GE 302 - Industry and the Environment

Chapter III – Air Pollution

Contents

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(Review Chapter 12 of the Textbook for more information)

Introduction

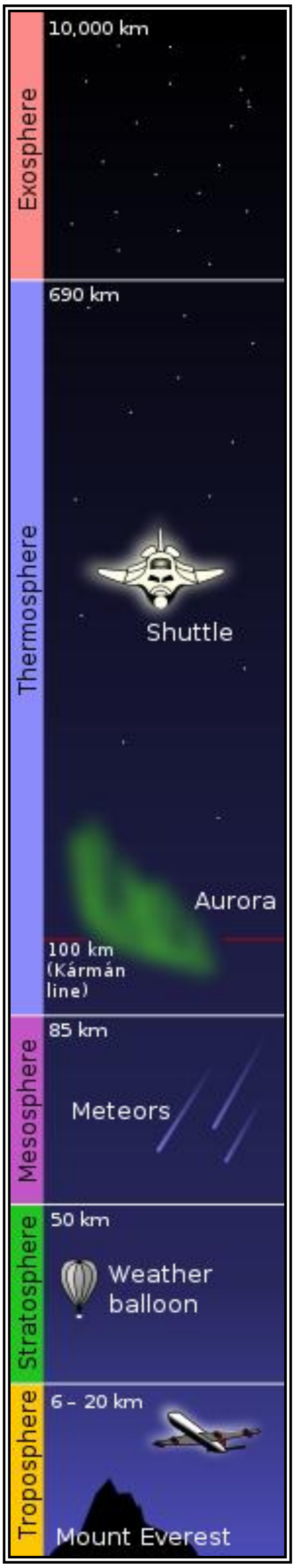
The **Earth's atmosphere** is a layer of gases surrounding the planet that is retained by gravity. The atmosphere protects life by:

1. absorbing ultraviolet solar radiation, which may harm the skin of living organisms,
2. warming the surface through heat retention (greenhouse effect), and
3. 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 includes: 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 [SO_2]).

Earth's atmosphere can be divided into five main layers according to whether temperature increases or decreases with altitude. From lowest to highest, these layers are: Troposphere, Stratosphere, Mesosphere, Thermosphere and Exosphere.



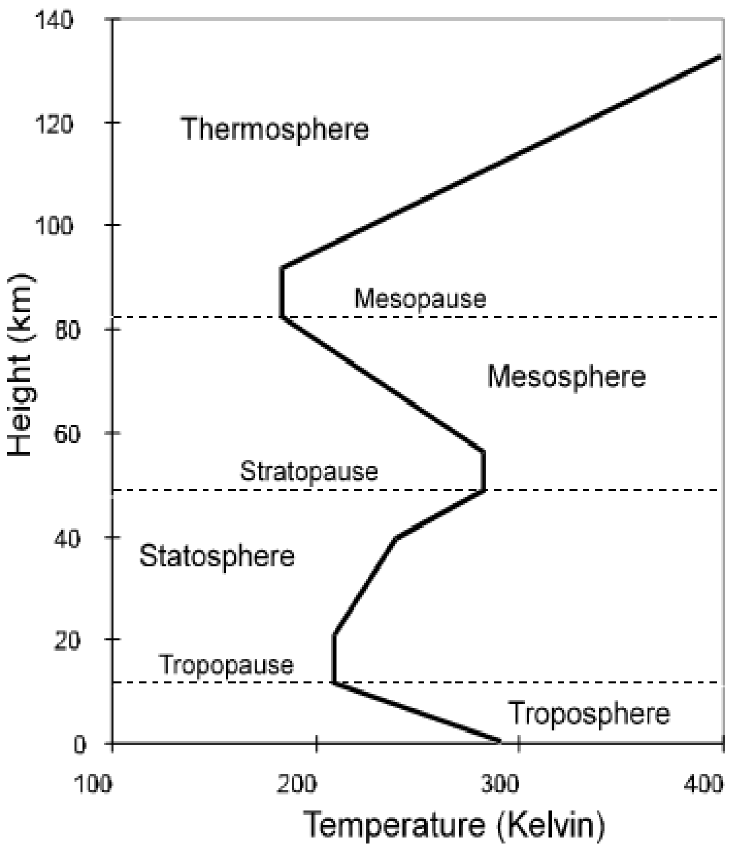


Figure 3.1: Temperature variation across the layers of the atmosphere.

