms from UV damage. Ozone is naturally created by the interaction of sunlight and atmospheric oxygen. The simplified reaction is

$$O_2 + \text{UV (sunlight)} \rightarrow O + O$$
$$O + O_2 \rightarrow O_3$$

As early as the mid-1950s, a thinning of the ozone layer above the Antarctic was observed. In the 1970s, atmospheric scientists hypothesized and later proved that declining stratospheric ozone levels were due a group of man-made chemicals known as **chlorofluorocarbons (CFCs)**. Invented in the 1930s, CFCs and many other related compounds (e.g., halons and hydrochlorofluorocarbons) were used in items such as propellants, fire extinguishers, and cans of hairspray.

Once released, CFCs migrate to the stratosphere through atmospheric mixing (they are very stable, which allows them to survive through the rise). In the upper stratosphere, intense UV radiation breaks the CFC molecules apart and releases chlorine atoms that form chlorine monoxide (ClO) while converting O_3 to O_2. Let's take a look at that reaction.

$$Cl + O_3 \rightarrow ClO + O_2$$

During the winter months, chlorine monoxide is concentrated on ice crystals that form in and around the Antarctic polar vortex. In early spring, the returning warmth of the sun frees the chlorine from the chlorine monoxide where it destroys more ozone. The reactions that frees the chlorine from chlorine monoxide is

$$ClO + O \rightarrow Cl + O_2$$

Ozone loss is greatest in the spring as the chlorine breaks down ozone into O_2. Remember that chlorine acts as a catalyst; it is not changed by its reaction with ozone and it can help break down another O_3 molecule immediately. As the air continues to warm, the natural production of ozone *increases* as more sunlight catalyzes the combination of oxygen back into ozone. This occurs in January and February (Antarctica's summer).

The Antarctic continent is the area exposed to the greatest amount of UV radiation, but prevailing winds can carry the ozone-depleted air to South America, Australia, and southern Africa. In 2006, the area of ozone thinness was over 26 million square kilometers. Reduced levels of ozone have been documented over the Arctic and even over some midlatitude regions.

The loss of ozone has serious implications for the earth's ecosystems as well as for human health. The increased number of UV rays that reach Earth through the thin ozone layer can kill phytoplankton and other primary producers. The decrease in primary productivity of both marine and terrestrial ecosystems lowers the amount of available fish and crops. Human health issues from increased exposure to UV rays include eye cataracts, skin cancers, and the weakening of our immune systems.

Now for the good news: There are several methods to manage the amounts of CFC's. In 1987 the Montreal Protocol was signed by more than 146 nations. The protocol calls for the worldwide end of CFC production. The United States stopped production in 1995. Since the institution of the Montreal Protocol, the release of ozone-depleting chemicals has been reduced by 95 percent. There are, however, many nations that still rely on CFCs, though work is being conducted to develop safe and effective substitutes.

Acid Rain

Acid precipitation—in the form of acid rain, acid hail, acid snow, etc.—occurs as a result of pollution in the atmosphere; primarily SO_2 and nitrogen oxides. These gases combine with water to form acids (typically nitric acid and sulfuric acid) that are deposited on the earth through precipitation. Because this acid is highly diluted, acid precipitation isn't acidic enough to burn the skin upon contact, but it does have a significant, measurable effect on humans and the environment. How acidic is acid rain? Well, rain usually has a pH of about 5.6, but acid rain can have a pH as low as 2.3.

Acid precipitation is responsible for the following effects:

- Leaching of some minerals from soil (which alters soil chemistry)
- Creating a buildup of sulfur and nitrogen in soil
- Increasing the aluminum concentration in soil to levels that are toxic for plants
- Leaching calcium from the needles of conifers
- Elevating the aluminum concentration in lakes to levels that are toxic to fish
- Lowering the pH of streams, rivers, ponds, and lakes, which may lead to fish kills
- Causing human respiratory irritation
- Damaging all types of rocks, including statues, monuments, and buildings

Acid precipitation can be a chronic and significant problem for large urban areas with many vehicles, and areas that are downwind of coal burning plants. While **dry acid particle deposition** occurs two to three days after emission into the atmosphere, **wet deposition** is usually delayed for four to fourteen days after emission; therefore it can travel in air currents to locations that are many miles downwind of the emission source.

Some areas, like those with already acidic soils that were derived from granite, are particularly vulnerable to acid precipitation. Other areas that are particularly vulnerable to acid precipitation are those where the soil has been leached of its natural calcium content. This is because calcium acts as a natural buffer and would temper the effects of acid precipitation.

In some areas of the world, progress has been made toward controlling acid precipitation. The 1990 amendment to the Clean Air Act (CAA) has led to significant reductions in the amounts of SO_2 and NO_x that are emitted from industrial plants. Despite **National Ambient Air Quality Standards**, there is still considerable damage being done to soils and lakes in many areas, and these ecosystems will not be able to continue to tolerate significant lowering of their pH.

Motor Vehicles and Air Pollution

Today, all new vehicles sold in the United States must meet the EPA standards (in California, they must meet certain standards set by the state). Due to the Clean Air Act (the CAA) and its amendment (the CAAA), new cars (those produced after the year 1999) emit 75 percent fewer pollutants than cars made before 1970. The most significant device in controlling emissions in cars is the **catalytic converter**. This platinum-coated device oxidizes most of the VOCs and some of the CO that would otherwise be emitted in exhaust, converting them to CO_2. Newer models of catalytic converters also reduce nitrogen oxides, but not very successfully.

In the Energy Policy and Conservation Act of 1975, the Department of Transportation (DOTS) was given the authority to set what's called **Corporate Average Fuel Economy (CAFE)** for motor vehicles. CAFE was intended to reduce both fuel consumption and emissions (not surprisingly, because burning less gas creates less air pollution). The standard today requires that vehicles have a fuel efficiency average of 27.5 miles per gallon, but larger vehicles such as pick-up trucks, SUVs, and minivans have a lower standard of just 22.7 mpg. Under new Federal Tier 2 standards, which went into effect in 2007, for the first time, light trucks will be held to the same standards as passenger cars.

Tier 2 standards also limit nitrous oxide (NO) emission to 0.07 grams per mile, which represents a reduction of 90 percent for passenger cars—and even more for light trucks. There is also a target reduction for sulfur emissions from gasoline; the new standards will decrease acceptable emissions from 300 ppm to 30 ppm.

All of these new standards will most likely result in higher purchase prices for vehicles, and they have certainly caused an outcry from auto manufacturer and oil refineries. However, the new standards are expected to reduce air pollutants by two million tons per year.

Vehicles of the Future

In 1990, the state of California passed a No-Pollution Vehicle Law mandating that, by 2003, 10 percent of the cars sold in the state would be pollution free. That law was later rescinded because of problems with the development of the zero pollution electric car, which looked promising at the time the bill was passed. The electric cars had a limited traveling range, were much lighter than their gasoline burning counterparts, and lacked amenities (such as air conditioning).

Since the California law was enacted, new technology has produced a hybrid car that is more acceptable to the public. Government regulations, incentives, and public acceptance will probably determine how quickly the hybrid car moves into the mainstream vehicle market. One incentive that's been offered at a federal level is a full-dollar tax credit. The amount of the credit varies by car model. That incentive is scheduled to be reduced unless a new energy bill changes it. Some individual states also provide incentives to residents who purchase a hybrid vehicle.

A hydrogen fuel cell vehicle would produce even less pollution than a hybrid vehicle, but don't expect to see them on the market very soon. Mass producing the cells is still not cheap enough to make the cars economically viable, as we mentioned in Chapter 7.

