**Hazards in the Air**

The Earth's atmosphere contains several layers but the two layers closest to the Earth's surface, the troposphere and the stratosphere, determine the quality of the air used by living things. The troposphere extends from the Earth's surface to about 10 miles (16 km) above sea level. The stratosphere lies above the troposphere and extends to 30 miles (48 km) above sea level. An area high in ozone gas (O3) lies where the troposphere and stratosphere meet. This ozone layer prevents living things on Earth from receiving too high an exposure to the Sun's ultraviolet radiation, which damages deoxyribonucleic acid (DNA) and causes some cancers. The combination of the ozone layer and the troposphere determine the quality of the air that people and animal life require.

Strict air pollution laws have lowered emissions in the United States, but other parts of the world continue to produce heavy air pollution. Large cities in China have been plagued by continual air pollution hazards. Much of this pollution has come from China's rapid industrial growth and a dramatic increase in the number of coal-fired power plants and of vehicle

The air used by Earth's living things contains 78.08 percent nitrogen, 20.95 percent oxygen, and 0.9 percent argon, plus other gases called *trace gases* because (aside from water vapor) they are found in low concentration in the atmosphere-0.038 percent or less. [Trace gases](https://online.infobase.com/HRC/LearningCenter/Details/8?articleId=368678&lcid=7) consist of ozone, carbon dioxide (CO2), water vapor (H2O), methane (CH4), nitrous oxide (N2O), and halons consisting of chlorofluorocarbons (CFCs) and bromine-containing CFCs. Nitrous oxide and nitrogen dioxide belong to a group of compounds known as nitrogen oxides. Carbon dioxide, water vapor (1 percent of the atmosphere), methane, CFCs, and nitrous oxide in addition to nitrogen dioxide (NO2) and fluorinated gases (such as hydrofluorocarbons) collectively make up greenhouse gases, which are components of the atmosphere that hold in heat and keep the troposphere warm.

Greenhouse gases contribute to global warming by preventing the Sun's heat from escaping back into space. Greenhouse gases, however, make up a small percentage of the composition of air and they present only part of the threats to air quality. The air also accumulates particles, soot, smoke, metals, allergy-causing material, photochemicals, ozone, and sulfur emissions from burning fossil fuels. [Photochemicals](https://online.infobase.com/HRC/LearningCenter/Details/8?articleId=368678&lcid=7) are compounds produced when certain gases react in the atmosphere with sunlight.

Air pollution has caused visible changes in the environment. The speckled light gray peppered moth has evolved from the light speckling shown here to a much darker version since the Industrial Revolution. Dark moths possess coloring that blends in with surfaces dirtied by soot and smog. In some industrialized places, 90 percent of the moths are dark, which was once a very rare mutation.

Three main types of air pollution affect human and wildlife health: particle pollution, noxious gas pollution, and indoor air pollution. This unit reviews each of these types of air pollution and the specific health threats they cause, the current trends in the Earth's air quality, and the technology and policies for improving the quality of the atmosphere. This unit includes additional topics that have grown into health issues within the past few decades: noise pollution, electromagnetic fields, thermal air pollution, and allergies.

**Earth's Air Quality**

Air quality varies across the globe and tends to become poorer in industrialized regions. For this reason air pollution causes a special concern to people living in central Europe, eastern Asia, and northeastern North America where there are dense areas of industrialization. In the United States, the Clean Air Act of 1990 directs the U.S. Environmental Protection Agency (EPA) to set limits for pollutants in the air and to enforce those limits, also called air pollution standards*.* Hundreds or even thousands of pollutants may be in the air at any one moment, so the EPA measures six pollutants to represent total air quality: particulate matter (soot and dust), carbon monoxide (CO), sulfur dioxide (SO2), nitrogen oxides, lead, and ozone.

Because the EPA has responsibility for controlling almost 200 different air pollutants, it sets strict standards for these six pollutants that will provide a picture of total air quality. These six pollutants, called criteria pollutants*,* are summarized in the following table. The EPA calls them criteria pollutants because their limits have been set according to criteria based on health and environmental studies. Therefore, air pollution experts know more about criteria pollutants than they do about many of the other compounds that pollute the air.

**The EPA's Criteria Pollutants for Assessing Air Quality**

|  |  |  |  |
| --- | --- | --- | --- |
| **Pollutant** | **Description** | **Health Effects** | **Main Sources** |
| PM2.5 particulate matter | solid particles measuring about 0.0001 inches (2.5 μm) and smaller | lung diseases (asthma, chronic bronchitis, respiratory infections) heart disease (heart attack, irregular heartbeat) | fires, road dust, electricity generation from burning fossil fuels), industry |
| PM10 particulate matter | solid particles measuring between 0.0001 inches (2.5 μm) and 0.0004 inches (10 μm) | road dust, other dust sources, fires |
| carbon monoxide | odorless, colorless gas | forms carboxyhemoglobin in the blood that prevents cells from getting oxygen | ineffi cient combustion engines in vehicles |
| sulfur dioxide | metal-containing gas released by burning coal or petroleum fuels | asthma, heart, and lung disease in the elderly, respiratory illnesses in children | electricity generation, fossil fuel combustion |
| nitrogen oxides | highly reactive gases: nitrous oxide, nitrogen dioxide, nitric oxide (NO), nitric acid (HNO3), nitrate compounds (X- NO3) | respiratory problems, reacts to form other toxic compounds in the air | vehicles, electricity generation, machinery, fossil fuel combustion, industry |
| lead | particles containing this heavy metal found naturally in the earth | damage to brain, nerves, and the cardiovascular, reproductive, and muscular systems | manufacturing plants, non-road equipment, electricity generation, fossil fuel combustion |
| ground-level ozone | naturally occurring gas made of three oxygen molecules; dangerous when at ground level rather than high altitude | respiratory irritation | vehicles, industry, gasoline vapors, chemical solvents |

The six pollutants monitored by the EPA also occur in other parts of the world. Asia has developed air pollution that may be a serious health threat. In 2008 the National Institutes of Environmental Health Sciences presented findings from a study in Bangkok, Thailand, in which mortality rates correlated to pollution levels. Of course, air pollution does not stay in one place; it moves to other places in a process called transboundary pollution*.* University of California-Davis atmospheric scientist Steven Cliff told the *Los Angeles Times* in 2007, "The air above Los Angeles is primarily from Asia. Presumably that air has Asian pollution incorporated into it. More stuff starting up over there means more stuff ending up over here." The major air pollutants found in the United States and other countries are shown in the table.