Figure 3.2: Principal layers of the atmosphere (average thicknesses and activities).

Troposphere

The troposphere begins at the surface and extends to between 7 km at the poles and 17 km 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, which promotes vertical mixing. The troposphere contains roughly 80% of the mass of the atmosphere.

Stratosphere

The stratosphere extends to about 51 km. Temperature increases with height, which restricts turbulence and mixing.

Mesosphere

The mesosphere extends to 80–85 km. 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. The International Space Station orbits in this layer, between 320 and 380 km. Its height varies with solar activity and ranges from about 350 to 800 km.

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 to 35 km, 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, or noxious chemicals, or any other material in the atmosphere. Stratospheric ozone depletion is believed to be caused by air pollution (chiefly from chlorofluorocarbons)

2) .

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") are 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 (NOx) 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 NOx 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, 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 <u>inversion conditions</u> 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).

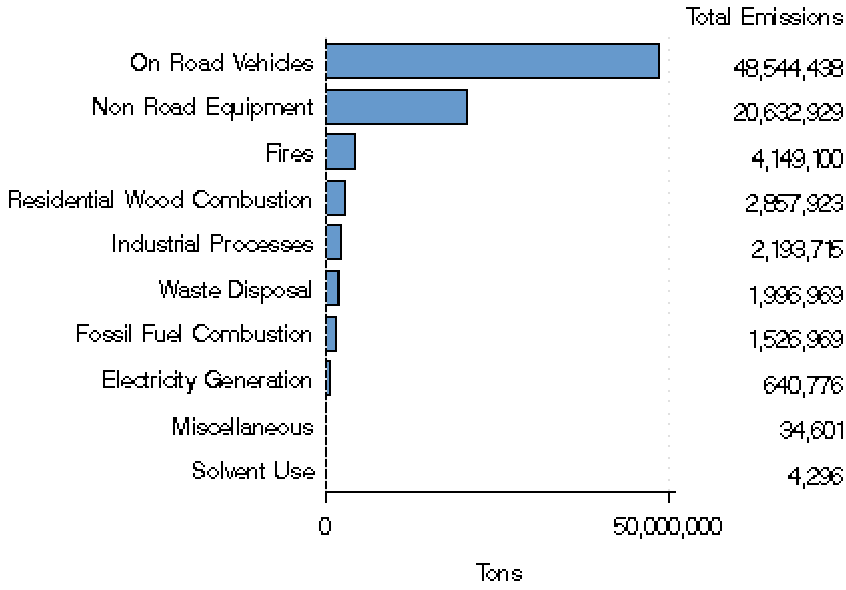


Figure 3.3: US Carbon Monoxide Emissions by Source Sector in 2005.

Impacts of Carbon Monoxide:

- It can cause harmful health effects by reducing oxygen delivery to the body organs; for example 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 (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 to humans is lethal, known medically 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 of less than 1% means no effects can be noticed. If %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 and air temperature = 32 ºC?

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

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

$T = 913.5$ minutes $=15.23$ hours

4) **Nitrogen dioxide** (NO_2) is one of a group of highly reactive gasses known as "oxides of nitrogen," or "nitrogen oxides (NOx)." Other nitrogen oxides include nitrous acid and nitric acid. While EPA's National Ambient Air Quality Standard covers this entire group of NOx, NO_2 is the component of greatest interest and the indicator for the larger group of nitrogen oxides. NO_2 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, NO_2 is linked with a number of adverse effects on the respiratory system.

   EPA first set standards for NO_2 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 SO_2, belongs to the family of sulfur oxide gases (SOx). 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.

