

GE 302 - Industry and the Environment

Chapter III – AIR POLLUTION

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Chapter III – AIR POLLUTION

(Review Chapter 12 - Textbook for more information)

Introduction

The **Earth's atmosphere** is a layer of [gases](#) surrounding the planet which is retained by [gravity](#). The [atmosphere](#) protects [life](#) by absorbing [ultraviolet solar radiation](#), warming the surface through heat retention ([greenhouse effect](#)), and reducing [temperature](#) extremes between [day](#) and [night](#).

Dry air contains roughly (by volume) 78.08% [nitrogen](#), 20.95% [oxygen](#), 0.93% [argon](#) which together constitute the "major gases" of the atmosphere. The remaining gases often are referred to as "trace gases" 0.038% [carbon dioxide](#), and trace amounts of other gases. Air also contains a variable amount of [water vapor](#), on average around 1%.

[Greenhouse gases](#) such as water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Filtered air includes trace amounts of many other [chemical compounds](#). Many natural substances may be present in little amounts in an unfiltered air sample, including [dust](#), [pollen](#) and [spores](#), [sea spray](#), [volcanic ash](#), and [meteoroids](#). Various industrial [pollutants](#) also may be present, such as [chlorine](#) (elementary or in compounds), [fluorine](#) (in compounds), elemental [mercury](#), and [sulfur](#) (in compounds such as [sulfur dioxide](#) [SO₂]).

Earth's atmosphere can be divided into five main layers. These layers are mainly determined by whether temperature increases or decreases with altitude. From lowest to highest, these layers are: [Troposphere](#), [Stratosphere](#), [Mesosphere](#), [Thermosphere](#) and [Exosphere](#).

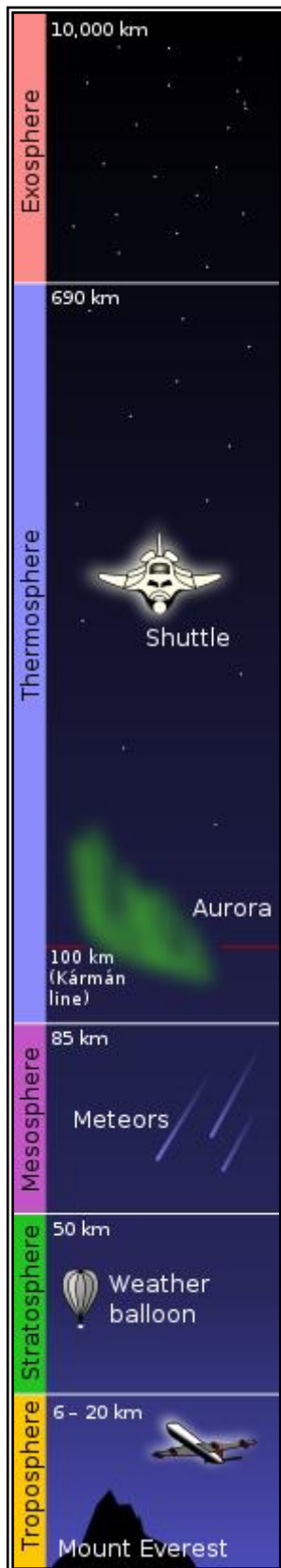


Figure 3.1: Principal layers of the atmosphere (thicknesses and temperatures)

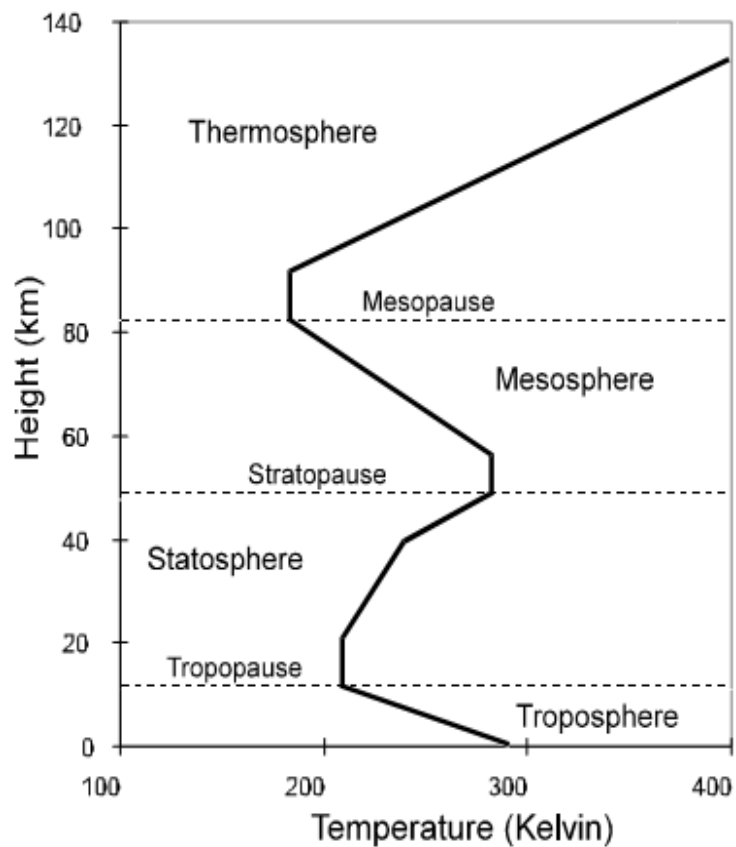


Figure 3.2 Temperature variation across the layers of the atmosphere)

Troposphere

The troposphere begins at the surface and extends to between 7 km (23,000 ft) at the poles and 17 km (56,000 ft) at the equator, with some variation due to weather. The troposphere is mostly heated by transfer of energy from the surface, so on average the lowest part of the troposphere is warmest and temperature decreases with altitude. This promotes vertical mixing (hence the origin of its name in the Greek word "τροπή", *trope*, meaning turn or overturn). The troposphere contains roughly 80% of the mass of the atmosphere.

