AIR POLLUTION

Air Pollution

- **Stationary and Mobile Sources of Air Pollution**
- The two major categories of air pollution sources are stationary sources and mobile sources. **Stationary sources** have a relatively fixed location and include point sources fugitive sources and area sources
- **Point sources** emit pollutants from one or more controllable sites such as power plant smokestacks
- **Fugitive sources** generate air pollutants from open areas exposed to wind. Examples include burning for agricultural purposes as well as dirt roads, construction sites, farmlands, storage piles, surface mines and other exposed areas.
- **Area sources** are well defined areas within which are several sources of air pollutants for example small urban communities, areas of intense industrialization within urban complexes and agricultural areas sprayed with herbicides and pesticides
- **Mobile sources i**nclude automobiles, trucks, buses, aircraft, ships, trains and anything else that pollutes as it moves from place to place.

General Effects of Air Pollution

- Air pollution affects many aspects of our environment including its visual qualities, vegetation, animals, soils, water quality, natural and artificial structures and human health. Air pollutants affect visual resources by discoloring the atmosphere and by reducing visual range and atmospheric clarity.
- Air pollutions numerous effects on vegetation include damage to leaves, needles and fruit, reduced or suppressed growth increased susceptibility to diseases, pests and adverse weather and disruption of reproductive processes

- Air pollution is a signifcant factor in the human death rate in many large cities, for example it has been estimated that in Athens Greece. The number of deaths is several times higher on days when the air is heavily polluted and in Hungary where air pollution has been a serious problem in recent years, it may contribute to as many as in deaths.

- Air pollutants can affect our health in several ways depending on the dose or concentration and other factors including individual susceptibility. Some of the primary effects are cancer, birth defects, eye and respiratory system irritation, greater susceptibility to heart disease and aggravation of chronic diseases such as asthma and emphysema
- Many air pollutants have synergistic effects that is, the combined effects are greater than the sum of the separate effects. For example sulfate and nitrate may attach to small particles in the air, facilitating their inhalation deep in to lung tissue. There, they may do greater damage than a combination of the two pollutants would be expected to based on their separate effects.

- Air pollution deposits can also make soil and water toxic. In addition, soils maybe leached of nutrients by pollutants that form acids. Air pollutions effects on man-made structures include discoloration, erosion and decomposition of building materials.

The Major Air Pollutants

- Nearly air pollutants are recognized and assessed by the EPA (environmental potection agency) and listed in the Clean Air Act. They can be classified as primary or secondary.
- **Primary pollutants** are emitted directly in to the air. They include particulates, sulfur dioxide, carbon monoxide, nitrogen oxides and hydrocarbons.
- **Secondary pollutants** are produced by reactions between primary pollutants and normal atmospheric compounds, for example ozone forms over urban areas, through reactions of primary pollutants sunlight and natural atmospheric gases. Thus ozone is a secondary pollutant.

- The major air pollutants occur either as particulate matter or in gaseous forms.
- **Particulates** are very small particles of solid or liquid substances and maybe organic or inorganic.
- **Gaseous pollutants** include sulfur dioxide, nitrogen oxides, carbonmonoxide, ozone and volatile organic compounds such as hydrocarbons (compounds containing only carbon and hydrogen that include petroleum products), hydrogen sulfide and hydrogen fluoride.

- The primary pollutants that account for nearly all air pollution problems are carbon monoxide, volatile organic compounds, nitrogen oxides, sulfur oxides and particulates. In the United States today about million metric tons of these substances enter the atmosphere from human related processes. If these pollutants were uniformly distributed in the atmosphere the concentration would be only a few parts per million by weight. Unfortunately pollutants are not uniformly distributed but tend to be produced, released and concentrated locally or regionally, for example in large cities.

- In addition to pollutants from human sources, atmosphere contains many pollutants of natural origin such as sulfur dioxide from volcanic eruptions, hydrogen sulfide from geysers and hot springs as well as from biological decay in bogs and marshes; ozone in the lower atmosphere as a result of unstable meteorological conditions such as violent thunderstorms; a variety of particles from wildfires and windstorms; and natural hydrocarbons seeps such as, La Brea Tar Pits in Los Angeles.
- Except for sulfur and nitrogen oxides natural emissions of air pollutants exceed human produced emissions. Nevertheless it is the human component that is most abundant in urban areas and leads to the most severe problems for human health.