It is highly unlikely that Congress will enact legislation that will provide real incentives for the purchase of hybrid vehicles or other alternatives that would reduce air pollution from vehicles. This is in part due to the fact that lobbying groups representing the oil companies and vehicle manufactures consistently lobby against these incentives. However, in the future grassroots organizations that are backed by the voting public may influence legislation.

Indoor Air Pollution

The idea of air pollution that exists indoors, and the concept of the condition "sick building syndrome" is still relatively new, but it is now widely recognized that air pollutants are usually at a higher concentration indoors than outside. This makes sense if you consider that pollutants that exist outside can also move inside as doors and windows are opened. Once the pollutant is indoors, it remains trapped until air currents move it out the door or windows or though a ventilation system. Additionally, indoor spaces have certain pollutants that are unique to them. The World Health Organization (WHO) estimates that indoor air pollution is responsible for 1.6 million annual deaths worldwide (that's one death every 20 seconds!). According to the Environmental Protection Agency (the EPA), indoor air pollution is one of the five major environmental risks to human heath.

One of the reasons that indoor air pollution has such a vast impact is the number of hours that people spend indoors. Especially in developed countries, people generally work and live in well-sealed buildings that have little air exchange. In developing countries, however, one of the worst indoor air pollutants is material that's used for fuel. Dung, wood, and crop waste are the primary fuels used by more than half the world's population in order to heat homes and cook food, and the particulate matter that results from burning these fuels can exceed acceptable levels by hundreds of times.

In developed countries, other pollutants play the biggest roles in the creation of indoor air pollution; the most abundant indoor pollutants is **volatile organic compounds (VOCs)**. VOCs are found in carpet, furniture, plastic, oils, paints, adhesives, pesticides, and cleaning fluids. Even dishwashers are responsible for the creation of VOCs, when chlorine detergent reacts with leftover foods. Another component of pollution in developed countries is CO; CO arises in indoor air as a result of gas leaks or poor gas combustion devices. CO detectors are available for homes, and can prevent CO poisoning.

Two of the most deadly and common indoor pollutants in developed countries are tobacco smoke and radon. Tobacco smoke affects not only the health of the smoker, but the health of those around the smoker as well. Secondhand smoke causes the same symptoms in nonsmokers who simply breathe in secondhand smoke. Secondhand smoke, which contains over 4,000 different chemicals, has been classified by the EPA as a Group A carcinogen (meaning that it causes cancer in humans). It's estimated that secondhand smoke causes 35,000–40,000 deaths per year from heart disease, and 3,000 deaths from lung cancer. In children younger than 18 months, it is responsible for 150,000–300,000 lower respiratory tract infections annually, and increases the number and severity of asthma attacks in about one million asthmatic children.

Radon is the second leading cause of lung cancer (after smoking) in the United States. Radon is a gas that's emitted by uranium as it undergoes radioactive decay. It seeps up through rocks and soil and enters buildings. It is not found everywhere, and must be tested for specifically. Homes that were built after 1990 have radon-resistant features.

The final indoor pollutants we'll review are actually living: Certain living organisms such as tiny insects, fungi, and bacteria are considered pollutants. Many people are allergic to mold spores, mites, and animal dander, but asthma attacks can also be triggered by these living pollutants. The water tanks for large air conditioning units are good places for certain types of bacteria to grow, and as air is distributed throughout the house, the bacteria are also distributed. Some bacteria can cause diseases; one example of this is bacillus, which causes Legionnaires disease.

Sick Building Syndrome

Sick building syndrome is a term that's used when the majority of a building's occupants experience certain symptoms that vary with the amount of time spent in the building and for which no other cause can be identified. SBS is somewhat difficult to diagnose, and specific culprits are very difficult to identify. A condition is referred to as a **building-related illness** when the signs and symptoms can be attributed to a specific infectious organism that resides in the building. One example of a building-related illness is Legionnaires disease. Some symptoms of SBS include

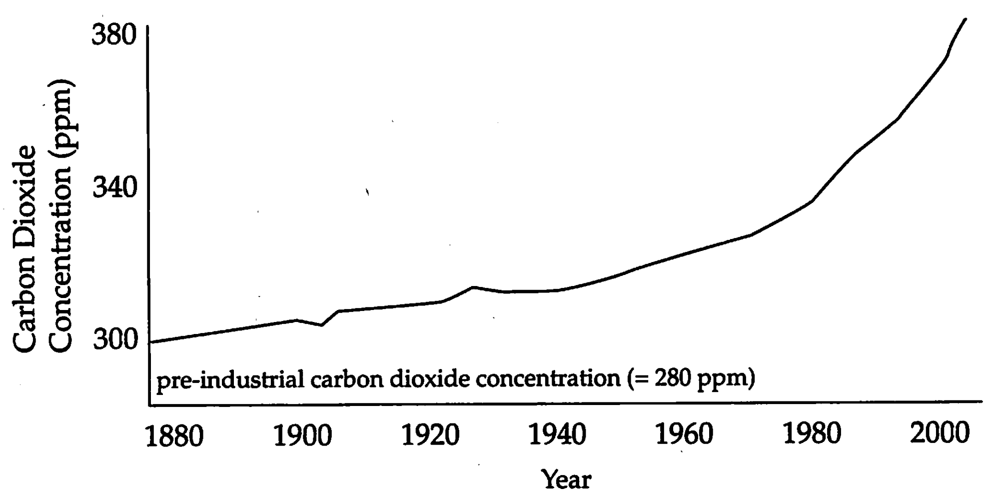
- irritation of the eyes, nose, and throat
- neurological symptoms, such as headaches and dizziness; reduction in the ability to concentrate; or memory loss
- skin irritation
- nausea or vomiting
- a change in odor or taste sensitivity

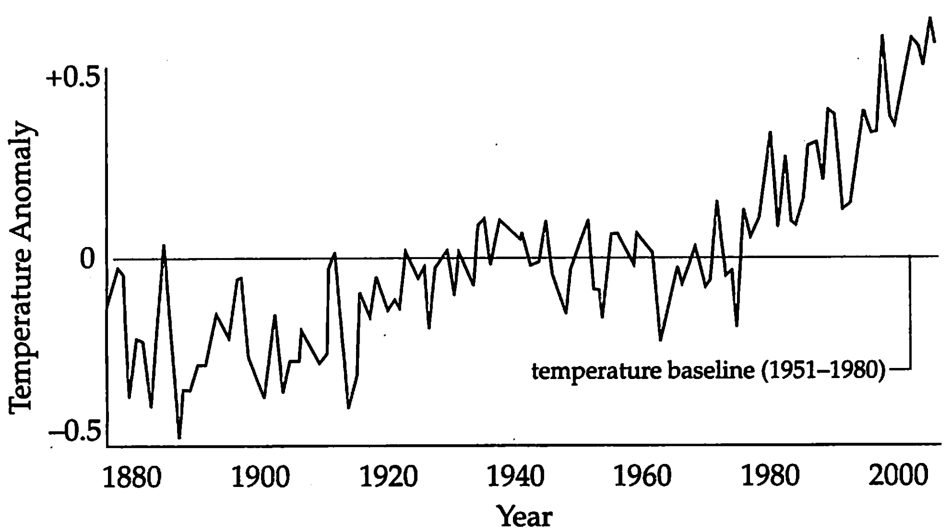
There are many ways in which people can reduce the amount of indoor pollutants that they're exposed to—for many people simply quitting smoking or encouraging roommates to quit would make a huge difference. Other precautions that people can take are to limit the amount of exposure they have to certain chemicals, such as pesticides or cleaning fluids. Perhaps the most important step to take is making sure that buildings are as well ventilated as possible.