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

SO_2 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.

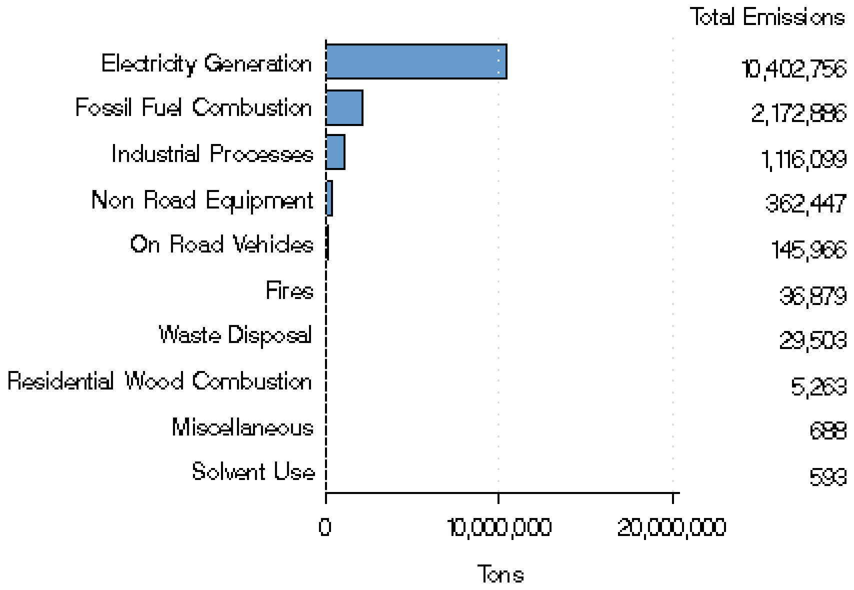


Figure 3.4: US Sulfur Dioxide Emissions by Source Sector in 2005.

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 and 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 SO_2 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.

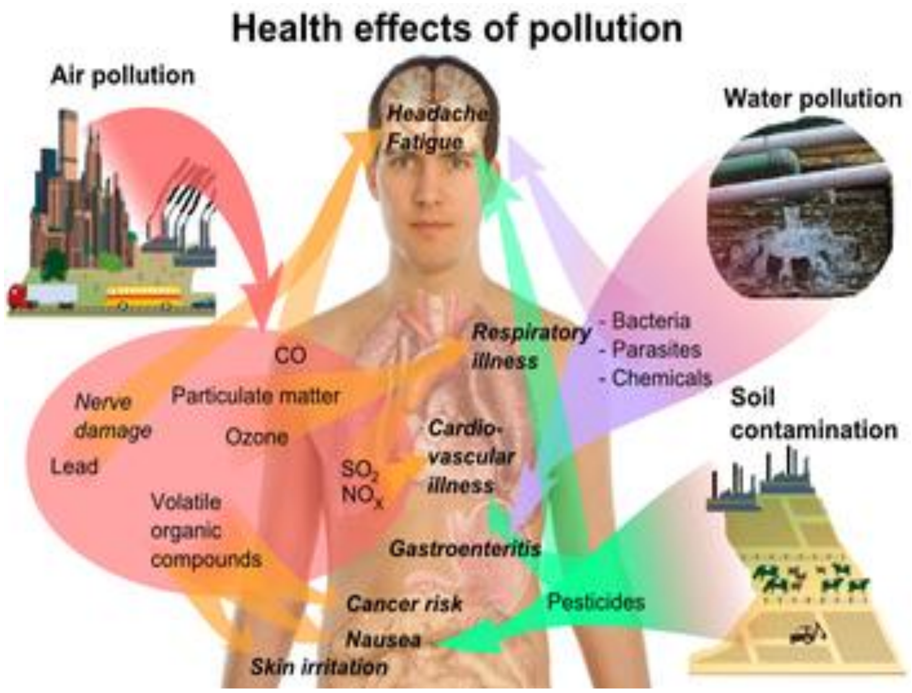


Figure 3.4**:** Respiratory disorders due to air and other types of pollution.