**Major Air Pollutants**

|  |  |
| --- | --- |
| **Pollutant** | **Main Sources** |
| particulate matter | industry, construction, incinerators, mining and quarries, metals processing, fuel combustion, forest fires |
| carbon monoxide | vehicles, heavy and small equipment, waste disposal facilities, metals processing, chemical industry |
| sulfur dioxide | electric utilities, industry, heavy equipment, petroleum refineries |
| hydrogen sulfide | oil wells, oil refineries |
| nitrogen oxides | vehicles, heavy equipment, electric utilities, industry |
| volatile organic compounds (VOCs) | solvent-using processes, vehicles, heavy equipment, transportation, fuel evaporation |
| lead particles | leaded-fuel combustion, smelters, battery plants |
| acid rain | sulfur dioxide and nitrogen oxides combines with compounds in atmosphere to create acids: sulfuric and nitric, respectively |
| ozone | reaction of nitrous oxide with VOCs; also vehicles, factories, landfills |

The air contains two types of pollution based on source: primary air pollutants and secondary air pollutants. Primary air pollutants are substances emitted directly into the air, such as carbon monoxide from vehicles. Secondary air pollutants form in the atmosphere when two or more primary pollutants react. Acid rain and ozone are secondary air pollutants.

In addition to Asia, Europe has fought a continuing battle against air pollution since industries began growing there in the 1930s. In 2002 the European Union issued *The Sixth Environment Action Program of the European Community 2002-2012* to outline objectives for cleaning up Europe's air pollution to the year 2012. The objectives are as follows:

* carbon dioxide concentration below 550 ppm
* reduction of greenhouse gases by 70 percent compared with 1990 levels
* reduction of greenhouse gas emissions from transportation, including aircraft and ships
* prevention and reduction of methane emissions
* reduction of greenhouse gases from vehicles, with an increase in the use of alternative fuels
* phasing out the use of industrial fluorinated gases including hydrofluorocarbons (HFCs)
* setting and achieving goals in reducing ozone, particles, and indoor air pollution

World carbon dioxide emissions have become a benchmark for all global air pollution because they correlate to the presence of industrial emissions and a large number of vehicles. The following table illustrates the wide variation of carbon dioxide emissions in the world.

**Examples of World Carbon Dioxide Emissions**

|  |  |
| --- | --- |
| **Countries or Regions** | **Million Tons (metric tons)** |
| Afghanistan | 1.1 (1.0) |
| Antarctica | 0.28 (0.25) |
| Brazil | 397 (360) |
| Canada | 696 (632) |
| China | 5,870 (5,325) |
| Denmark | 56 (51) |
| Germany | 931 (845) |
| India | 1,290 (1,170) |
| Russia | 1,874 (1,700) |
| Saudi Arabia | 454 (412) |
| Somalia | 0.83 (0.75) |
| United Kingdom | 639 (580) |
| United States | 6,570 (5,960) |

*Source*: U.S. Department of Energy.

The world's total carbon dioxide emissions have been increasing for the past several decades. At present all regions of the world pour about 31,970 tons (29,000 metric tons) of carbon dioxide into the atmosphere each year.

**Measuring and Forecasting Air Quality**

Air quality monitoring has made use of global imaging to assess the density of pollution that covers continents or the entire globe. In global imaging, a satellite equipped with an instrument called a spectrometer detects different wavelengths of the Sun's light as it reacts with substances in the atmosphere. The European Space Agency (ESA) operates *Envisat,* a satellite carrying analytical instruments that monitors a 596-mile (960-km) band of the Earth as it covers the entire planet every six days. Sunlight may do one of three things when it hits a compound: (1) reflect in the opposite direction; (2) pass through the substance in a process called transmittance; or (3) scatter in many directions. Each of these distortions to sunlight's path changes the light's wavelength, and each wavelength of the light spectrum correlates with a different color. The spectrometer in a satellite detects and measures the various wavelengths in the ultraviolet, visible, and infrared portions of the spectrum, and the instrument then interprets the wavelengths as colors. A computer generates a map containing the colors indicating regions of good to bad air quality.

For the United States, National Aeronautics and Space Administration (NASA) satellites measure wavelengths correlated to single pollutants. For example, a satellite's spectrometer differentiates carbon monoxide levels: Red indicates high concentrations of 450 parts per billion (ppb); blue indicates low carbon monoxide levels of 50 ppb. The colors between these two ends of the spectrum represent intermediate carbon monoxide levels. NASA scientists then use atmospheric wind speeds to create a video of pollution as it moves over the land and oceans. Atmospheric scientist John Gille explained, "With these new observations you clearly see that air pollution is much more than a local problem. It's a global issue. Much of the air pollution that humans generate comes from natural sources such as large fires that travel great distances and affects areas far from the source." Global assessments such as those by the ESA and NASA have helped environmental scientists build a more complete picture of air pollution than ever before.