CLIMATE CHANGE

Scientists use very sophisticated computer models and several thousand meteorological observations each day to monitor the daily temperature of the earth's atmosphere. Over the last several years, their observations have shown that there has been a slow but steady rise in the earth's average temperature. The summers of 1998, 2002, and 2003 were the warmest on record. Other qualified scientists have carefully documented a decrease in the size of glaciers and ice sheets, a slight rise in the average ocean level, and more severe rains storms and tornados. In response to these concerns, the Intergovernmental Panel on Climate Change (IPCC) gathered hundreds of scientists from around the world to study these problems. In a 2006 report, the IPCC stated that most of the observed increase in the global average temperature since the mid-20th century is very likely (greater than 90 percent) due to the observed increase in **anthropogenic greenhouse gas** concentrations. The three major gases are carbon dioxide (from pre-industrial levels of 280 ppm to 2003 levels of 380 ppm), **methane** (from pre-industrial levels of 715 ppb to 1774 ppb in 2005), and nitrous oxide (from pre-industrial levels of 270 ppb to 319 ppb in 2005). These gasses absorb the infrared heat radiating from the earth and thus heat the lower atmosphere. This warming is in addition to the normal warming of the atmosphere by the greenhouse effect. Review the diagram on page 36.

CO_2 and Temperature Graphs





The increase in the earth's temperature will lead to a variety of changes to the earth. Physical changes on Earth include: further lessening of glaciers and ice sheets, continued rising of average ocean levels (due mostly to the thermal expansion of water), changes in precipitation patterns (with wet areas getting more precipitation and dry areas getting less precipitation), an increase in the frequency and duration of storms, an increase in the number of hot days, and a decrease in the number of cold days.

Climate change will also affect biota. While there will be increased crop yields in cold environments, this is likely to be offset by loss of croplands as other areas suffer droughts and higher temperatures. Cold-tolerant species will need to migrate to cooler climates or they may become extinct. Heat-tolerant species (including mosquitoes and other disease vectors) may spread and invade new habitats. Human health will show additional deaths from water and insect-borne diseases. More frequent heat spells will endanger the very young and old. It is very likely that commerce, transport facilities, and coastal settlements will be disrupted by ocean level changes and stronger and more frequent storms. Marine ecosystem productivity and fishery productivity is also likely to change.

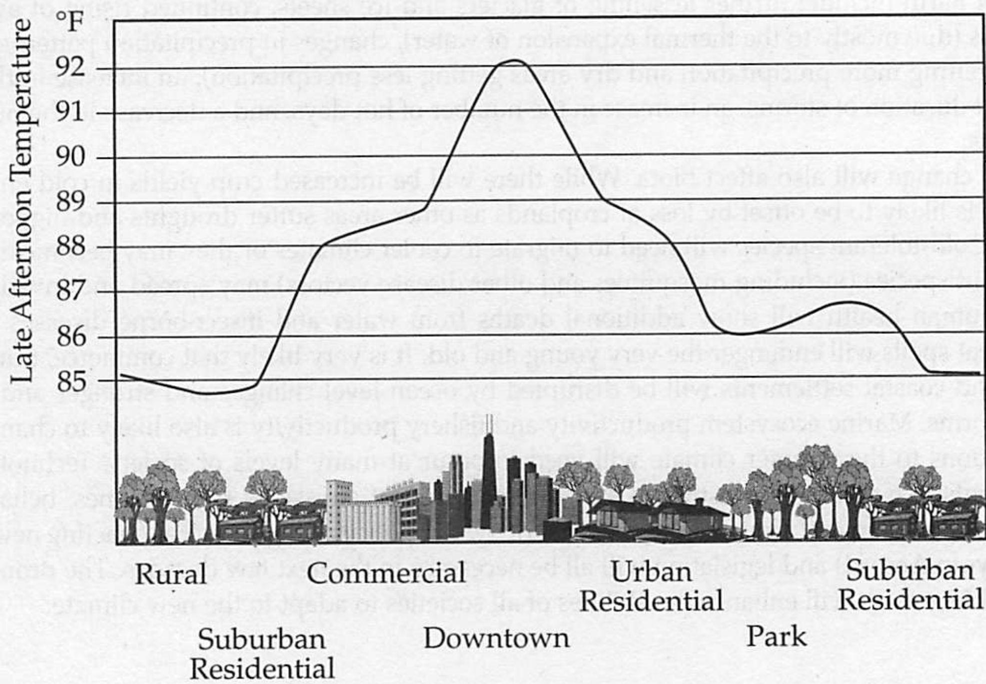
Adaptations to the warmer climate will need to occur at many levels of society. Technological improvements like carbon sequestration and the reduction of emissions from engines, behavioral changes such as turning off lights to conserve electricity, and policy changes such as enacting new laws (like the **Kyoto Accord**) and legislation will all be necessary in the next few decades. The promotion of sustainable growth will enhance the abilities of all societies to adapt to the new climate.

THERMAL POLLUTION

Urban environments are generally about 20 degrees warmer than the countryside that surrounds them, and this is due to the heat absorbing capacity of buildings, concrete, and asphalt, which radiate the heat that they have absorbed from the sun. Industrial and domestic machines also directly warm the air. Because of their high temperatures, urban areas are known as **heat islands.** The high temperatures of heat islands increase the rates of photochemical reactions, which in turn leads to photochemical smog.

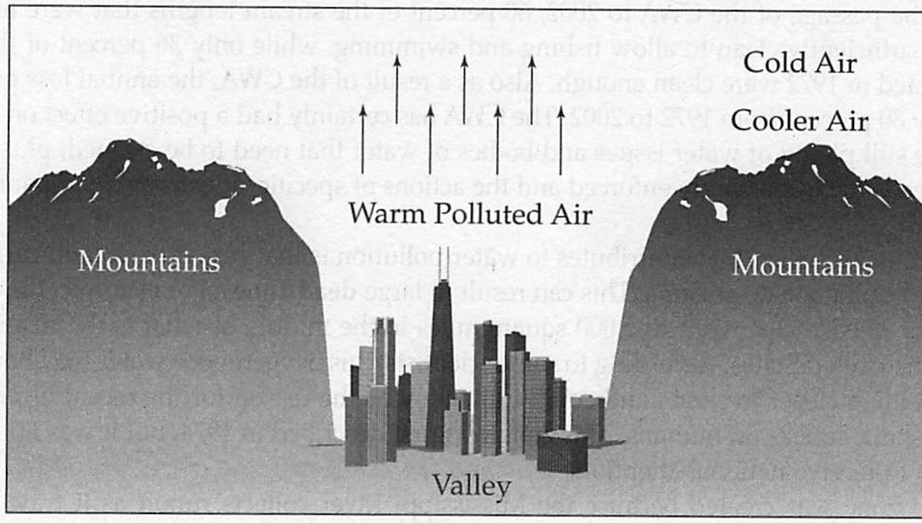
The temperature profile of an urban area shows peaks and valleys in temperature based on how the land is used. For example, green spaces have lower temperatures than commercial areas, which have lots of parking lots, cars, buildings, and asphalt. Two ways in which the heat island effect can be significantly reduced are: replace dark, heat-absorbing surfaces (such as roofs) with light-colored heat-reflecting surfaces; and plant trees and add to green spaces. Trees shade the urban environment from solar radiation; in addition, the process of transpiration (the release of water through plant leaves) creates a cooling effect for the surround area. Another reason why urban areas are often less cool than rural areas is that the concrete and asphalt in cities increase water runoff. Runoff leads to increased temperatures because the deep pools of water that are created as a result of runoff are less affected by evaporation than are areas where water is spread out thinly over a larger surface area. Green spaces can reduce runoff by trapping the water and distributing it more evenly across a larger surface area.