- **Criteria Pollutants**
- The six most common pollutants are called criteria pollutants because the EPA has set specific limits on the levels of these six and they are responsible for most of our air pollution problems. The six are
    - **sulfur dioxide, nitrogen oxides, carbon monoxide, ozone particulates and lead.**

- **Sulfur dioxide**
- is a colorless and odorless gas normally present at Earths surface in low concentrations.
- A significant feature of it is that once emitted in to the atmosphere it can be converted into fine particulate sulfate and removed from the atmosphere by wet or dry deposition.

- **Nitrogen Oxides**
- Although nitrogen oxides occur in many forms in the atmosphere, they are emitted largely as nitric oxide and nitrogen dioxide and only these two forms are subject to emission regulations. The more important of the two is nitrogen dioxide a yellow brown to reddish brown gas.
- A major concern with nitrogen dioxide is that it maybe converted by complex reactions in the atmosphere to an ion NO3 (-2), within small water particulates impairing visibility. Both nitrogen dioxide and nitrogen monoxide are major contributors to smog and nitrogen dioxide is also a major contributor to acid rain. Nitrogen oxides contribute to nutrient enrichment and eutrophication of water in ponds, lakes, rivers and the ocean. Nearly all nitrogen dioxide is emitted from anthropogenic sources.

- **Carbon Monoxide**
- Carbon monoxide is a colorless, odorless gas that even at very low concentrations is extremely toxic to humans and other animals. The high toxicity results from a physiological effect: carbon monoxide and hemoglobin have a strong natural attraction for one another. If there is any carbon monoxide in the vicinity the hemoglobin in our blood will take it up nearly 250 times faster than it will oxygen and carry mostly carbon monoxide rather than oxygen from the atmosphere to the internal organs. Effects range from dizziness and headaches to death.

- **Ozone and Other Photochemical Oxidants**
- Photochemical oxidants are secondary pollutants arising from atmospheric interactions of nitrogendioxide and sunlight. Ozone of primary concern here is a form of oxygen in which three atoms of oxygen occur together rather than the normal two. A number of other photochemical oxidants known as PANs (peroxyacylnitrates) occur with photochemical smog.

- Ozone is relatively unstable and releases its third oxygen atom readily so it oxidizes or burns things more readily at lower concentrations than does normal oxygen released in to the air or produced in the air ozone may injure living things.
- Ozone in the lower atmosphere is a secondary pollutant produced on bright sunny days in areas where there is significant primary pollution.
- Ozones effects on plants can be subtle at very low concentrations it can slow growth without visible injury. At higher concentrations it kills leaf tissue and if pollutant levels remain high whole plants.

- **Particulate Matter: PM10 , PM2.5 , and Ultrafine Particles (UP)**
- Particulate matter is made up of tiny particles the term particulate matter is used for varying mixtures of particles suspended in the air we breathe but in regulations these are divided into three categories: PM10; particles up to 10 micrometers in diameter, PM2.5; particles between 2.5-0.18 microns and UP- ultrafine particles smaller than micrometers in diameter released into the air by vehicles on streets and freeways.
- **Fine particles** are easily inhaled into the lungs where they can be absorbed into the blood stream or remain embedded for along time. sulfates and nitrates.
- **Ultrafine particles** released into the air by motor vehicles are so small that they can not be easily filtered and can enter the blood stream. Rich in organic compounds and other reactive chemicals, they may be the most hazardous components of air pollution especially with respect to heart disease.

- **Lead**
- Lead a heavy metal is an important constituent of automobile batteries and many other industrial products. Leaded gasoline still used in some countries helps protect engines and promotes more effective fuel consumption. Once released, lead can be transported through the air as particulates to be taken up by plants through the soil or deposited directly on their leaves. Thus it enters terrestrial food chains. When lead is carried by streams and rivers deposited in quiet waters or transported to oceans or lakes it is taken up by aquatic organisms and enters aquatic food chains, lead is toxic to wildlife and people. it can damage the nervous system impair learning and reduce IQ and memory in children. It can also contribute to behavioral problems in adults. It can contribute to cardiovascular and kidney disease as well as anemia.

- **Air Toxics**
- Toxic air pollutants, or **air toxics**, are among those pollutants known or suspected to cause cancer and other serious health problems after either long term or short term exposure the most serious exposure to air toxics occurs.