People depend on air pollution information on a more daily basis than satellite data by referring to their local *Air Quality Index* (AQI) produced by the EPA. Other countries have similar indices. The EPA's system measures five air components to calculate AQI: ozone, carbon monoxide, sulfur dioxide, PM2.5, and PM1.0 (particles of about 1 μm). Local health officials then convert these measurements into a numerical score to create the AQI and give each category a standard color code to make the scores easy to interpret by the public. The following table provides a description of the AQI.

**The Air Quality Index**

|  |  |  |  |
| --- | --- | --- | --- |
| **AQI** | **Health Concern Level** | **Health Concern Description** | **AQI Color Code** |
| 0-50 | good | little or no risk | green |
| 51-100 | moderate | slight health concern for some people | yellow |
| 101-150 | unhealthy for sensitive groups | health effects in high-risk health individuals | orange |
| 151-200 | unhealthy | everyone experiences a health effect | red |
| 201-300 | very unhealthy | health alert; possibly serious | purple |
| 302-500 | hazardous | serious health alert | maroon |

Ozone and ground-level particles present the biggest health hazards on the AQI. Ozone in the stratosphere protects people and animals from ultraviolet radiation, but air pollution has caused much of this ozone to become trapped at lower levels in the troposphere so it cannot reach the stratosphere. People inhale this ozone, which causes coughing, irritation, and lung damage. Inhaled ozone also worsens bronchitis, emphysema, and asthma in people with these illnesses, and long-term exposure may scar the lungs. Because ozone has both good effects and harmful effects in the atmosphere, the EPA uses the catchphrase "Good Up High, Bad Nearby" to describe ozone.

Local ozone levels can be measured using data-collecting aircraft, balloons, or portable devices used on the ground. Ozone-measuring balloons carry an instrument called an ozonesonde*,* which takes in a set volume of air and measures ozone by either detecting light wavelengths or by chemical reactions. Handheld devices contain either a spectrometer or a sensor that detects ozone by measuring the ability of the air sample to conduct an electrical charge-greater conduction equals higher levels of ozone.

Temperature inversions make air pollution worse. In an unusual weather pattern, a layer of warm air sits atop a layer of cool air, trapping pollutants. Temperature inversions occur in depressions or valleys and become a health hazard in urbanized and industrialized places.

The EPA categorizes air particles into two groups according to size: (1) inhalable coarse particles of 2.5-10 μm in diameter, which are dense near roadways and construction sites, and (2) fine particles of 2.5 μm in diameter or smaller, emitted from forest fires, power plants, manufacturing plants, and cars as exhaust, gas emissions, smoke, or haze. Scientists monitor the amount of total particles in the air with sensors that contain a laser light source. As the instrument takes in a volume of particle-laden air, the air moves through the sensor and particles intercept the laser beam. Each disruption in the beam equals one particle-the instrument reports the results as particles per volume.

Temperature inversions affect the amount of air pollution. Warm air at the Earth's surface usually rises and mixes with the cool air at higher altitudes. This mixing creates local winds and air turbulence. On occasion the warm layer does not mix, but merely sits atop a cool air layer nearer the ground. This situation is called an inversion because the air becomes warmer as the altitude rises, which is the opposite of the normal circumstance of cooler temperatures at higher altitudes. The dense, cool air traps pollutants that would normally flow upward and disperse. As a result the pollution builds up in the air, especially over metropolitan areas located in valleys, which further traps the cool air. Temperature inversions increase the concentration of air pollutants and aggravate lung ailments such as asthma.



Indoor air pollution comes from various sources. New carpeting, furniture, paint, and wood finishes produce chemicals that evaporate into the air and create a health hazard. This sofa illustrates the many chemicals or chemical groups that emanate from it for many months.

When a local AQI is high, news outlets warn that people with respiratory problems should avoid spending time outside. Unfortunately, many buildings contain air of a quality equal to or worse than heavily polluted outdoor air.

**Greenhouse Gases and the Ozone Layer**

The greenhouse effect and the stratosphere ozone layer represent two components of the Earth's atmosphere that sustain life. Oxygen, carbon dioxide, water and nutrient cycles-called biogeochemical cycles-are the other components that biota require for life.

The greenhouse effect is a natural occurrence in which certain gases in the atmosphere regulate the temperature of the Earth's surface. Greenhouse gases and water vapor allow the Sun's energy to pass through the atmosphere and reach the planet's surface, but they retain a portion of the heat that reflects back from the surface in the form of long-wavelength light. The gases then release heat energy from the light they absorb and the reflected light. The effect has been named the greenhouse effect because the absorption, reflection, and heating resemble the actions that take place inside plant greenhouses. The resulting heat in the atmosphere sets up a comfortable temperature range that supports the evolution of life on Earth; without the greenhouse effect, the Earth's average temperature would be about - 0.4°F (-18°C) and the oceans would freeze.

Ozone also plays a protective role by absorbing the Sun's ultraviolet-B (UVB) radiation, thereby shielding biota from its DNA-damaging effects. About 10 percent of atmospheric ozone lies in the troposphere, much of it formed when nitrogen oxide emissions in car exhaust react with sunlight to form nitrogen dioxide and oxygen, as follows:

NOx + O3 → NO2 + O2

This tropospheric reaction causes ozone smog*,* which does not protect people from UVB but instead irritates the eyes, nasal passages, and throat. Ozone smog can also reduce resistance to colds and may aggravate chronic diseases such as asthma, bronchitis, and heart disease.