Temperature Profile of an Urban Heat Island

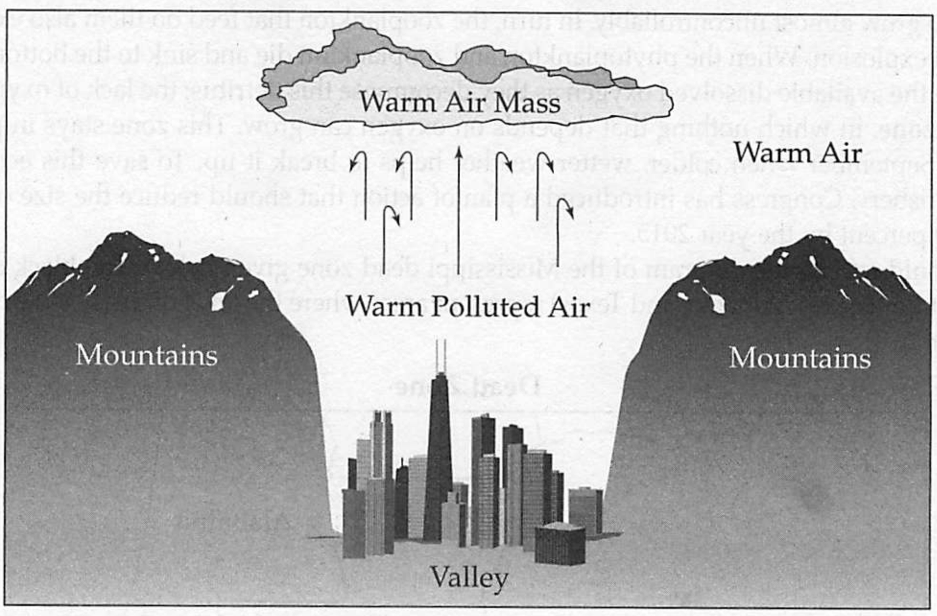


Another type of thermal pollution associated with many urban environments is **temperature inversion**. In this phenomenon, air pollutants become trapped over cities because they are not able to rise into the atmosphere. In normal atmospheric conditions, the warm polluted air over a city rises into the cooler atmosphere. (Remember that warm air is less dense than the surrounding cool air, and less dense objects float!) In an inversion, the air above the city is warm, and blocks the polluted air from rising. The polluted air remains hanging above the city, and can cause respiratory problems.

Thermal Inversion



Normal Conditions



A Temperature Inversion

Inversions often occur in cities surrounded by mountains, but they can occur over any city where large masses of warm air can become stalled.

WATER POLLUTION

When the Cuyahoga River near Cleveland, Ohio caught fire in 1969, it became a symbol of polluted America. This fire, along with many other problems that began to arise with polluted bodies of water at that time, eventually resulted in the Clean Water Act (CWA) of 1972. The CWA had a dramatic effect on the quality of water in the United States. By 2002, 94 percent of community water systems met federal health standards—this number was up from the 79 percent that were considered clean by the government just a decade before.

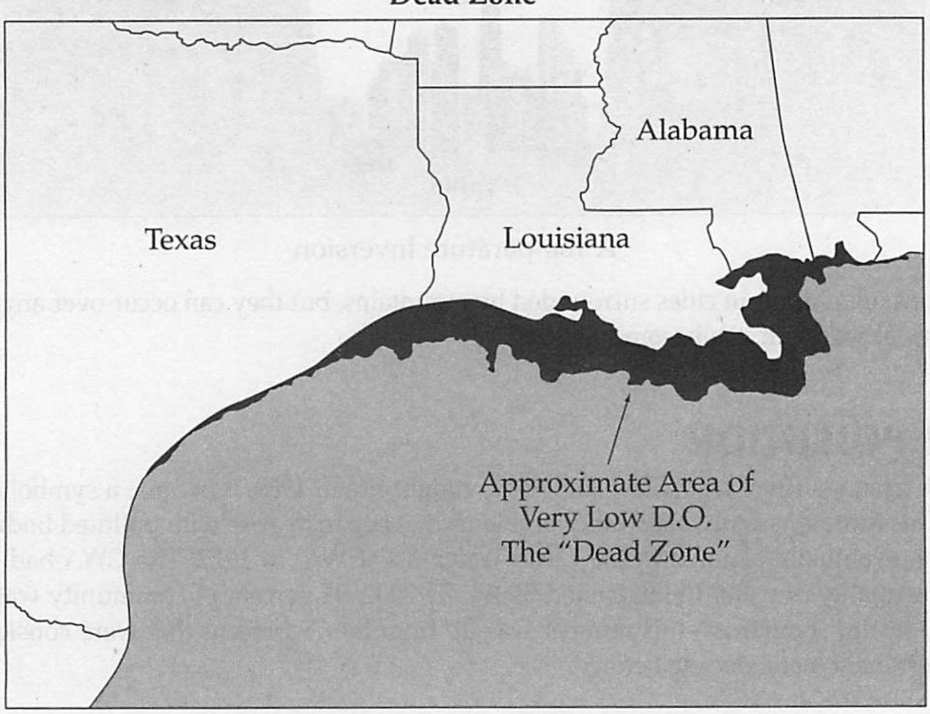
Experts say that Americans have some of the cleanest drinking (tap) water in the world. From the time of the passage of the CWA to 2002, 60 percent of the stream lengths that were tested were found to be sufficiently clean to allow fishing and swimming, while only 36 percent of the streams that were tested in 1972 were clean enough. Also as a result of the CWA, the annual loss of wetlands decreased by 80 percent from 1972 to 2002. The CWA has certainly had a positive effect on our water, but there are still plenty of water issues and bodies of water that need to be cleaned; plus the Clean Water Act needs to be constantly enforced and the actions of specific citizens and companies need to be monitored.

One continual problem that contributes to water pollution is that runoff from land carries **excess nutrients** and pollutants to streams. This can result in large **dead zones**. For example, the dead zone in the Gulf of Mexico covers up to 5,000 square miles in the middle of what is the richest area for shellfish in the United States. According to some scientists, this oxygen-poor water may be the reason sharks are coming closer to shore, and could ultimately be the reason for the recent unprecedented numbers of shark attacks on humans. This zone was first described in 1974, but it was not until 1998 that it began to receive national attention.

The dead zone was created because the Mississippi River collects runoff as it travels through farmlands and dumps all of this nutrient-rich water into the Gulf. The warm, nutrient-rich freshwater does not mix well with the colder saltwater and this results in **eutrophication**, which allows phytoplankton to grow almost uncontrollably. In turn, the zooplankton that feed on them also experience a population explosion. When the phytoplankton and zooplankton die and sink to the bottom, bacteria metabolize the available dissolved oxygen as they decompose this detritus; the lack of oxygen creates a **hypoxic zone**, in which nothing that depends on oxygen can grow. This zone stays in place from May until September when colder, wetter weather helps to break it up. To save this economically important fishery, Congress has introduced a plan of action that should reduce the size of the dead zone by 50 percent by the year 2015.

You should review the diagram of the Mississippi dead zone given below. The black areas (near the coast of Louisiana, Alabama, and Texas) represent areas where the level of dissolved oxygen (DO) is very low.