- **Hydrogen Sulfide**
- is a highly toxic corrosive gas easily identified by its rotten egg odor. Hydrogensulfide is produced from natural sources such as geysers, swamps and bogs, and from human sources such as petroleum refineries and metal smelters. The potential effects of hydrogen sulfide include functional damage to plants and health problems ranging from toxicity to death for humans and other animals.
- **Hydrogen Fluoride**
- is a gas released by some industrial activities such as aluminum production, coal gasification, and burning of coal in power plants. it is extremely toxic; even a small concentration may cause problems for plants and animals. it is potentially dangerous to grazing animals because some forage plants can become toxic when exposed to this gass.

- Mercury
- Volatile organic compounds
- Methyl isocyanata
- Benzene
- Acrolein

Urban Air Pollution: Chemical and Atmospheric Processes

- There are two major types of urban smog; photochemical smog sometimes called L.A. Type smog or brown air, and sulfurous smog sometimes referred to as London type smog, gray air or industrial smog.
- **Sulfurous smog** is produced primarily by the burning of coal or oil at large power plants. Sulfuroxides and particulates combine under certain conditions to produce a concentrated sulfurous smog.
- **Photochemical smog** is directly related to automobile use.

in the lower atmosphere restricted circulation associated with an **atmospheric inversion** may lead to pollution events. An atmospheric inversion occurs when warmer air lies above cooler air and there is little wind. The air stays still both vertically and horizontally so any pollutant emissions stay there and build up.

- **The potential for air pollution in urban areas is determined by the following:**

- The rate of emission of pollutants per unit area
- The distance that an air mass moves down wind through a city
- The average speed of the wind
- The elevation to which potential pollutants can be thoroughly mixed by naturally moving air in the lower atmosphere

High-Altitude (Stratospheric) Ozone Depletion

- The serious problem of ozone depletion in the stratosphere (about 9 to 25 km above Earth's surface) starts down here in the lower atmosphere.

Ultraviolet Radiation and Ozone

- The ozone layer in the stratosphere is often called the **ozone shield** because it absorbs most of the potentially hazardous ultraviolet radiation that enters Earth's atmosphere from the sun. Ultraviolet radiation has wavelengths between 0.1 and 0.4 μm and is subdivided into ultraviolet A, ultraviolet B and ultraviolet C. Ultraviolet radiation with a wavelength of less than about 0.3 μm can be very hazardous to life. If much of this radiation reached Earth's surface it would injure or kill most living things.

Ultraviolet C has the shortest wavelength and is the most energetic of the three types. It has enough energy to break down diatomic oxygen in the stratosphere into two oxygen atoms, each of which may combine with an O2 molecule to create ozone. Ultraviolet C is strongly absorbed in the stratosphere and negligible amounts reach Earth's surface.

- Ultraviolet A radiation has the longest wavelength and the least energy of the three types. UVA can cause some damage to living cells is not affected by stratospheric ozone and is transmitted to the surface of Earth.

- Ultraviolet B radiation is energetic and strongly absorbed by stratospheric ozone. Infact ozone is the only known gas that absorbs UVB. Thus depletion of ozone in the stratosphere allows more UVB to reach the Earth. Because UVB radiation is known to be hazardous to living things, this increase in UVB is the hazard we are talking about when we discuss the problem of ozone depletion in the stratosphere.

Ozone Depletion and CFCs

- The hypothesis that ozone in the stratosphere is being depleted by chlorofluorocarbons (CFCs) was first suggested in 1974 by Mario Molina and F. Sherwood Rowland. This hypothesis based mostly on physical and chemical properties of CFCs and knowledge about atmospheric conditions was immediately controversial and vigorously debated by scientists, companies producing CFCs and other interested parties. The major features of the Molina and Rowland hypothesis are as follows:

- *CFCs emitted in the lower atmosphere by human activity are very stable and nonreactive in the lower atmosphere and therefore have a very long residence time about years. No significant sinks for CFCs are known with the possible exception of soils which evidently do remove an unknown amount of CFCs from the atmosphere at Earth's surface.
- *Because of their long residence time in the lower atmosphere and because the lower atmosphere is very fluid the CFCs eventually disperse, wander upward and enter the stratosphere. Once they reach altitudes above most of the stratospheric ozone, they maybe destroyed by the highly energetic solar ultraviolet radiation. This releases chlorine, a highly reactive atom.
- *The reactive Chlorine may then enter into reactions that deplete ozone in the stratosphere.
- *Ozone depletion allows an increased amount of UVB radiation to reach Earth. Ultraviolet B is a cause of human skin cancers and is also believed to be harmful to the human immune system.