While ozone smog exerts these unhealthy effects, other emissions destroy some of the beneficial ozone in the upper atmosphere: chlorofluorocarbons (CFCs) and halon flame retardants such as carbon tetrachloride, methyl bromide, and methyl chloroform. In the 1970s scientists had developed instruments to study the Earth's ozone layer. During the 1980s, they began noticing a marked thinning of the ozone layer and a hole in the ozone above Antarctica began enlarging. By 1991 the hole covered the entire Antarctic continent.

Beginning in 1986, several national governments banned the use of CFCs for the purpose of halting further damage to the Earth's protective ozone layer, but their effects would not be instantaneous. Ozone weakening continued until the end of 2005 when the ban finally seemed to be making a positive effect; the Antarctic ozone hole stopped growing. David Hoffman of the U.S. National Oceanographic and Atmospheric Administration (NOAA) told *BBC News* in 2006, "I'm very optimistic that we will have a normal ozone layer sometime, not in my lifetime, but perhaps in yours." Though the layer no longer decreases near the South Pole, neither is it improving. Ozone holes now appear each summer over western Siberia's Ural Mountains and over an area covering the Baltic nations (Latvia, Lithuania, and Estonia), northeast to Moscow, and northwest to St. Petersburg. Saving beneficial ozone continues to be a long-term goal.

Though the greenhouse effect helps life on Earth, too much warming has led to the unhealthy condition now recognized as global warming. Until humans arrived on the planet, average amounts of atmospheric carbon dioxide fluctuated between 200 ppm and 280 ppm for 650,000 years. Carbon dioxide levels have risen 40 percent to 387 ppm since the Industrial Revolution and they may exceed 600 ppm in less than 50 years at their present rate of production. The rise in the Earth's average temperature has correlated with this rise in carbon dioxide levels. Carbon dioxide receives the most blame for global warming, but other substances contribute as much or more to global warming. The table lists today's most troublesome greenhouse gases and their effect on global temperatures, described as Global Warming Potential (GWP). GWP equals the global warming caused by 2.2 pounds (1 kg) of a gas relative to the same amount of carbon dioxide. For example, in 20 years methane raises the troposphere's average temperature 62 times more than the same amount of carbon dioxide.

**The Major Greenhouse Gases and Their Effect on Global Warming**

|  |  |  |
| --- | --- | --- |
| **Greenhouse Gas** | **Time in the Troposphere before Degrading (years)** | **Global Warming Potential** |
| 20 years | 100 years |
| carbon dioxide | 100 | 1 | 1 |
| methane | 12 | 62 | 23 |
| nitrous oxide | 115 | 275 | 296 |
| chlorofluorocarbons (CFCs) | 55-550 | 5,500 | 5,800 |
| hydrochlorofluorocarbons (CHXFX) | 1-260 | 100-9,400 | 100-12,000 |
| hydrofluorocarbons (CXFX) | 3,000-50,000 | 6,000-15,000 | 8,600-22,000 |
| ethers (CH3OCH3) | 0.015 | 1 | 1 |
| halogenated ethers (CHXOCFX) | 2.5-100 | 100-13,000 | 30-15,000 |

*Source*: University of Michigan Global Change Program.

In 2008 Martin Perry of the Intergovernmental Panel on Climate Change warned the United Kingdom's *Guardian,* "Despite all the talk, the situation is getting worse. Levels of greenhouse gases continue to rise in the atmosphere and the rate of that rise is accelerating. We are already seeing the impacts of climate change and the scale of those impacts will also accelerate, until we decide to do something about it." The Kyoto Protocol represented one important step to do something about climate change.

**Carbon Dioxide**

Carbon dioxide is a colorless, odorless greenhouse gas composed of one carbon molecule and two oxygen molecules. Carbon dioxide makes up only 0.04 percent of the atmosphere but it is essential for photosynthesis performed by plants, algae, and some bacteria. Photosynthesis converts carbon dioxide to oxygen and it is the main source of oxygen in the atmosphere. Natural levels of carbon dioxide in the atmosphere contribute to the use and reuse of carbon on Earth, known as the carbon cycle*.* Carbon is a central component in all living things on Earth, and the [carbon cycle](https://online.infobase.com/HRC/LearningCenter/Details/8?articleId=368678&lcid=7) helps conserve this element.

The atmosphere's current carbon dioxide level of 387 ppm is the highest concentration this gas has reached in 160,000 years. If carbon dioxide levels reach 550 ppm within the next 50 years, as predicted, the world's average surface temperature will increase by 1.8 to 6.3°F (1-3.5°C). The world's normal temperatures fall into a very wide range from the warm equator to cold polar regions. A rise of only one or two degrees in the planet's average temperature therefore signifies a dramatic increase in global temperature. This global warming effect is demonstrated by the following estimates:

* At 1.8°F (1°C) global temperature increase, animals begin migrating toward the poles and high-elevation forests begin to disappear.
* By a 3.6°F (2°C) increase, 30 percent of species are threatened.
* By a 5.4°F (3°C) increase, 30 percent of all wetlands disappear.
* By a 7.2°F (4°C) increase, 40 percent of all species are extinct.

Only drastic and immediate cuts in carbon dioxide emissions can reverse this trend.

Carbon dioxide makes up about 85 percent of all emissions from human activities. The ranking of the top carbon dioxide-producing nations varies every few years, but the following countries consistently top the list: The United States, China, Russia, Japan, India, Germany, Canada, the United Kingdom, South Korea, and Mexico. Worldwide, fossil fuel combustion by cars, trucks, ships, boating, off-road vehicles, and other transportation serves as the largest single source of carbon dioxide, about 40 times greater than the next biggest carbon dioxide source, which is fossil fuel use in manufacturing processes. The following listing by the EPA ranks in order the major producers of carbon dioxide today: (1) fossil fuel combustion; (2) nonenergy fuel use; (3) iron and steel production; (4) cement manufacture; (5) natural gas systems; (6) municipal solid waste combustion; (7) lime production; (8) ammonia production and urea consumption; (9) limestone and dolomite use; (10) croplands; (11) soda ash (sodium carbonate) manufacture; (12) aluminum production; and (13) petrochemical production.