Stratosphere

The stratosphere extends to about 51 km (32 mi; 170,000 ft). Temperature increases with height, which restricts turbulence and mixing.

Mesosphere

The mesosphere extends to 80–85 km (50–53 mi; 260,000–280,000 ft). It is the layer where most [meteors](#) burn up upon entering the atmosphere. Temperature decreases with height in the mesosphere.

Thermosphere

Temperature increases with height in the thermosphere. The temperature of this layer can rise to 1,500 °C (2,730 °F). The [International Space Station](#) orbits in this layer, between 320 and 380 km (200 and 240 mi). Its height varies with solar activity and ranges from about 350–800 km (220–500 mi; 1,100,000–2,600,000 ft).

Exosphere

Is the outermost layer of Earth's atmosphere. The exosphere is mainly composed of hydrogen and helium.

Other layers

Within the five principal layers determined by temperature are several layers determined by other properties. The [ozone layer](#) is contained within the stratosphere. In this layer [ozone](#) concentrations are about 2 to 8 parts per million, which is much higher than in the lower atmosphere but still very small compared to the main components of the atmosphere. It is

mainly located in the lower portion of the stratosphere from about 15–35 km (9.3–22 mi; 49,000–110,000 ft), though the thickness varies seasonally and geographically. About 90% of the ozone in our atmosphere is contained in the stratosphere.

Definition of Air Pollution

- 1) Air pollution means the presence in the atmosphere of one or more air contaminants thereof in such quantities and of such duration as are or may tend to be hazard to human, plant, animal life, or property.

Contaminants include smoke, vapors, charred paper, dust, soot, grime, carbon fumes, gases, mist, odors, particulate matter, radioactive materials, noxious chemicals or any other material in the atmosphere.

- 2) Air pollution is the human introduction of [chemicals](#), [particulate matter](#), or [biological materials](#) into the atmosphere that cause harm or discomfort to organisms, e.g. [Stratospheric ozone depletion](#) is believed to be caused by air pollution (chiefly from [chlorofluorocarbons](#)).

Worldwide, air pollution is responsible for large numbers of deaths and [respiratory disease](#). Enforced air quality standards, like the [Clean Air Act](#) use by governments, have reduced the presence of pollutants. While [major stationary sources](#) are often identified with air pollution, the greatest [source of emissions](#) is actually mobile sources, principally the [automobile](#).

Atmospheric pollution occurs because the release of air pollutants takes place at a rate much faster than they can be accommodated by the environment and removed from the atmosphere without causing serious harm.

The Six Common Air Pollutants

The Clean Air Act requires EPA to set [National Ambient Air Quality Standards](#) for six common air pollutants. These commonly found air pollutants (also known as "criteria pollutants") found all over the United States. They are:

- 1) ground-level ozone,
- 2) particle pollution (often referred to as particulate matter),

- 3) carbon monoxide,
- 4) sulfur oxides,
- 5) nitrogen oxides, and
- 6) lead.

These pollutants can harm human health and the environment, and cause property damage; these pollutants have science-based guidelines/standards based on human health and environmental criteria for setting permissible levels. The set of limits based on human health is called primary standards, the limits intended to prevent environmental and property damage are called secondary standards.

- 1) **Ozone** (O_3) is a gas composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen ([NO_x](#)) and volatile organic compounds (VOC) in the presence of sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground-level and can be "good" or "bad," depending on its location in the atmosphere.

In the earth's lower atmosphere, ground-level ozone is considered "bad." Motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents as well as natural sources emit NO_x and VOC that help form ozone. Ground-level ozone is the primary constituent of smog. Sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. As a result, it is known as a summertime air pollutant. Many urban areas tend to have high levels of "bad" ozone, but even rural areas are also subject to increased ozone levels because wind carries ozone and pollutants that form it hundreds of miles away from their original sources.

["Good" ozone](#) occurs naturally in the stratosphere approximately 10 to 30 miles above the earth's surface and forms a layer that protects life on earth from the sun's harmful rays.

- 2) "Particulate matter," also known as particle pollution or PM, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

The size of particles is directly linked to their potential for causing health problems. EPA is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. EPA groups particle pollution into two categories:

- "Inhalable coarse particles," such as those found near roadways and dusty industries, are larger than 2.5 micrometers and smaller than 10 micrometers in diameter.
- "Fine particles," such as those found in smoke and haze, are 2.5 micrometers in diameter and smaller. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

3) Carbon Monoxide or CO is a colorless and odorless gas that is formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust which contributes about 56 percent of all CO emissions. Other non-road engines and vehicles (such as construction equipment and boats) contribute about 22 percent of CO emissions. Higher levels of CO generally occur in areas with heavy traffic congestion. In cities, 85 to 95 percent of all CO emissions may come from motor vehicle exhaust. Other sources of CO emissions include industrial processes such as metals processing, chemical manufacturing, residential wood burning and natural sources (e.g. forest fires). Indoor CO sources are commonly woodstoves, gas stoves, cigarette smoke, unvented gas and kerosene space heaters.