Dead Zone



Sources

Like the terms that are used to describe sources of air pollution, particular sources that are responsible for water pollution, like paper mills, are called **point sources,** and pollution that does not have a definitive source (or results from contributions of many sources) are **nonpoint sources.**

Right now, the biggest source of water pollution is agricultural activities; the runners-up are industrial and mining activities. Unfortunately, standing bodies of water such as ponds, reservoirs, and lakes do not recover quickly from the addition of pollutants. The lack of water flow prevents the pollutants from being diluted, which means that they accumulate in the water and undergo biomagnification in the food chain. In a similar way, groundwater does not recover well from the addition of pollutants; this is again because there is very little movement of water and therefore very little flushing, mixing, or dilution. Furthermore, groundwater is generally very cold and low in dissolved oxygen, which makes recovery from degradable waste a slow process. The porous rock that surrounds the groundwater absorbs the pollutants, which makes them difficult to remove.

However, flowing streams and rivers can recover from moderate levels of pollutants if the pollutants are degradable. As illustrated by the implementation of long sewage pipes that once dumped raw sewage into the ocean off coastal areas, people thought that the ocean was able to dilute and recover from the addition of any amount of pollutants. While oceans can dilute, flush, and decompose large amounts of degradable waste, their capacity for recovery is unknown.

Water pollution is dealt with in two basic ways: reducing or removing the sources of pollution, and treating the water in order to remove pollutants or render them harmless in some way. Here's a list of the major water pollutants.

- Excess nutrients (nitrogen, phosphate, etc.)
- Organic waste
- Toxic waste (pesticides, petroleum products, heavy metals, acids)
- Sediments (soil washed with runoff water into streams)
- Hot or Cold water (hot water discharged from industrial facilities where it was used as a coolant; cold water from dam releases discharging it from the bottom of a reservoir)
- Coliform bacteria (bacteria found in the intestines of animals that indicate the presence of fecal matter in water)
- Invasive species (zebra muscles)
- Thermal pollution

Finally, perhaps your AP Environmental Science class has performed water quality tests on water samples. They test for the presence of various chemicals as well as insect larvae, which act as indicator species. Among the most important factors in judging water quality are

- **pH,** which is a measure of acidity or alkalinity (normal for water is 6–8)
- **Hardness,** which is a measure of the concentrations of calcium and magnesium
- **Dissolved oxygen**—low levels of dissolved oxygen indicate an inability to sustain life (warm water holds less dissolved oxygen than cool water)
- **Turbidity**—or the density of suspended particles in the water
- **BOD,** which is a measure of the rate at which bacteria absorb O from the water.

Now, let's talk more specifically about a major water pollutant—wastewater.

WASTEWATER

Another group of water pollutants that are very dangerous to human health are infectious agents, such as those found in human and animal waste. Fecal waste not only contains the symbiotic bacteria that aid in the human digestive processes, it also contains disease-causing bacteria. Several human diseases, such as cholera and typhoid fever, are caused as a result of human waste entering the water source of a community. In fact, the major reason for the increase in the life span of humans was not modern developments in medicine; it was the introduction of cleaner drinking water and better ways of disposing of wastewater.

The term **wastewater** is used to refer to any water that has been used by humans. This includes human sewage; water drained from showers, tubs, sinks, dishwashers, and washing machines; water from industrial processes; and storm water runoff. Water that is channeled into storm drains, such as storm water, is generally dumped directly into rivers. (This is why storm drain covers in many locations have been stenciled with warnings about not dumping material down them.)

Today in the United States, wastewater that isn't storm water is moved through sewage pipes to a sewage treatment facility, but this was not always the case. Sewage water once was, and in developing countries still is, merely dumped into the nearest river or ocean. While some amounts of sewage can be diluted and broken down in these waters, too much waste poses serious risks to human health and the health of the aquatic ecosystems.

Now in the United States, sewage pipes deliver wastewater to a municipal sewage treatment plant, where it is first filtered through screens (in what's called a **physical treatment**) to remove debris such as stones, sticks, rags, toys, and other objects that were flushed down the toilet. This debris is then usually separated and sent to a landfill. The remaining water is passed into a settling tank, where suspended solids settle out as sludge—chemically treated polymers may be added to help the suspended solids separate and settle out. This treatment is known as **primary treatment** and it removes about 60 percent of the suspended solids and 30 percent of the organic waste that requires oxygen in order to decompose.

Secondary treatment refers to the biological treatment of the wastewater in order to continue to remove biodegradable waste. This treatment can be done using trickling filters, in which aerobic bacteria digest waste as it seeps over bacteria-covered rock beds. Alternately, the wastewater can be pumped into an activated **sludge processor,** which is basically a tank filled with aerobic bacteria. The solids in the water, including the bacteria, are once again left to settle out. The solids remaining are considered **sludge,** which is combined with the sludge from the primary treatment. Sludge used to be dumped into the ocean, but that practice has been banned. Instead, the sludge is further processed with anaerobic bacteria (to breakdown more organic material). This digestion also produces methane gas that can be used as an alternative fuel to run the treatment plant. After drying, this sludge cake can be processed and sold as fertilizer.

At the end of secondary treatment, 97 percent of the suspended solids; 95–97 percent of the organic waste; 70 percent of the toxic metals, organic chemicals, and phosphates; 50 percent of the nitrogen; and 5 percent of the dissolved salts have been removed from the wastewater. However, almost no persistent organic chemicals, such as pesticides, are removed, nor are radioactive isotopes. Generally, after secondary treatment, the wastewater is chlorinated to remove any remaining living cells and then discharged into a stream, the ocean, or water that's used to water lawns (called **gray water**). A negative effect of the final chlorination of the water is that trihalomethanes (potential carcinogens) can be formed when any organic matter left in the water reacts with the chlorine, and this is problematic. Two alternate processes to chlorination—ozonation and UV radiation—have been used to treat secondary-treatment water, but they have not proven to be as effective or long-lasting as chlorine, and are also much more expensive.

Some municipal plants deposit wastewater directly into ground water; this is done in San Jose Creek in Los Angeles County. In these places, the water must be further treated by tertiary treatment. **Tertiary treatment** involves passing the secondary treated water through a series of sand and carbon filters, and then further chlorination. At the San Jose Creek Plant, the tertiary treated water from the reclamation plants is discharged into percolation basins, where it replenishes groundwater, or it is used for irrigation and for watering lawns, golf courses, and plants in nurseries. Tertiary treatment is expensive, but in arid or semi-arid regions, every gallon that can be reclaimed is one that need not come from rapidly depleting sources, such as diminished rivers or underground aquifers.

Private wastewater treatment in the form of septic tank systems is hallmarked by some as the most environmentally friendly type of waste disposal. Septic tanks act in a way that's similar to the primary and secondary treatments that take place in municipal treatment plants. The water is then discharged into leachate (drain) fields. In order to install these types of systems, the soil must be able to percolate the water—that is, the water must be made to move from the top of the soil though its various horizons. Some clay soils are not porous enough to allow percolation and thus are unsuitable for a septic field.

Water Quality Legislation

There are many pieces of federal law that cover water quality. Be sure that you are familiar with these laws for the exam.