Industries supply the world with the products that help people live or to simply make life enjoyable. But the health of the environment and the health of living things pay a price for conveniences manufactured by industries large and small. Robin Oakley, head of Greenpeace's climate change campaign, told the United Kingdom's *Guardian* in 2008, "We're now witnessing a key moment in the climate change story, and it's not good news. The last time the atmosphere was this choked with carbon dioxide humans were yet to evolve as a species." Carbon dioxide currently represents the single biggest focus area in environmental studies.

Places that were at one time pristine areas now contain pollution. Haze covering the Grand Canyon comes from power plant emissions, vehicle traffic, and west coast urban air pollution carried by winds.

The task of reversing the upward trend of carbon dioxide in the atmosphere seems daunting if not impossible. Hopes rest on new technologies in transportation, alternative fuels, sustainable manufacturing, and the cooperation of industries and nations to make these things possible. Cutting-edge technologies might also soon emerge such as huge air scrubbers stationed across the landscape to pull excess carbon dioxide out of the air. Global Research Technologies has experimented with this idea in Tucson, Arizona. Company president Alan Wright gave a glimpse of the promise as well as the scale of atmosphere air scrubbers when he told *Time* magazine in 2008, "If we built one [a scrubber] the size of the Great Wall of China and it removed 100 percent of the carbon dioxide that went through it, it would capture half of all emissions in the world." It is encouraging to think that a single device could actually have such a dramatic effect on the environment, but the magnitude of such a project makes it very unrealistic. Global warming technology will likely need a combination of many different powerful techniques for controlling carbon dioxide and other greenhouse gases.

**Radiation**

Radiation consists of energy in the form of either electromagnetic waves or particles that travel through the air. Electromagnetic waves occur when a magnetic field crosses perpendicularly with an electric field. This collision creates waves of different wavelengths-the distance between waves. Particle radiation occurs when an atom releases a subatomic particle: a positively charged proton (alpha particle), a neutral neutron, or a negatively charged electron (beta particle). (Gamma rays represent a fourth type of radiation.) Elements in the universe that emit any of these particles are said to be radioactive, and the term radioactivity refers to the disintegration of an element by emitting protons, neutrons, or electrons.

People exposed to increasingly large doses of radiation suffer radiation burns, radiation sickness, or cancer, described in the following table. Natural radioactivity comes from the elements radium, radon, and uranium, and human-created radioactivity comes from new elements created in nuclear reactors, such as plutonium. Radiation causes a variety of general health risks such as red blood cell damage, lymph system damage, injury to DNA, bone and bone marrow damage, hair loss, and skin damage. Many of these health effects occur only with exposure to high levels of radiation. Therefore, people living in areas with no known high-level sources have few health risks from radiation.

**Radiation and Environmental Health**

|  |  |  |
| --- | --- | --- |
| **Radiation Illness** | **Absorbed Dose (grays) \*** | **Health Effects** |
| radiation burn | 1-2 | reddened skin, fatigue, nausea, headache |
| mild-moderate radiation sickness (or syndrome) | 2-3.5 | vomiting, diarrhea, bloody stool, hair loss, red blood cell damage |
| severe radiation sickness | 3.5-8 | nausea and vomiting within 30 minutes, disorientation, fever, low blood pressure, death |
| cancer | Any dose increases risk in later life | cancers in bone, lungs, and other organs, death |

*Source*: Mayo Clinic
\* A gray equals a quantity of absorbed radiation: 1 gray = 100 rad (radiation absorbed dose).

Radioactive substances of most concern in the environment are those associated with nuclear power generation-uranium and plutonium-and naturally occurring radium. Nuclear power generators use natural uranium in forms that produce new elements that are also radioactive. The nuclear reactors inside nuclear power plants can then be a source of radioactive uranium, plutonium, and hundreds of other by-products made during nuclear reactions to produce energy. These by-products contain dozens of [isotopes](https://online.infobase.com/HRC/LearningCenter/Details/8?articleId=368678&lcid=7) of uranium and other elements, meaning their atoms contain an unusual number of neutrons. Well-managed nuclear power plants have safeguards to protect against the release of these elements into the environment, although accidents have occurred in the United States and abroad whereby radioactivity escaped into surrounding communities.

Uranium is the heaviest of the natural elements, a dense, silver-white metal found deposited in other minerals. In the United States, the Nuclear Regulatory Commission controls the use and sale of uranium for energy production and nuclear weapons. Earth's natural uranium consists mostly of uranium 238, which has a half-life of 4.6 billion years. (The isotope uranium 235 makes up a very small percentage of natural uranium.) This long half-life means that uranium possesses weak radioactivity because it emits alpha particles very slowly. As uranium decays it produces other radioactive elements, principally radon and plutonium.

People take small amounts of natural uranium into their bodies in food and water and by breathing it in. The body rids itself of most of this uranium, but a fraction remains in bone and stays there for many years. High levels of uranium cause more serious problems. It can damage the kidney as this organ tries to excrete it and can lead to bone and lung cancers.

The nuclear industry makes plutonium 239 from uranium 238 and uses this plutonium in fission reactions. Fission consists of the splitting of an atom's nucleus into two or more pieces with a simultaneous release of energy. Plutonium 239 has a half-life of 24,000 years and is toxic to humans and animals if it escapes from nuclear facilities into the environment. Inhaled plutonium moves from the lungs into the bloodstream and concentrates in bone and the liver and remains there for up to 50 years; the liver flushes plutonium out of its tissue slightly faster than bone can. High-level plutonium exposure leads to lung disease and cancers.