The highest levels of CO in the outside air typically occur during the colder months of the year when inversion conditions are more frequent, air pollution becomes trapped near the ground beneath a layer of warm air leading to the formation of smog being trapped close to the ground, with possible adverse effects on health. An inversion can also suppress convection by acting as a "cap"(stratification).

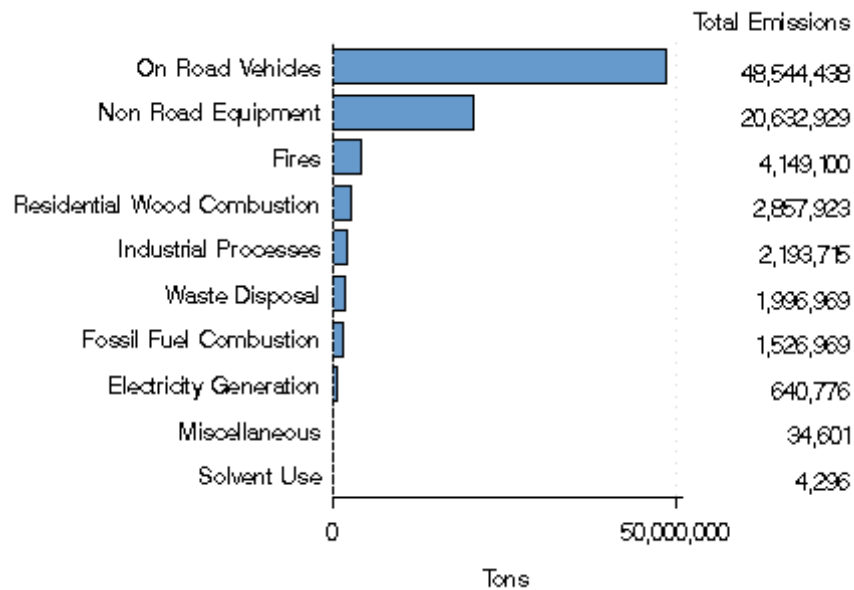


Figure 3.3: National Carbon Monoxide Emissions by Source Sector in 2005; these values refer to the US emissions.

Impacts of Carbon monoxide:

- It can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues.

- **Central Nervous System Effects:**

Even healthy people can be affected by high levels of CO. People who breathe high levels of CO can develop vision problems, reduced ability to work or learn, reduced manual dexterity and difficulty performing complex tasks. At extremely high levels, CO is poisonous and can cause death.

- Smog formation: CO contributes to the formation of smog ground-level ozone, which can trigger serious respiratory problems.

- **Carboxyhemoglobin:**

Carboxyhemoglobin (British English: Carboxyhaemoglobin) (COHb) is a stable [complex](#) of [carbon monoxide](#) and [hemoglobin](#) that forms in red [blood cells](#) when carbon monoxide is inhaled, it hinders delivery of [oxygen](#) to the body.

Hemoglobin binds to carbon monoxide preferentially compared to oxygen (approx 240:1), so effectively, COHb will not release the carbon monoxide, and therefore hemoglobin will not be available to transport oxygen from the lungs to the rest of the body. Humans should survive with very small amounts of COHb in their blood with very little or no observable effects. COHb has a half-life in the blood of 4 to 6 hours, but this can be reduced to 40 minutes with administration of 100% oxygen.

In large quantities, the effect of COHb is to humans is lethal, known medically as carboxyhemoglobinemia or [carbon monoxide poisoning](#). However in smaller quantities COHb leads to oxygen deprivation of the body causing [tiredness](#), [dizziness](#), [unconsciousness](#) and increases risk of [blood clots](#).

[Tobacco smoking](#) (carbon monoxide inhalation) raises the blood levels of COHb increases the risk of having an [ischemic stroke](#)., furthermore pregnant smokers may give birth to babies of a lower birth mass as fetal hemoglobin takes up carbon monoxide more readily than in an adult, therefore the fetus of a smoker will suffer from mild hypoxia potentially retarding its development.

$$\%COHb = 0.005 \times [CO]^{0.85} [T \times F]^{0.63}$$

[CO] = CO concentration in air (ppm)

T = time of exposure (min)

F = exposed person activity factor (1 for resting, 2 for walking, or 3 for hard work)

%COHb less than 1 no effects can be noticed

%COHb exceeds 50 it might cause death

Example: How long does it need to reach to a COHb of 11.3% in the blood of a hard working person if; [CO] = 25 ppm?

Solution: $\% \text{COHb} = 0.005 \times [\text{CO}]^{0.85} [\text{T} \times \text{F}]^{0.63}$

$$11.3 = 0.005 \times [25]^{0.85} [\text{T} \times 3]^{0.63}$$

$$\text{T} = 913.5 \text{ minutes} = 15.23 \text{ hours}$$

- 4) Nitrogen dioxide (NO₂)** is one of a group of highly reactive gasses known as "oxides of nitrogen," or "nitrogen oxides (NO_x)." Other nitrogen oxides include nitrous acid and nitric acid. While EPA's National Ambient Air Quality Standard covers this entire group of NO_x, NO₂ is the component of greatest interest and the indicator for the larger group of nitrogen oxides. NO₂ forms quickly from emissions from cars, trucks and buses, power plants, and off-road equipment. In addition to contributing to the formation of ground-level ozone, and fine particle pollution, NO₂ is linked with a number of adverse effects on the respiratory system.