Date	Name of Legislation	What It Did
1972	Clean Water Act	Used regulatory and non-regulatory tools to protect all surface waters in the United States. • Sharply reduced direct pollutant discharges into waterways • Financed municipal wastewater treatment facilities, and manages polluted runoff • Achieved the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters • Supported "the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water"
1974, 1996	Safe Drinking Water Act	Established a federal program to monitor and increase the safety of the drinking water supply. It does not apply to wells that supply fewer than 25 people.
1972	Ocean Dumping Act	Made it unlawful for any person to dump, or transport for the purpose of dumping, sewage sludge or industrial waste into ocean waters.
1990	Oil Spill Prevention and Liability Act	Strengthened EPA's ability to prevent and respond to catastrophic oil spills. Established a trust fund (financed by a tax on oil), which is available to clean up spills.

SOLID WASTE (GARBAGE)

Solid waste can consist of hazardous waste, industrial solid waste, or municipal waste. Many types of solid waste provide a threat to human health and the environment.

The phrase "reduce, reuse, recycle" might seem simplistic, but it does outline the steps needed to reduce the amount of solid waste that must be dealt with. "Reduce," of course, refers to the minimizing of disposable waste. There are many types of packaging that are extremely wasteful—if you keep an eye out, you'll see them everywhere. "Reuse" applies to products that in some cases are disposable but in other forms can be used over and over again, such as refillable bottles and tanks, reusable packing materials, secondhand goods, and cloth shopping bags. Reusing products prevents these high-quality goods from becoming waste. Finally, "recycling" is the reuse of materials. In **primary recycling,** materials such as plastic or aluminum are used to rebuild the same product—an example of this is the use of the aluminum from aluminum cans to produce more aluminum cans. Alternately, in **secondary recycling,** materials are reused to form new products that are usually lower quality goods—examples of this are old tires are recycled to form carpet, and plastic bottles are recycled to create decking material. Finally, another environmentally important process is composting. **Composting** allows the organic material in solid waste to be decomposed and reintroduced into the soil.

According to the EPA, one of the most effective steps in aiding the environment that occurred in the twentieth century was the marked growth in the use of recycling and composting to deal with solid waste. Although there are still some products that are not feasibly recycled, those that were either recyclable or suitable for composting diverted more than 72 millions tons of material away from landfills and incinerators in 2003! That's double the amount that was recycled or composted in 1993. According to the EPA, the following percent of each of these materials was recycled in the year 2003:

Material	Percent of all of this material that was recycled in 2003
Newspapers	82.4
Corrugated cardboard boxes	71.3
Steel cans	60.0
Yard trimmings	56.3
Aluminum cans	43.9
Scrap tires	35.6
Magazines	33.0
Plastic milk and water bottles	31.9
Plastic soft drink bottles	25.2
Glass containers	22.0

In order to encourage people to reduce, reduce, and recycle, many communities have established Pay-As-You-Throw (PAYT) programs, which charge municipal customers for the amount of household garbage they throw away. As you can imagine, this has been a strong incentive for people to practice these good habits.

Landfills

In 1987, after it was discovered that landfills on Long Island were contaminating local groundwater, the barge Mabro left New York towing 3,186 tons of garbage, in search of a dumping ground. However, it was barred from docking in several southern states, and then the countries of Mexico, Cuba, and Belize. Three months and 6,000 miles later it returned to New York, where it became a symbol for Americans who were concerned about the status of landfills in the United States. It was also at this time that the term NIMBY (which stands for Not In My Backyard) became popular. It was widely agreed upon that landfills were needed, but no one wanted a landfill close to their home.

Modern landfills are very different from the traditional caricature of a garbage dump filled with heaps of junked cars and rats foraging for food scraps. Federal regulations that protect human health and the environment have paved the way for **sanitary landfills.** For example, federal law prohibits landfills from being located near geological faults, wetlands, or flood plains. Additionally, landfill sites are periodically required to dig large holes in the ground and line them with geomembranes or plastic sheets that are reinforced with two feet of clay on the bottom and sides. Smoothing wet clay is much like making a clay pot; the layer that is created is virtually impermeable. Also, the waste in the landfill must be frequently covered with soil in order to control insects, bacteria, rodents, and odor; and the decomposed material that percolates to the bottom of the landfill (called **leachate**) is piped to the top of the site and collected in leachate ponds, which are closely monitored. Gases from the landfill, like methane, may even be piped up from the site and used to generate electricity. Sometimes the methane is burned in continuously flaming flares to avoid larger fires or explosions. To ensure that landfills do not contaminate the environment, they are required to be positioned at least six feet above the water table, and groundwater at the sites must be tested frequently for quality. When one site (hole) is full, it must be capped with an engineered cover, monitored, and provided with long-term care.

Waste may also be burned in municipal incinerators, which are generally capable of sorting out recyclables first. The energy released from the incineration can be used to generate electricity in what's called the **Waste-to-Energy (WTE) program.** This type of system is particularly effective in large municipal areas, where waste only needs to be transported short distances.

HAZARDOUS WASTE

Hazardous waste is any waste that poses a danger to human health; it must be dealt with in a different way than other types of waste. Hazardous waste includes such common items as batteries, cleaners, paints, solvents, and pesticides. Industry produces the largest amounts of hazardous waste, and most developed countries now regulate the disposal of these wastes. United States law mandates that hazardous materials be tracked "from cradle to grave." The EPA breaks hazardous wastes down into four categories.

- **Corrosive waste:** Waste that corrodes metal
- **Ignitable waste:** Substances such as alcohol or gasoline that can easily catch fire
- **Reactive waste:** Substances that are chemically unstable or react readily with other compounds, resulting in explosions or causing other problems
- **Toxic waste:** Waste that creates health risks when inhaled or ingested, or when it comes into contact with skin

Hazardous wastes are disposed of in three main ways: in injection wells, in surface impoundments, and in landfills. Many communities have specific areas in their landfills that are designated for hazardous waste, and the standards for those areas of the landfills are higher than standards for non-hazardous waste areas. **Surface impoundment** is typically used for liquid waste; it involves the creation of shallow, lined pools from which the hazardous liquid evaporates. **Deep well injection** involves drilling a hole in the ground that's below the water table. These wells must reach below the impervious soil layer into porous rock, and waste is injected into the well. All three of these methods have their advantages, but none of them is satisfactory.

As you can probably imagine, radioactive waste must be contained in a different way than other hazardous wastes. For years, the United States has been trying to develop one major site for the disposal of all of our radioactive waste. Yucca Mountain, Nevada was selected as the location of this site because of its remoteness and because nuclear testing had previously been done at the site. This decision is still controversial, primarily because of the NIMBY principle (Not in my backyard!). However, it is critical that some plan for the long-term storage of nuclear waste is made, because in the very near future the nation's nuclear power plants will be at maximum capacity for the storage of spent fuel. The Waste Isolation Pilot Plant in New Mexico is a new permanent site for **nuclear waste burial**. Waste that's left over from the construction of nuclear weapons is known as **transuranic waste.**

Some people define radioactive wastes that produce low levels of ionizing radiation as **low-level radioactive waste** and those that produce high levels of ionizing radiation as **high-level radioactive waste.** However, the EPA categorizes radioactive waste according to its place of origin. Therefore, in the EPA's classification system, some wastes that are considered high level may actually be less radioactive than certain low-level wastes. The EPA puts all radioactive wastes into six categories.

- Nuclear reactor waste: high level
- Waste from the reprocessing of spent nuclear fuel: high level
- Waste from the manufacture of nuclear weapons: high level
- Waste from the mining and processing of uranium ore-high: high level
- Radioactive waste from industrial or research industries, including clothing, gloves, tubes, needles, animal carcasses, etc.: low level
- Radioactive natural materials: not a waste

In general, low-level waste is either stored on-site by licensed facilities until the radioactivity has degraded, or it is shipped to a low-level waste disposal facility. Mixed waste, containing both chemically hazardous waste and radioactive waste, is generally disposed of in the same manner.