The half-life of a radioactive molecule is the time required for half of the atoms to decay to a more stable form. The Earth contains about 100 naturally radioactive elements. Krypton 90 possesses the shortest half-life at 33 seconds; rubidium 87 has the longest half-life at 47 billion years.

Radium is a rare, metallic element that has a half-life of 1,620 years, meaning it requires that many years for half of its radioactivity to disintegrate to safe levels. Radium forms radon gas as it decays, which presents a health concern because radon can seep into homes, buildings, and well water, and contributes to sick building syndrome.

Radon is a colorless, odorless, tasteless, and nonreactive gas. Radon diffuses through soil and drifts through the air; it commonly enters buildings by seeping through basement floors and walls, and stays there because it is heavier than air. Without an exchange of fresh air, radon builds up indoors and chronic exposure may lead to lung cancer. Radon produces different isotopes*,* most of which have a half-life of no longer than four days. They decay into a variety of new isotopes that attach to dust and other particles in the air. One of these isotopes, lead 210, can be harmful when inhaled, and lead 210 furthermore has a half-life of 20.4 years. Lead 210 and other radon isotopes stick to the cells lining the lung's airways. In the lungs, the isotopes emit a constant stream of alpha particles, and this long-term exposure to radioactivity damages DNA. Radon may be a major cause of cancer worldwide. In the United States, radon is a major cause of lung cancer among nonsmokers.

**Electromagnetic Fields**

The electromagnetic spectrum encompasses the following wave sources: electric fields, magnetic fields, alternating electric and magnetic fields, radio and television waves, microwaves, infrared light, visible light, ultraviolet light, and [ionizing radiation](https://online.infobase.com/HRC/LearningCenter/Details/8?articleId=368678&lcid=7) or X-rays. Electric and magnetic fields occur at the low-frequency end of this spectrum and X-rays occur at the high-frequency end of the spectrum. Frequency is the number of waves generated per second. These forms of energy are usually described as fields because an area, or field, radiates outward from the source in all directions as opposed to moving in a straight line as an alpha particle does. An electric lamp, for example, generates a small electric field in the air around it due to the current flowing to the lamp; large electric generating stations create a similar but much larger electromagnetic field.

Growing demand for electricity and an increasing number of electric products have increased the potential number of electromagnetic fields people encounter each day. The human body itself contains electric current, such as the currents used to transport substances into and out of cells and the communication between nerve-cell endings. When weak electric charges in the body meet an electromagnetic field, the field alters the body's normal current. Small changes in the body's currents do not affect health, but higher energy fields can induce headaches, anxiety, depression, or fatigue.

Human exposure to electromagnetic waves has increased dramatically with the enormous increase in use of electronic devices. Scientific studies on the effect of electromagnetic fields and health are ongoing. To date, long-term exposure has been found to cause an increase in childhood leukemia, but not in other types of cancers.

The public's concern about high-voltage lines and health has grown since about 1980. Wisconsin's *Midwest Today* in 1996 quoted Robert Becker, physician and author of *Cross Currents,* a book that explores the dangers of electromagnetic fields: "Electromagnetic fields could turn out to be a far worse environmental disaster, affecting far more people, than toxic waste, radiation, or asbestos." This debate has not ended. While *Medical News Today* warned in 2004 that high-voltage lines may double the risk of leukemia in children living within 330 feet (100 m) of them, the Health Physics Society based in Virginia stated in 2008, "there are no known health risks that have been conclusively demonstrated in relation to living near high-voltage power lines." Medical researchers who have conducted studies in the effort to find a connection between power lines and disease generally agree with the Health Physics Society's statement. Scientists, nevertheless, measure the electromagnetic fields emitted by household appliances in order to add to their store of knowledge on high-power and low-power fields and human health. The following table lists electromagnetic fields emitted by various household appliances.

**Approximate Electric and Magnetic Field Strength of Household Appliances**

|  |  |  |
| --- | --- | --- |
| **Appliance** | **Electric Field Strength (volts/meter)1** | **Magnetic Field Strength (μT)2** |
| microwave oven | 250 | 4-8 at 30 cm |
| refrigerator | 120 | 0.5-1.0 at 30 cm |
| hair dryer | 80 | 6-2,000 at 3 cm |
| coffeemaker | 60 | 0.3-1.0 at 1 m |
| television | 60 | 0.01-0.15 at 1 m |
| computer | 14 | less than 0.01 at 30 cm |
| dishwasher | 12 | 0.6-3.0 at 30 cm |
| washing machine | 10 | 0.15-3.0 at 30 cm |
| **Maximum Recommended Limit** | **5,000** | **100** |

*Source*: The World Health Organization and the Consumer Law Page (URL: www. consumerlawpage.com)
1 field strength is the intensity of an electric field measured in volts/meter (volts per 3.28 feet)
2 a microtesla (μT) is a unit of measurement of a magnetic field; the Earth's natural magnetic field has a strength of 50 μT. 1 cm = 0.4 inches, 1 m = 3.28 feet.

Electromagnetic field sources in addition to power lines are mobile phones, televisions, radios, electric trains and trams, security systems, and radar. Mobile phone radiation emissions are measured as Specific Absorption Rate (SAR), on which the United States and Europe have set upper limits at 0.2 to 1.6 watts per kg (W/kg) in 1.0 gram of body tissue (one kg equals 2.2 pounds). A person with greater body weight can safely absorb more radiation than a smaller person. Some of the digital phones in use today approach an SAR of 1.5 W/kg.