EPA first set standards for NO₂ in 1971, setting both a primary standard (to protect health) and a secondary standard (to protect the public welfare) at 0.053 parts per million (53 ppb), averaged annually.

- 5) Sulfur dioxide**, or SO₂, belongs to the family of sulfur oxide gases (SO_x). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron.

SO_x gases are formed when fuel containing sulfur, such as coal and oil is burned, when gasoline is extracted from oil or metals are extracted from ore.

SO₂ dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment.

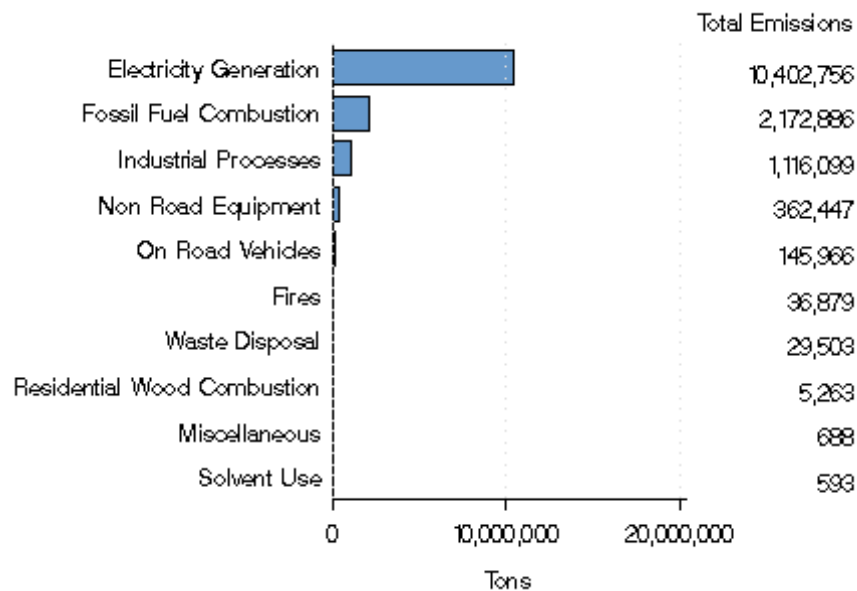


Figure 3.4: National Sulfur Dioxide Emissions by Source Sector in 2005; these values refer to the US emissions

Impacts of Sulfur Dioxide:

SO₂ causes a wide variety of health and environmental impacts because of the way it reacts with other substances in the air. Particularly sensitive groups include people with asthma who are active outdoors, children, the elderly, and people with heart or lung disease.

- **Respiratory illness**, particularly in children and the elderly, and in the longer-term exposures to high levels of SO₂ gas and particles aggravate existing heart and lung disease and are associated with increased respiratory symptoms and disease, difficulty in breathing and premature death. Figure 3.4 displays the effects of pollutants on humans.

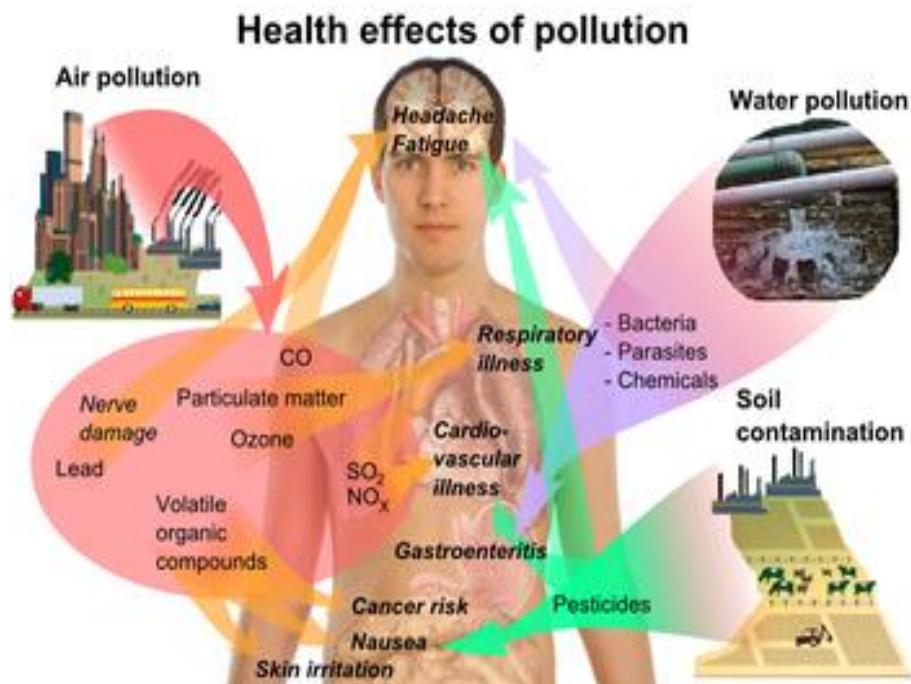


Figure 3.4: A range of disorders due to air and other types of pollution.

- **Visibility Impairment** Forming atmospheric particles that cause visibility impairment, most noticeably in national parks. Where haze occurs when light is scattered or absorbed by particles and gases in the air. Sulfate particles are the major cause of reduced visibility in many parts of the US.

High levels of SO₂ (peak levels) emitted over a short period, such as a day, can be particularly problematic for people with asthma causing temporary breathing difficulty. People are encouraged to learn about the types of industries in their communities and to work with local industrial facilities to address pollution control equipment failures or process upsets that could result in peak levels of SO₂.