- **Visibility Impairment** Sulfate particles are the major cause of reduced visibility in many parts of the US; particularly in national parks where haze occurs when light is scattered or absorbed by particles and gasses in the air.

High levels of SO_2 (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 SO_2.

- 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).

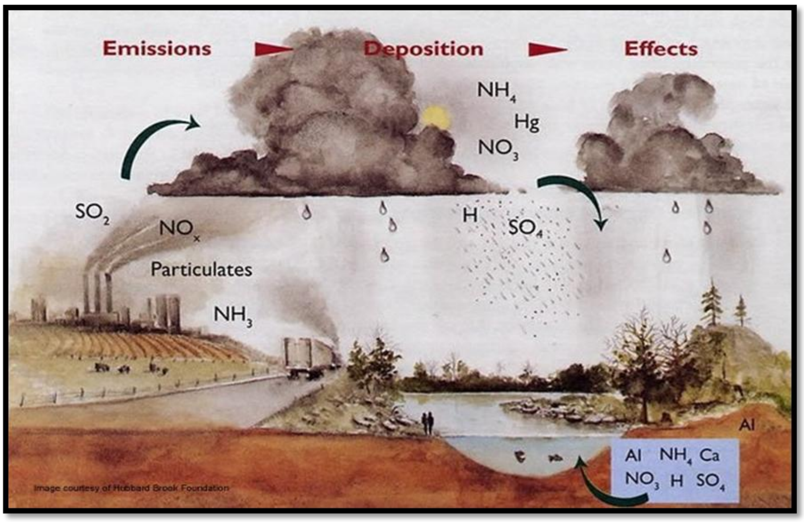


Figure 3.5: Diagram showing acid rain formation

Figure 3.7: Aesthetic damage of acid rain

Figure 3.6: Forest damage of acid rain

Mobility of SO2

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 (O_3) into oxygen gas (O_2).

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

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

MW = molecular weight (in grams/mole)

T = temperature (ºKelvin) = 273 + ºC

P = Pressure (atm.) = mm Hg / 760

Atomic Weight (grams/mole): O = 16 N = 14 H = 1 S = 32 C = 12

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

Solution: Molecular weight of nitrogen dioxide (NO_2) = 14 + (2x16) = 46

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

$$[NO_2] = 0.25 \text{ ppm}$$

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 (H_2CO) 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 (NO_2), ozone (O_3), particulate matter (PM2.5 and PM10), sulphur dioxide (SO_2), and hydrogen sulphide (H_2S).