**Particulates**

Air particles range from large visible matter to tiny invisible particles. A so-called large particle is considered to be any particle greater than 10 μm in diameter, or about one-seventh the width of a human hair. The EPA enforces limits only on particles in the air measuring less than 10 μm in diameter. The EPA also distinguishes between primary and secondary particles. Primary particles come directly from a point source such as a construction site, an agricultural field, a smokestack, or a forest fire, and these tend to be large particles. Secondary particles are very small particles that form in the atmosphere from chemical reactions or electrostatic attractions. These fine particles make up the majority of health risks from particulate air pollution.

Particles in the air affect both visibility and health. When sunlight hits tiny particles in the air, haze forms and the distance a person can see decreases. This decreased visibility is not a health hazard, but it indicates that potentially harmful particles are in the air. Haze-forming particles come from natural sources such as fires and windblown mater, or from human activities involving cars, burning fuel, electric power plants, and industry. Haze potentially injures the respiratory tract and may lead to a shortened life span. Respiratory ailments take the form of coughing, respiratory irritation, difficulty breathing, asthma, and bronchitis. Particles in the air also cause a higher chance of illness in people with existing heart ailments.

Pollen from plants makes up a unique category of airborne pollutants. Pollen consists of particles invisible to the unaided eye that drift on the air from plant to plant as part of plant reproduction. Each type of plant produces pollen with its own unique shape and these pollen shapes contain hundreds of sharp spikes that enable the pollen to stick to surfaces when it falls from the air. Of course, the sticky nature of pollen allows it to adhere to the inside of nasal passages when people inhale, leading to an allergic reaction. An allergy is any severe immune response to foreign particles; an allergy to pollen is called hay fever*.*

Most areas in the United States have a local pollen-counting station that collects 35 cubic feet (1 m3) of air over a 24-hour period. In a laboratory a technician then counts the magnified particles in a microscope. The unique pollen shapes allow technicians to estimate the amount of pollen belonging to different plant types, such as grass, ragweed, dogwood, and so on. The table gives an example of a typical pollen count scale.

**Pollen Counts**

|  |  |  |
| --- | --- | --- |
| **Pollen Count (number of pollen grains counted in 1 m3 of air over 24 hours)** | **Category** | **Potential Health Hazard** |
| 1-15 | low | poses little health risk |
| 16-90 | medium | acceptable for most people, except those with chronic respiratory problems or allergy sensitivities |
| 91-1,500 | high | health alert in which almost everyone will experience some irritation or more serious symptoms |
| more than 1,500 | very high | affects everyone, but hazardous to people with serious respiratory conditions; may lead to emergency medical care |

Hay fever, also called allergic rhinitis or pollinosis, ranges from a mild ailment to a serious health hazard. When people experience a mild allergic reaction to pollen, they may have temporary runny nose, sneezing, coughing, congestion, or a combination of these symptoms. Serious [hay fever](https://online.infobase.com/HRC/LearningCenter/Details/8?articleId=368678&lcid=7) lasts year-round, saps a person's energy, and irritates the nasal passages. In moderate to serious allergies, sinusitis may develop in which the person's sinuses become inflamed. Asthma sufferers are especially at risk for complications from severe allergy.

Pollen allergies may get worse over time because of the way the immune system responds to foreign particles in the body. When the immune system recognizes an *allergen* it has confronted before, it sets up a faster response than it did the previous time the [allergen](https://online.infobase.com/HRC/LearningCenter/Details/8?articleId=368678&lcid=7) appeared. Unfortunately, in hay fever the body mistakes harmless pollen for a more dangerous particle and overreacts to the pollen's presence. In doing its best to protect the body from infection, the immune system actually can make a hay fever sufferer quite miserable. Hay fever has become a point of discussion within the larger issue of global warming due to changes in the growth of the world's plant life.

**Noise Pollution**

Urbanization offers advantages that are not always available to people in rural settings. Urbanization has also brought a growing list of disadvantages to human and environmental health. Some of these factors are discussed in the case study "The Industrial Revolution." The most serious disadvantages are the following: loss of habitat or habitat fragmentation; increased pollution; concentration of greenhouse gases; depletion of natural resources; increased volume of wastes; and generation of wasted heat energy. Water, air, and soil pollution are well-known problems, but cities also produce light and noise pollution. Light pollution interferes with the migration routes of birds and land animals and even interferes with aquatic life. For example, sea turtles come on shore only at night for laying their eggs on the beach. High light intensities that emanate from cities seem to prevent turtles from heading toward the shore because the light confuses their normal movements.

Noise pollution also causes subtle but troublesome effects in the environment. Noise that fills the air where people live and work is a health hazard for two main reasons: hearing loss and stress. Noisy areas also affect wildlife behavior. In humans, loud noise causes temporary hearing loss and sustained noise can lead to permanent hearing loss or impairment. Noise-induced hearing loss (NIHL) results from a combination of physical, genetic, and environmental factors. Loud noises damage the sensory cells lining the inner ear tube called the cochlea. Tiny hair cells that help sense sounds become distorted by sustained loud noise. They may then stiffen in this abnormal arrangement and thus become less effective at distinguishing sounds. NIHL is variable from person to person, but in general prolonged exposure to sounds louder than 85 decibels causes injury to the inner ear and possible hearing loss.

Noise pollution in an overlooked aspect of overall pollution of the environment. Long-term exposure to high levels of noise or certain frequencies harms human health. Noise pollution likely affects the normal behavior and reproduction of a wildlife as well.

Sound loudness is measured in a unit called a bel (B); a decibel (dB) is one-tenth of a bel and the unit used for measuring the intensity of sound detected by the human ear. Bels and decibels are measured on a logarithmic scale to define the very wide range of sound intensities heard by humans. (A logarithm is a number expressed to a power; for example, 102 equals "10 to the power of 2" or 10 × 10.) An increase of 10 dB equals an increase in loudness of 101 or 10 times louder, and an increase of 20 dB or 102 is 100 times louder.