In this book, we use the radioactive waste disposal terms used in the EPA classification system. However, on the AP Environmental Science Exam, a discussion of either system of classification would be considered correct—as long as you identify which classification system you're using.

Contaminated Waste Sites

After the 1970s, new regulations for the disposal of hazardous wastes solved many of the problems of how to add new wastes to landfills with minimal impact on the environment; at the same time, the issue lingered of what to do with sites that were already problematic. These sites had to be cleaned up and those who had acted irresponsibly had to be held accountable for the environmental problems they'd caused. For these reasons, the United States legislature created the **Superfund Program,** which was administered by the EPA.

Rocky Flats, Colorado is a Superfund site where the party responsible for the damage happened to be the United States government. Starting in 1952 and continuing for almost 40 years, components of nuclear weapons, such as plutonium, uranium, beryllium, and stainless steel were all manufactured on this site. Now that the area has been significantly cleaned up, it is home to a variety of plants and animals, including bald eagles, and acts as a wind-power testing site.

Along with the Rocky Flats, you should know the story of **Love Canal** near Niagara Falls, NY. The site was originally a canal built to bring power and employment to the surrounding community. After the canal's failure, the land was purchased by various companies that turned the canal into a landfill. After the town purchased the covered landfill area, 100 homes and a school were built on the site. In 1978 people saw rusting drums full of waste sticking up above ground. They also noticed dead and dying trees and gardens. Homeowners even reported having pools of smelly liquids in their basements; their children reported burning hands and faces after coming in from playing. Environmental Protection Agency employees soon came to the canal area, and by the end of August, 220 families had moved or said they would move out of the area. It was in response to the situation at Love Canal (and other cites in the United States) that laws like The Resource Conservation and Recovery Act and The Comprehensive Environmental Response, Compensation, and Liability Act were passed.

Laws for Solid and Hazardous Wastes

There are many federal statutes that cover issues concerning solid and hazardous wastes. You should be familiar with the ones given below.

Date	Law	What It Did
1976	The Resource Conservation and Recovery Act	• The solid waste program encouraged states to develop comprehensive plans to manage nonhazardous industrial solid waste and municipal solid waste; sets criteria for municipal solid waste landfills and other solid waste disposal facilities; and prohibits the open dumping of solid waste. • The hazardous waste program established a system for controlling hazardous waste from the time it is generated until its ultimate disposal—in effect, from "cradle to grave." • The underground storage tank (UST) program regulates underground storage tanks containing hazardous substances and petroleum products.
1980	The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund	• Created a tax on the chemical and petroleum industries and provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. • Established prohibitions and requirements concerning closed and abandoned hazardous waste sites. • Provided for liability of persons responsible for releases of hazardous waste at these sites. • Established a trust fund to provide for cleanup when no responsible party could be identified.

1976	Toxic Substances Control Act (TOSCA)	Gave the EPA the ability to track the 75,000 industrial chemicals currently produced in or imported to the United States. EPA repeatedly screens these chemicals and can require reporting or testing of those that may pose an environmental or human-health hazard. Allows the EPA to ban the manufacture and import of those chemicals that pose an unreasonable risk.
1982	Nuclear Waste Policy Act	Established both the Federal government's responsibility to provide a place for the permanent disposal of high-level radioactive waste and spent nuclear fuel, and the generators' responsibility to bear the costs of permanent disposal.

NOISE POLLUTION

Take your earphones off and think about this for a minute: The EPA considers noise to be a controllable pollutant. The **U.S. Noise Control Act** of 1972 gave the EPA power to set emission standards for major sources of noise, including transportation, machinery, and construction. Occupational Safety and Health Association (OSHA) has also set limits on the amount of noise that people can be exposed to in the workplace. Although the definition of noise pollution can be quite flexible, **noise pollution** in a broad sense is any noise that causes stress or has the potential to damage human health.

One concern about noise is that continued exposure to high levels can damage hearing. The louder the noise, the shorter the exposure it takes to damage inner ear cells and cause hearing impairment. Unfortunately, certain essential cells in the ear that are involved in hearing do not regenerate: so the loss of hearing is permanent. There are federal laws that regulate noise emissions from some equipment and modes of transportation, and OSHA is responsible for the regulation of noise in the workplace; in local communities, however, noise pollution is usually controlled by state or local laws.

All right, we're finished explaining pollution. You have two more chapters to get through and then you'll be ready to take the practice exam. In the next chapter, we discuss aspects of culture and society that are pertinent to the exam. First, study the key terms. Then, complete the drill and read carefully through the answers and explanations—and move on: you're almost done!

KEY TERMS

Don't *waste* any time; study these words now!

Toxicity

- dose-response analysis
- dose-response curve
- LD_{50}
- ED_{50}
- poison
- threshold dose
- acute effect
- chronic effect
- infection
- disease
- pathogen
- vector
- risk assessment
- risk management

Air Pollution

- National Ambient Air Quality Standards
- primary and secondary pollutants
- sulfur oxides
- nitrogen oxides
- CO and CO_2
- stationary sources
- moving sources
- point source pollution
- non-point source pollution
- criteria pollutants
- tropospheric ozone vs stratospheric ozone
- industrial smog
- photochemical smog
- chlorofluorocarbons (CFCs)
- ozone loss
- acid precipitation
- dry acid particle deposition
- wet deposition
- catalytic converter
- CAFE
- VOCs
- sick building syndrome

Climate Change

- IPCC
- methane
- anthropogenic greenhouse gases
- carbon sequestration
- Kyoto accord
- heat island
- temperature inversion

Water Pollution

- excess nutrients
- dead zone
- eutrophication
- point sources
- non-point sources
- pH
- hardness
- dissolved oxygen
- turbidity
- wastewater
- physical treatment
- primary, secondary, tertiary treatment
- sludge processor
- gray water

Solid Waste

- secondary recycling
- primary recycling
- composting
- sanitary landfill
- leachate
- Waste-to-Energy programs

Hazardous Waste

- surface impoundment
- deep well injection
- nuclear waste burial
- transuranic waste
- low-level, high-level radioactive waste
- nuclear waste burial
- Superfund Program
- Love Canal

Noise Pollution

- U.S. Noise Control Act
- noise pollution

CHAPTER 8 QUIZ

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case.

1. Which of the following is NOT a direct source of groundwater pollution?

   (A) Automobile exhaust
   (B) Wastewater lagoons
   (C) Underground storage tanks
   (D) Waste injected into deep wells
   (E) Pesticides sprayed on the land

2. Which of the following cities would have the greatest amount of gray-air smog?

   (A) New York, New York
   (B) Beijing, China
   (C) Los Angles, California
   (D) Chicago, Illinois
   (E) London, England

3. All of the following are true about sanitary landfills EXCEPT that they

   (A) have methods of monitoring leaks in the clay and plastic liners
   (B) pipe generated methane gas to storage tanks
   (C) pump leachate out of the landfill for treatment and disposal
   (D) are built so that trash sits on top of the land
   (E) contain clay and plastic liners that prevent leachate form entering the soil

4. Which of the following correctly explains what happens to the level of oxygen dissolved in water when organic waste is put in the water?

   (A) The levels would remain the same after the waste was added.
   (B) The levels would increase because of the availability of nutrients to animals that live in the water.
   (C) The levels would increase because of the higher temperatures of the water.
   (D) The levels would decrease because of the waste absorbing the oxygen.
   (E) The levels would decrease because of the bacteria feeding off the waste and using the oxygen to live.