- Formation of **acid rain**, which is [rain](#) or any other form of [precipitation](#) that is unusually [acidic](#), i.e. elevated levels of hydrogen ions (low [pH](#)). Acid rain is mostly caused by emissions of compounds of [sulfur](#), [nitrogen](#), and [carbon](#) as displayed in figure 3.5, which react with the [water](#) molecules in the atmosphere to produce acids, which fall to earth as rain, fog, snow, or dry particles. Some may be carried by the wind for hundreds of miles.

However, it can also be caused naturally by the splitting of nitrogen compounds by the energy produced by [lightning](#) strikes, or the release of sulfur dioxide into the atmosphere by phenomena of [volcano eruptions](#).

Impacts of acid rain:

- **Plant and Water Damage** - Acid rain damages forests and crops (Figure 3.6), changes the makeup of soil, and makes lakes and streams acidic and unsuitable for fish. Continued exposure over a long time changes the natural variety of plants and animals in an ecosystem.
- **Aesthetic Damage** - SO_2 accelerates the decay of building materials and paints, including irreplaceable monuments, statues and sculptures that are part of our nation's cultural heritage (Figure 3.7).

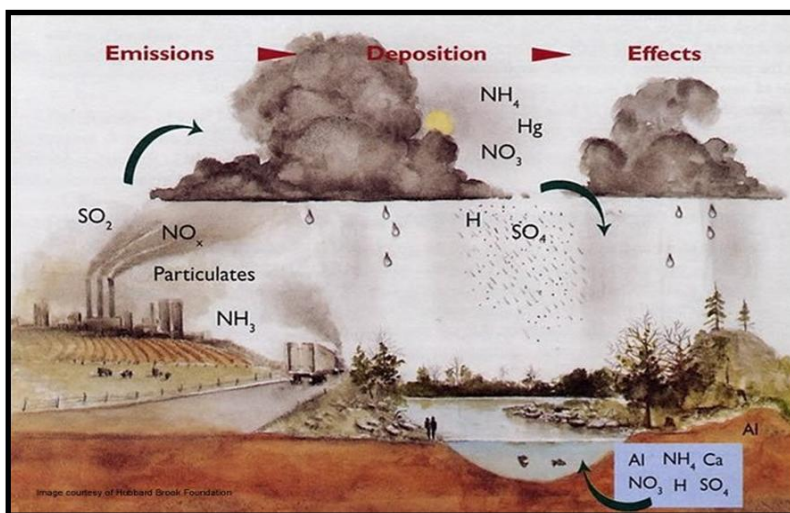


Figure 3.5: Diagram showing acid rain formation



Figure 3.7: Aesthetic damage of acid rain



Figure 3.6: Forest damage of acid rain

Mobility of SO_2 :

SO_2 and the pollutants formed from SO_2 such as sulfate particles can be transported over long distances and deposited far from the point of origin. This means that problems with SO_2 are not confined to areas where it is emitted.

- 6) **Lead (Pb)** is a metal found naturally in the environment as well as in manufactured products. The major sources of lead emissions have historically been motor vehicles (such as cars and trucks) and industrial sources. As a result of EPA's regulatory efforts to remove lead from gasoline, emissions of lead from the transportation sector dramatically declined by 95 percent between 1980 and 1999, and levels of lead in the air decreased by 94 percent between 1980 and 1999. Today, the highest levels of lead in air are usually found near lead smelters. Other stationary sources are waste incinerators, utilities, and lead-acid battery manufacturers.

Chlorofluorocarbons (CFCs)

CFCs are lowering the average concentration of ozone in the stratosphere. "Since 1978 the use of CFCs in aerosol cans has been banned in the United States, Canada, and most Scandinavian countries. Aerosols are still the largest use, accounting for 25% of global CFC use". (Miller 448) Spray cans, discarded or leaking refrigeration and air conditioning equipment, and the burning plastic foam products release the CFCs into the atmosphere. Depending on the type, CFCs stay in the atmosphere from 22 to 111 years. Chlorofluorocarbons move up to the stratosphere gradually over several decades. Under high energy ultra violet (UV) radiation, they break down and release chlorine atoms, which speed up the breakdown of ozone (O₃) into oxygen gas (O₂).

Chlorofluorocarbons, also known as Freons, are greenhouse gases that contribute to global warming. Photochemical air pollution is commonly referred to as "smog". Smog, a contraction of the words smoke and fog, has been caused throughout recorded history by water condensing on smoke particles, usually from burning coal. With the introduction of petroleum to replace coal economies in countries, photochemical smog has become predominant in many cities, which are located in sunny, warm, and dry climates with many motor vehicles. The worst episodes of photochemical smog tend to occur in summer.

Relationship between ppm and mg/L for gases

$$\text{mg/m}^3 = (\text{ppm} \times \text{MW} \times 273 \times P) / (T \times 22.4)$$

MW = molecular weight (in grams/mole)

$T = \text{temperature (°Kelvin)} = 273 + ^\circ\text{C}$

$P = \text{Pressure (atm.)} = \text{mm Hg} / 760$

Atomic Weight (grams/mole): O = 16 N = 16 H = 1 S = 32.1 C = 12

Example: Riyadh's air quality standard for nitrogen dioxide (NO_2) is 470 ug/m^3 (at a temperature of 25°C and 760 mm Hg of pressure). Express the concentration in ppm.