Sound frequency is measured in a unit called a hertz (Hz). Like loudness, frequency beyond a certain level can impair hearing. A person may experience hearing impairment exposed to frequencies nearing 4,000 Hz-normal speech ranges from 500 to 3,000 Hz.

Animals, including humans, evolved using hearing as a means of finding prey and sensing impending danger. Noise perception therefore relates to behavior that has been part of biological history. The constant din of noise in urban centers may interfere with these normal functions. Studies in England and Germany have showed that children attending schools near airports had higher levels of adrenaline and cortisol-the "fight or flight" hormones-in their blood, indicating that they lived in a constant state of physical stress. WHO environmental scientist Roberto Bertollini told the *Washington Post* in 2007, "This is the most disturbing thing about noise, because it means you are being exposed to this reaction all the time." Workers in jobs that expose them to high noise levels wear ear protection and have their hearing checked annually, but people in cities usually do not take precautions to avoid constant noise. The easiest thing for people to do is to leave noisy areas as soon as possible to avoid prolonged exposure.

**Air Pollution Reduction Technology**

Europe's air pollution condenses in an area known as the Black Triangle where Germany, Poland, and the Czech Republic meet. The Black Triangle is one of Europe's most industrialized regions and for many years at least 10 coal-burning power plants and several manufacturing plants filled the skies with sulfur dioxide and other pollutants. People in the area suffered respiratory disease and cancer at rates above the rest of Europe, soot-covered forests died and deprived wildlife of habitat, and schools announced "smog days" to keep students home on the most polluted days. In 1987 electrical engineer Eduard Vacka described his hometown of Teplice in the Czech Republic: "It was one of those miserable fall days, when you wake up in the morning with a throbbing headache. Out the window, it looks like a dark sack has been thrown over the whole town.… God, what a stench! What the hell are they putting in the air? It's unbelievable: they're waging chemical warfare against their own people." In the past two decades the dire situation in the Black Triangle evolved from an environmental disaster to a cleaner and healthier place to live and work. How did this happen?

In 1990 the Czech Republic shook off the effects of the Soviet Union's domination. The Czechs began dismantling inefficient and dirty manufacturing plants and diversified their power sources with natural gas, hydropower (power generated from water), and nuclear power. Neighboring countries Germany, Hungary, and Poland received aid from the European Union to clean up their polluters as well. These countries tried a combination of approaches to reduce air pollution: employing emissions technologies such as desulfurization filters for cleaning emissions; closing down the small and most inefficient power plants and open-pit mines; and monitoring air quality in each country within the Black Triangle. The area also turned to clean coal technology, which enabled coal-burning power plants to release only emissions that have been cleaned of greenhouse gases and particles. Some groups tried a new device called an electrostatic precipitator, which removes tiny particles from emissions by capturing positively and negatively charged particles.

Countries in the Black Triangle also addressed air quality by asking industries to install pollution filters on manufacturing and power plants and improving mass transit. Czech historian Miroslav Vanek explained his country's progress to Radio Prague in 2005: "I think it was visible in the early '90s how quick the situation in northern Bohemia and all the Czech Republic got better and better … and you can see that now the situation in Teplice, for example, Ústí and other towns from North Bohemia is better, for example than Prague." The sulfur dioxide, nitrogen oxides, and particles in today's air over the Black Triangle have decreased more than 90 percent, 80 percent, and 95 percent, respectively since 1989. The Black Triangle illustrated that even very difficult air pollution crises can be reversed with cooperation between governments and residents.

**Conclusion**

Earth's lower atmosphere contains a multitude of gases and particles that have increased in density since the industrial revolution. These substances cause a variety of health hazards in people and animals. Many of the gases harmful to health are greenhouse gases, which are a major cause of global warming. The United States government and international agreements such as the Kyoto Protocol have put limits on the amount of greenhouse gases and fine particles that businesses may emit into the air. These actions have helped clean up the air in some regions but air pollution can travel to other places. Global air pollution truly requires the work of several countries at once to make a difference. The air pollution problem must be managed fast because scientists have shown that air pollutants have spread worldwide and airborne substances have been found in human and animal bodies.

Indoor air quality also presents a health risk, but offices and households have a better chance at improving it compared with outdoor air quality. Much indoor air pollution comes from common household items that emit irritating vapors. Homeowners can improve the air quality inside houses by storing chemical products safely, trying to purchase low-emitting products, and improving the home's ventilation.

The air seems to hold a bewildering array of substances that all cause health problems. People certainly would be justified in wondering how to deal with a diverse collection of substances such as carbon dioxide, particles, radiation, noise, and numerous other harmful pollutants. People can reduce the hazards of air pollution in several ways. First, strict government regulations on pollutants can improve air quality. Second, people could change behaviors that impact air quality, such as reducing their use of personal cars. Third, simply avoiding areas with obvious air pollution helps prevent respiratory irritation and more serious illnesses. The body can eliminate many inhaled substances and, provided that people steer clear of further contamination, they can return to good health. Some pollutants such as heavy metals, however, stay in the body for a long time and cause serious harm. Environmental medicine possesses a range of treatments that help rid the body of pollutants, but this area of medicine needs a good deal more study and the development of new treatments.

Poor air quality correlates with industrialized life. Though industry has brought benefits to society, society must now correct the damage it has done to the atmosphere. Science has developed an encouraging selection of technologies to clean up emissions and many local and national governments have instituted effective air pollution laws. Environmental medicine must do its part to study the health effects of air pollutants and add to the existing knowledge of hazardous gases and particles.