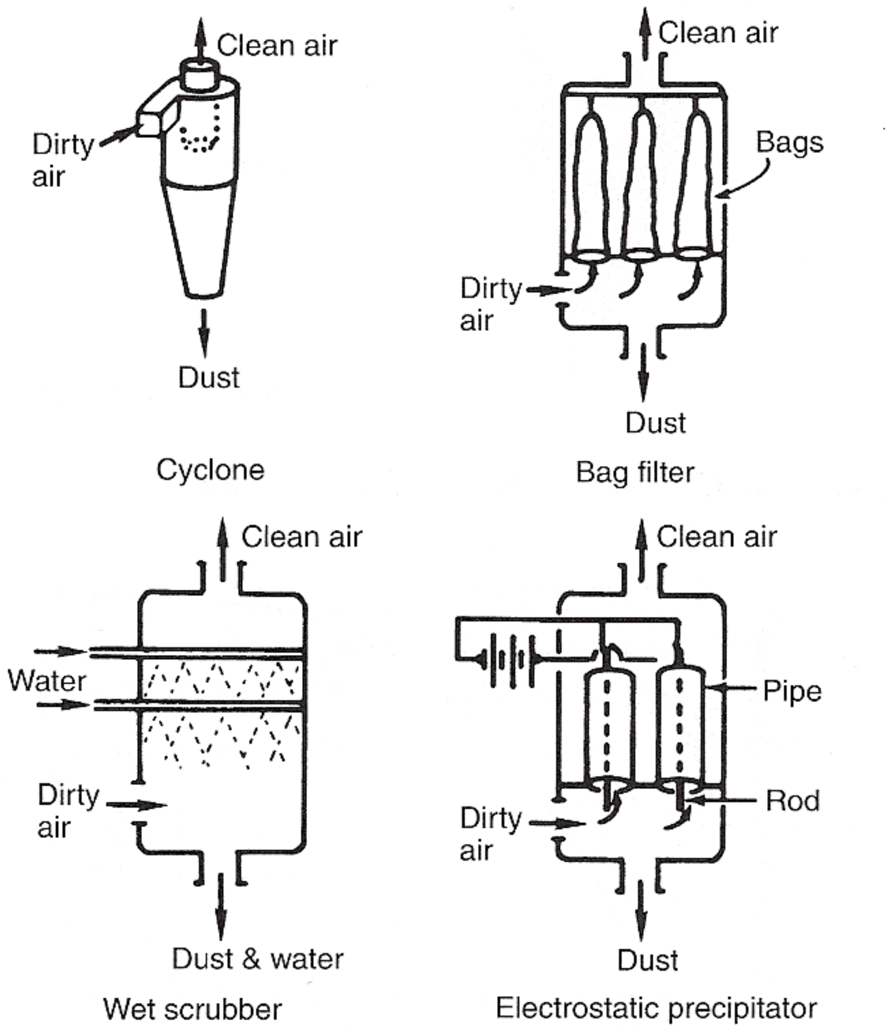
Air Quality Standards

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 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



Cyclone
Bag filter
Wet scrubber
Electrostatic precipitator

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 SO_2, NO_2, CO, and Pb, is easier than control of pollutants that are either entirely secondary (O_3) or have a significant secondary component ($PM_{2.5}$). Primary pollutants may be controlled at the source. For example, SO_2 is controlled by the use of scrubbers, which are industrial devices that remove SO_2 from the exhaust gases from power plants. SO_2 emissions are also reduced by the use of low-sulfur coal or other fuels, such as natural gas, that contain lower amounts of sulfur. NO_2 from industrial sources also may be minimized by scrubbing. NO_2 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 SO_2, NO_2 , 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.

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.

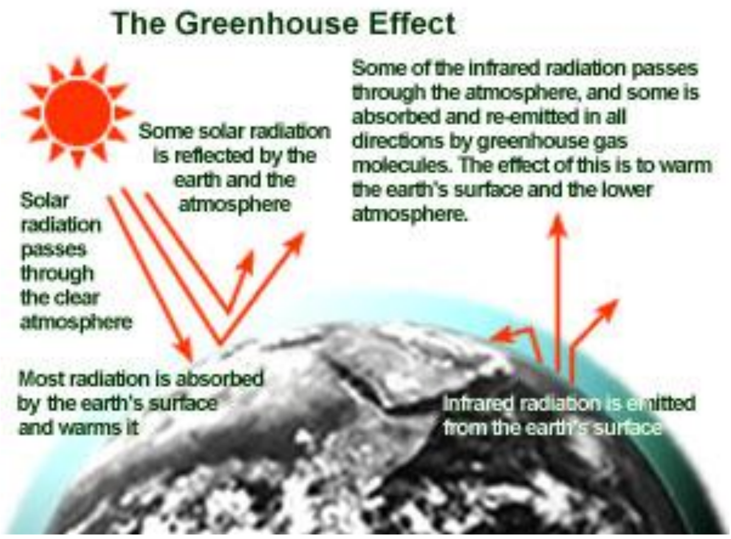


Figure 3.9**:** A schematic representation of the exchanges of energy between outer space, the Earth's atmosphere, and the Earth's surface. The ability of the atmosphere to capture and recycle energy emitted by the Earth surface is the defining characteristic of the greenhouse effect.

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 ± 0.18 °C 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) 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

AQI = 301

Descriptor = Hazardous