Solution: Molecular weight of nitrogen dioxide (NO_2) = $14 + (2 \times 16) = 46$

$$0.470 = [\text{ppm} \times 46 \times 273 \times (760/760)] / [(25+273) \times 22.4]$$

$$[\text{NO}_2] = 0.25 \text{ ppm}$$

Classification of Air Pollutants:

- Natural: volcanoes, fires, oceans, soils, plants and microbes.
- Anthropogenic: arson fires, combustion-type engines, construction/destruction, chemical processes, mining and agriculture.

Air pollutants also are classified (according to the source) as:

A- Primary pollutants are those that are emitted directly into the atmosphere from an identifiable source, i.e. carbon monoxide and sulfur dioxide.

B- Secondary pollutants are those that are produced in the atmosphere by chemical and physical processes from primary pollutants and natural constituents. For example, ozone is produced by hydrocarbons and oxides of nitrogen (both of which may be produced by car emissions) and sunlight.

Indoor Air Pollution

It is usually thought of air pollution as being an outdoors event, but the air in houses or offices could also be polluted. Sources of indoor pollution include:

- Biological contaminants like [mold](#) and pollen
- Tobacco smoke
- [Household products](#) and [pesticides](#)

- Gases such as [radon](#) and [carbon monoxide](#)
- Materials used in the building such as [asbestos](#), formaldehyde and [lead](#)

Some pollutants can cause diseases that show up much later, such as respiratory diseases or cancer. Making sure that your building is well-ventilated and eliminating pollutants can improve the quality of your indoor air.

Cooking and heating with solid fuels on open fires or traditional stoves results in high levels of indoor air pollution. Indoor smoke contains a range of health-damaging pollutants, such as small particles and carbon monoxide, and particulate pollution levels may be 20 times higher than accepted guideline values.

According to The world health report 2002 indoor air pollution is responsible for 2.7% of the global burden of disease.

Lack of ventilation indoors concentrates air pollution where people often spend the majority of their time. Radon (Rn) gas, a [carcinogen](#), is exuded from the Earth in certain locations and trapped inside houses. Building materials including [carpeting](#) and [plywood](#) emit [formaldehyde](#) (H₂CO) gas. Paint and solvents give off [volatile organic compounds](#) (VOCs) as they dry. [Lead](#) paint can degenerate into [dust](#) and be inhaled. Intentional air pollution is introduced with the use of [air fresheners](#), [incense](#), and other scented items. Controlled wood fires in stoves and [fireplaces](#) can add significant amounts of smoke particulates into the air, inside and out. Indoor pollution fatalities may be caused by using [pesticides](#) and other chemical sprays indoors without proper ventilation.

Radon

Radon cannot be seen and has no smell or taste, but it may be a problem at homes. Radon comes from the natural breakdown of uranium in soil, rock and water. It is the second leading cause of [lung cancer](#) in the United States.

Radon can enter homes and buildings through cracks in floors, walls or foundations. Radon can also be in water supplies, especially well water. Testing is the only way to know if indoor areas have elevated radon levels. Reduction systems can bring the amount of radon down to a safe level and the cost depends on the size and design of building.

Air Quality Measurement

Number of methods are used to measure air quality, including permanent monitoring stations in communities, mobile instrumentation (e.g. on a truck or airplane), and industrial stack monitoring.

These monitoring stations measure the presence of contaminants in the air, such as carbon monoxide (CO), nitrogen dioxide (NO₂), ozone (O₃), particulate matter (PM_{2.5} and PM₁₀), sulphur dioxide (SO₂), and hydrogen sulphide (H₂S).

Air Quality Standards

Emissions standards are requirements that set specific limits to the amount of [pollutants](#) that can be released into the environment. Many emissions standards focus on regulating pollutants released by [automobiles](#) (motor cars) and other powered [vehicles](#) but they can also regulate emissions from [industry](#), power plants, small equipment such as lawn mowers and diesel [generators](#).

Air Pollutants Control Devices

The following items are commonly used as pollution control devices by industry or transportation devices. They can either destroy [contaminants](#) or remove them from an exhaust stream before it is emitted into the atmosphere.

- [Particulate control](#) (Figure 3.8)
 - Mechanical collectors ([dust cyclones](#), [multicyclones](#))
 - [Electrostatic precipitators](#) An electrostatic precipitator (ESP), or electrostatic air cleaner is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge. Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulate matter such as dust and smoke from the air stream.
 - [Baghouses](#) Designed to handle heavy dust loads, a dust collector consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle

or dust removal system (distinguished from air cleaners which utilize disposable filters to remove the dust).

- [Particulate scrubbers](#) Wet scrubber is a form of pollution control technology. The term describes a variety of devices that use pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants.