5. An abundance of which of the following would indicate that water is polluted?

   (A) Trout and other game fish
   (B) Sludge worms, anaerobic bacteria, and fungi
   (C) Carp, gar, and leeches
   (D) Salamanders and turtles
   (E) Insect larvae and nymphs

6. Which of the following is the most common way of disposing of municipal solid waste?

   (A) Recycling
   (B) Composting
   (C) Placing in landfills
   (D) Burning
   (E) Transporting to other countries

7. Which of the following gases involved in global climate change is increasing in the atmosphere at the fastest rate?

   (A) H_2O
   (B) Methane
   (C) Chlorofluorocarbons
   (D) CO_2
   (E) O_2

8. Which of the following choices gives the correct order of processing sanitary waste in a sewage treatment plant?

   (A) Disinfection—breakdown of organics by bacteria—solid separation
   (B) Solid separation—breakdown of organics by bacteria—disinfection
   (C) Solid separation—disinfection—breakdown of organics by bacteria
   (D) Breakdown of organics by bacteria—solid separation—disinfection
   (E) Breakdown of organics by bacteria—disinfection—solid separation

9. Which of the following is a secondary pollutant?

   (A) CO
   (B) Soot
   (C) VOCs
   (D) PANs
   (E) CO_2

10. The United States was building a nuclear waste disposal site in

    (A) Wheeling, West Virginia
    (B) Yucca Mountain, Nevada
    (C) Gallup, New Mexico
    (D) Hudson, New York
    (E) Johnstown, Pennsylvania

11. Oxides of nitrogen create the pollutant

    (A) nitric acid
    (B) nitrogen gas
    (C) sulfuric acid
    (D) carbonic acid
    (E) phosphoric acid

Directions: Each set of lettered choices below refers to the numbered questions or statements immediately following it. Select the one lettered choice that best answers each questions or best fits each statement. A choice may be used once, more than once, or not at all in each set.

Questions 12-16 refer to the following methods of treating hazardous wastes.

(A) underground burial
(B) reduce the amount made
(C) incineration
(D) neutralization
(E) bioremediation

12. Involves mixing waste with other chemicals to produce less toxic substances

13. This process can cause secondary pollutants in the atmosphere

14. Injection into deep wells

15. The easiest and cheapest method

16. Living organisms process the waste and remove it from the ecosystem

Free-Response Question

1. Photochemical smog is one of the most common forms of air pollution today.
   (a) Identify two primary pollutants that cause photochemical smog. Describe how they are produced.
   (b) Identify two secondary pollutants that make up photochemical smog. Describe how they are produced.
   (c) Give one reason why photochemical smog is more likely to be found in industrialized nations and gray-air smog is more likely to be found in non-industrialized nations.
   (d) Give one component of photochemical smog that affects human health. Explain its consequences.

ANSWERS AND EXPLANATIONS

Multiple-Choice Answers

1. **A** (B) to (E) all contribute directly to the pollution of groundwater. (A) can contribute indirectly if the exhaust is converted into a secondary pollutant (such as acid precipitation).

2. **B** Gray-air smog is a result of the burning of large volumes of coal to generate electricity and provide heat to homes. China uses a great deal of coal to meet its energy needs. The other cities listed have reasonably effective controls on their generation stations, and people in those countries do not use much coal to heat their homes.

3. **D** Sanitary landfills are designed to completely isolate garbage. These landfills contain clay and plastic liners that hold back and collect water as it passes through. The trash is compacted into the smallest area possible and covered with soil and more plastic and clay. As the trash decomposes, the methane generated is collected to be used for other purposes.

4. **E** This process is called eutrophication, and it occurs when organic material (or nutrients) is added to water. The waste supplies food to the bacteria, which thrive using the oxygen for metabolism. This lowers the level of oxygen in the water, which deprives fish and other aquatic animals.

5. **B** The presence of anaerobic organisms, such as bacteria and fungi, indicate that there is little oxygen in a body of water. The presence of trout, perch, and insect larvae would mean that the water was not very polluted. The absence of these indicator species would indicate that the water is polluted.

6. **C** Each person in the United States produces 770 kgs (1,700 lbs) of waste each year. 54 percent of this waste is put in landfills, 30 percent is recycled, and most of the rest is burned (16 percent).

7. **D** The concentration of CO_2 in the atmosphere is increasing more rapidly than that of any other gas. Carbon dioxide is produced during the combustion of fossil fuels and levels of CO_2 are expected to increase rapidly in the next 20 years. Water vapor also contributes to the Greenhouse Effect, but its levels have remained consistent for hundreds of years.

8. **B** In the correct order, first, solids are removed by a series of screens. Next, the water is passed into tanks that contain bacteria. They remove 97 percent of the organic waste. Finally, chlorine is added to kill bacteria and denature viruses.

9. **D** PANs (Peroxyacyl nitrates) are secondary pollutants. They are produced from the reaction of hydrocarbons, oxygen, and nitrogen dioxide. All the remaining options are primary pollutants, which are produced from burning fossil fuels.

10. **B** The repository was being built in Yucca Mountain, Nevada. President Obama has delayed the storage of any radioactive material there.

11. **A** When nitrogen oxides react with water vapor in the atmosphere, the result is nitric acid HNO_3.

12. **D** Chemicals can be added to bring the pH of hazardous wastes to the neutral seven, which can render some wastes less harmful.

13. **C** Peroxyacyl nitrates are an example of a pollutant that's generated by combustion of wastes. Additionally, hydrocarbons and chlorine can combine during burning to create PANs.

14. **A** Deep wells are created to isolate wastes deep underground. They are cheap and easy to do, but this type of disposal involves the risk of allowing the pollutant to spread into underground aquifers.

15. **B** By reducing the amount of pollutants we produce, we do not have to pay to clean them up or dispose of them. Reduction can occur by changing manufacturing processes or lowering the demand for products that cause waste.

16. **E** In bioremediation, bacteria absorb the material and convert it into other compounds. Bacteria are useful in processing pesticides and diesel fuel.

Free-Response Answer

1. **(a)** Primary pollutants include
Oxides of carbon—CO and CO_2
Oxides of nitrogen—NO and NO_2
Oxides of sulfur—SO_2
Unburned hydrocarbons
All of these primary pollutants are produced by the burning of fossil fuels.
(3 points maximum—1 point for each correct pollutant and 1 point for correct origin)

(b) Secondary pollutants include

Sulfur trioxide—SO_3

Nitric acid—HNO_3

Sulfuric acid—H_2SO_4

Hydrogen peroxide—H_2O_2

Ozone—O_3

Peroxyacyl nitrates or PANs—R-C(O)OONO$_2$

Aldehydes—R-COH

All of these secondary pollutants are formed in the atmosphere. When primary pollutants combine with water vapor and sunlight energy, the reactions that take place produce the above products.
(3 points maximum—1 point for each correct pollutant and 1 point for a correct explanation of how it's produced)

(c) Photochemical smog is more likely to be found in industrialized nations because of their extensive use of fossil fuels (mostly coal and oil). Gray-air smog is found in areas where coal is the dominant fossil fuel.
(2 points maximum—1 point for photochemical smog explanation and 1 point for gray-air smog explanation)

(d) Ozone causes breathing problems, eye irritation, coughing, and reduced immune response. It also aggravates chronic diseases. CO can reduce the oxygen-carrying capacity of blood and cause dizziness and nausea. It can also retard fetal development. NO_2, SO_2, and PANs cause breathing problems, aggravate existing breathing problems, and increase susceptibility to disease.
(2 points maximum—1 point for irritant and 1 point for human effect)