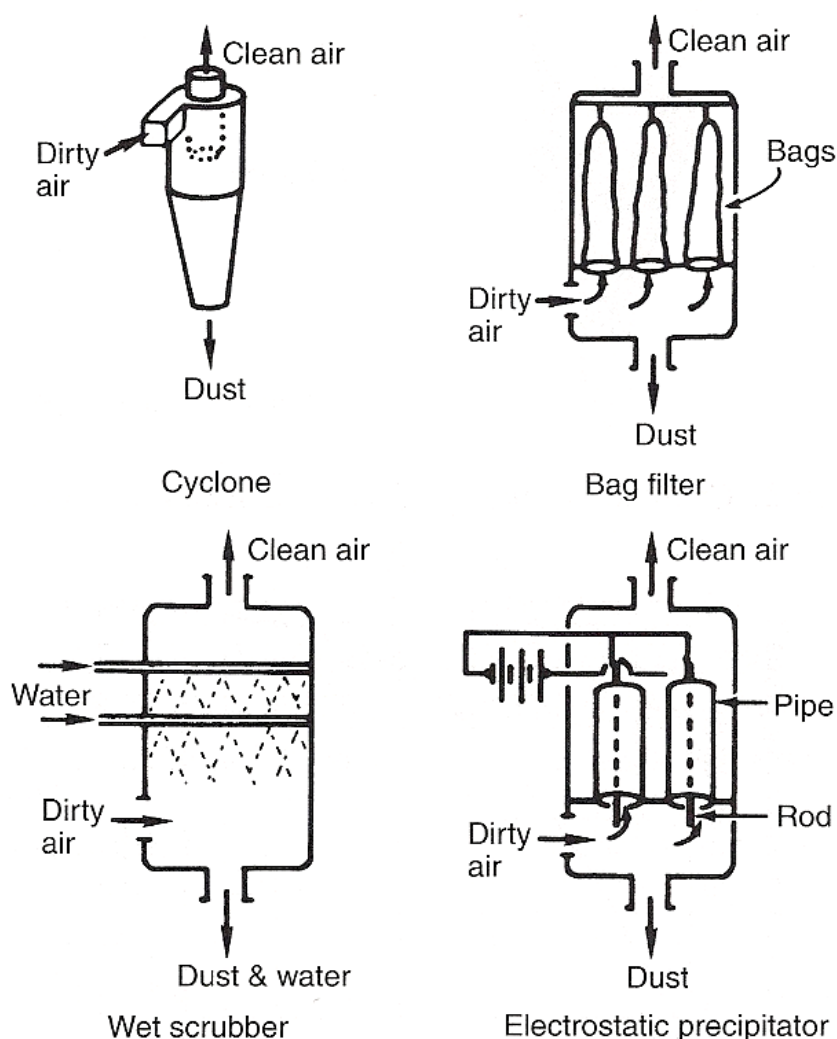


Figure 3.8: Four methods of controlling (trapping) particulate matter from stationary sources. (adapted from Ruth & Robin, Environmental Engineering, Fourth edition, 2003)

In general, control of pollutants that are primary in nature, such as SO₂, NO₂, CO, and Pb, is easier than control of pollutants that are either entirely secondary (O₃) or have a significant secondary component (PM_{2.5}). Primary pollutants may be controlled at the source. For example, SO₂ is controlled by the use of scrubbers, which are industrial devices that remove SO₂ from the exhaust gases from power plants. SO₂ emissions are also reduced by the use of low-sulfur coal or other fuels, such as natural gas, that contain lower amounts of sulfur. NO₂ from industrial sources also may be minimized by scrubbing. NO₂ from cars, as well as CO, are controlled by the use of catalytic converters, engine design modifications, and the use of cleaner burning grades of gasoline. Lead emissions have been reduced significantly since the introduction of lead-free gasoline.

Ozone and particulate matter are two of the most difficult pollutants to control. Reduction of oxides of nitrogen emissions, together with a reduction of VOC emissions is the primary control strategy for minimizing ozone concentrations. Because a large portion of PM 2.5 is secondary in nature, its control is achieved by control of SO₂, NO₂, and VOC (which are the precursors of sulfates, nitrates, and carbon-containing particulates).

Greenhouse Effect

The **greenhouse effect** is the heating of the surface of a planet or moon due to the presence of an [atmosphere](#) containing gases (e.g. water vapor, [carbon dioxide](#), [nitrous oxide](#), and [methane](#)) that absorb and emit [infrared radiation](#). Thus, greenhouse gases trap heat within the surface-troposphere system. This mechanism is fundamentally different from that of an actual [greenhouse](#), which works by isolating warm air inside the structure so that heat is not lost by [convection](#). The greenhouse effect was discovered by [Joseph Fourier](#) in 1824, first reliably experimented on by [John Tyndall](#) in 1858, and first reported quantitatively by [Svante Arrhenius](#) in 1896.

In the absence of the greenhouse effect and an atmosphere, the [Earth's](#) average surface temperature of 14 °C (57 °F) could be as low as −18 °C (−0.4 °F), the [black body](#) temperature of the Earth.

Human activities since the start of the [industrial era](#) around 1750 have increased the levels of greenhouse gases in the atmosphere.

The Earth's atmosphere is all around us. It is the air that we breathe. Greenhouse gases in the atmosphere behave much like the glass panes in a greenhouse. Sunlight enters the Earth's atmosphere, passing through the blanket of greenhouse gases. As it reaches the Earth's surface, land, water, and [biosphere](#) absorb the sunlight's energy. Once absorbed, this energy is sent back into the atmosphere. Some of the energy passes back into space, but much of it remains trapped in the atmosphere by the greenhouse gases, causing our world to heat up (Figure 3.9). But if the greenhouse effect becomes stronger, it could make the Earth warmer than usual. Even a little extra warming may cause problems for humans, plants, and animals.

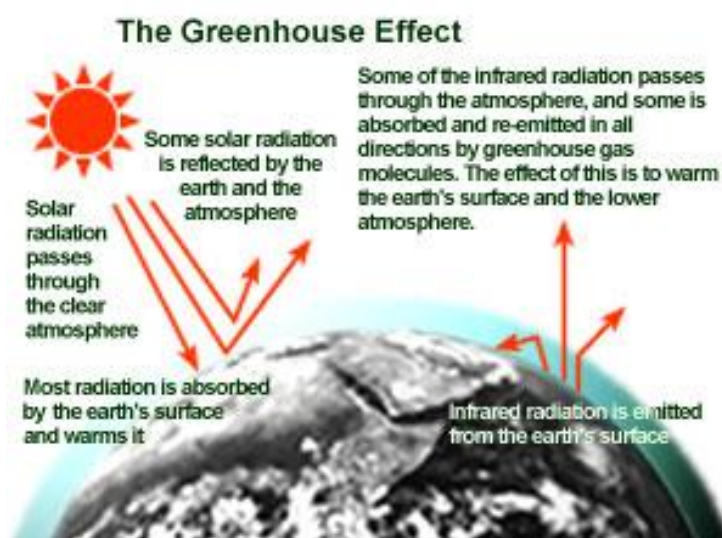


Figure 3.9: A schematic representation of the exchanges of energy between [outer space](#), the [Earth's atmosphere](#), and the Earth's surface. The ability of the atmosphere to capture and recycle energy emitted by the Earth surface is the defining characteristic of the greenhouse effect.

Global warming

Global warming is a major international problem caused mostly by human actions. It is considered a consequence of air pollution.

Global warming is the increase in the average temperature of the Earth's near-surface air and oceans since the mid-20th century and its projected continuation. Global surface temperature increased $0.74 \pm 0.18 \text{ }^{\circ}\text{C}$ ($1.33 \pm 0.32 \text{ }^{\circ}\text{F}$) during the last century. Increase in global temperature caused by increasing concentrations of greenhouse gases resulting from human

activity such as fossil fuel burning and deforestation referred to as anthropogenic global warming (AGW).

An increase in global temperature will cause sea levels to rise and will change the amount and pattern of precipitation, probably including expansion of subtropical deserts. The continuing retreat of glaciers, permafrost and sea ice is expected, with warming being strongest in the Arctic. Other likely effects include increases in the intensity of extreme weather events, species extinctions, and changes in agricultural yields.

Global warming is a result of greenhouse gas emissions such as carbon dioxide, methane and nitrous oxide. Because global warming has become a huge issue, greenhouse gases as air pollutants are usually discussed separately from air pollution.

Air Quality Index (AQI)

The Air Quality Index (AQI) (also known as the Air Pollution Index (API) or Pollutant Standard Index (PSI)) is a number used by government agencies to characterize the quality of the air at a given location. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects.

To compute the AQI requires an air pollutant concentration from a monitor or model. The function used to convert from air pollutant concentration to AQI varies by pollutant, and is different in different countries. Air quality index values are divided into ranges, and each range is assigned a descriptor and a color code. Standardized public health advisories are associated with each AQI range.

The AQI is an index for reporting daily air quality. It the degree of how clean or polluted air is, and what associated health concerns are present. The AQI focuses on health effects that can happen within a few hours or days after breathing polluted air.

EPA uses the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect against harmful health effects. The higher the AQI value is, the greater the level of air pollution and the greater the health danger.

Environmental agencies encourage members of the public to take public transportation to work from home when AQI levels are high.

AQI Breakpoint Definitions (Source: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/aqi_rpt.pl)						
AQI Range	1-hr Ozone (ppm)	8-hr Ozone (ppm)	8-hr Carbon Monoxide (ppm)	24-hr Sulfur Dioxide (ppm)	24-hr PM-10 (ug/m ³)	24-hr PM-2.5 (ug/m ³)
0 – 50	Not Defined	0 - 0.059	0 - 4.4	0 - 0.034	0 – 54	0 - 15.4
51 - 100	Not Defined	0.06 - 0.075	4.5 - 9.4	0.035 - 0.144	55 - 154	15.5 - 40.4
101 - 150	0.125 - 0.164	0.076 - 0.095	9.5 - 12.4	0.145 - 0.224	155 - 254	40.5 - 65.4
151 - 200	0.165 - 0.204	0.096 - 0.115	12.5 - 15.4	0.225 - 0.304	255 - 354	65.5 - 150.4
201 - 300	0.205 - 0.404	0.116 - 0.374	15.5 - 30.4	0.305 - 0.604	355 - 424	150.5 - 250.4
301 - 400	0.405 - 0.504	Not Defined	30.5 - 40.4	0.605 - 0.804	425 - 504	250.5 - 350.4
401 - 500	0.505 - 0.604	Not Defined	40.5 - 50.4	0.805 - 1.004	505 - 604	350.5 - 500.4
500	Not Defined	Not Defined	Not Defined	Not Defined	605 - 4999	500.5 - 999.9

AQI Values and Air Quality Descriptors	
AQI	Descriptor
0 – 50	Good
51 – 100	Moderate
101 – 150	Unhealthy for Sensitive Groups
151 – 200	Unhealthy
201 – 300	Very Unhealthy
301 – 400	Hazardous
500	Hazardous

Example on AQI:

Suppose on a given day the following maximum concentrations are measured:

24-hr SO ₂	0.25 ppm
24-hr PM-10	425 ug/m ³
8-hr O ₃	0.25 ppm
8-hr CO	8 ppm
4-hr O ₃	0.42 ppm

For that day's air quality:

- 1) Determine the Air Quality Index, and
- 2) Indicate the descriptor that would be used to characterize the day's air quality.

Solution:

24-hr SO ₂	0.25 ppm	151-200
24-hr PM-10	425 ug/m ³	301
8-hr O ₃	0.25 ppm	201-300
8-hr CO	8 ppm	51-100
4-hr O ₃	0.42 ppm	Not defined

$$\text{AQI} = 301$$

Descriptor = Hazardous