Simplified Stratospheric Chlorine Chemistry

- CFCs are considered responsible for most of the ozone depletion. CFCs are nonreactive in the lower atmosphere
- When CFCs wander to the upper part of the stratosphere, however, reactions do occur. Highly energetic ultraviolet B radiation splits up the CFC, releasing chlorine. When this happens the following two reactions can take place
  - (1) $Cl + O_3 \rightarrow ClO + O_2$
  - (2) $ClO + O \rightarrow Cl + O_2$
- These two equations define a chemical cycle that can deplete ozone.

- The **catalytic chain reaction** can be interrupted through storage of chlorine in other compounds in the stratosphere. Two possibilities are as follows:
- 1. Ultraviolet light breaks down CFCs to release chlorine which combines with ozone to form chlorine monoxide. The chlorine monoxide may then react with nitrogen dioxide to form a chlorine nitrate. If this reaction occurs ozone depletion is minimal. The chlorine nitrate however is only a temporary reservoir for chlorine. The compound may be destroyed and the chlorine released again.
- 2. Chlorine released from CFCs combine with methane to form hydrochloric acid. The hydrochloric acid may then diffuse down ward. If it enters the troposphere, rain may remove it, thus removing the chlorine from the ozone destroying chain reaction. This is the ultimate end for most chlorine atoms in the stratosphere. However, while the hydrochloric acid molecule is in the stratosphere, it maybe destroyed by incoming solar radiation releasing the chlorine for additional ozone depletion.

- **The Antarctic Ozone Hole**
- First reported in 1985.
- It has captured the interest of many people around the world every year since then ozone depletion has been observed in the Antarctic in october, the spring season there. Because the thickness of the ozone layer above the Antarctic in spring time has been declining since the mid-1970’s, the geographic area covered by the ozone hole has grown from a million or so square kilometers in the late 1970’s and early 1980’s to about 29 million square kilometers by 1995 - about the size of North America in 2000. It has since stabilized as the ozone concentration has ceased it’s steep decline.

- **Polar Stratospheric Clouds**
- The minimum concentration of ozone in the antarctic since 1980 has varied from about 50% to 70% of that in the 1970s. Polar stratospheric clouds over the antarctic appear to be one of the causes of this variation, the clouds have an eerie beauty and an iridescent glow. They form during the polar winter called the polar night, because the tilt of Earth’s axis limits sunlight.

During the polar winter the Antarctic air mass is isolated from the rest of the atmosphere and circulates about the pole in what is known as the **Antarctic polar vortex**. The vortex forms as the isolated air mass cools, condenses and descends.

- Clouds form in the vortex when the air mass reaches a temperature between -78 to -83 C.
- At these low temperatures small sulfuric acid particles freeze and serve as seed particles for nitric acid. These clouds are called **Type 1 polar stratospheric clouds**.
- If temperatures drop below -83 C water vapor condenses around some of the earlier formed Type 1 cloud particles, forming **Type 2 polar stratospheric clouds**, which contain larger particles. Type2 polar stratospheric clouds are the ones with the mother of pearl color.
- During the formation of polar stratospheric clouds nearly all the nitrogen oxides in the air mass are converted to the clouds as nitric acid particles which grow heavy and descend below the stratosphere, leaving very little nitrogen oxide in the vicinity of the cloud. This facilitates ozone depleting reactions in the polar vortex by as much as 1% to 2% per day in the early spring when sunlight returns to the polar region.

- In the dark Antarctic winter almost all available nitrogen oxides are tied up on the edges of particles in the polar stratospheric clouds or have settled out. Hydrochloric acid and chlorine nitrate the two important sinks of chlorine act on particles of polar stratospheric clouds to form di molecular chlorine and nitric acid through the following reaction
- $HCl + ClONO2 \longrightarrow Cl2 + HNO3$

- In the spring, when sunlight returns and breaks apart chlorine, the ozone depleting reactions occur. Nitrogen oxides are absent from the antarctic stratosphere in the spring so the chlorine can not be sequestered to form chlorine nitrate, one of its major sinks and remains free to destroy ozone.
- Ozone depletion in the Antarctic vortex ceases later in spring as the environment warms and the polar stratospheric clouds disappear, releasing nitrogen back into the atmosphere, where it can combine with chlorine and thus be removed from ozone depleting reactions. Stratospheric ozone concentrations then increase as ozone rich air masses again migrate to the polar region.
- A weaker, shorter polar vortex forms over the north pole area and can lead to ozone depletion of as much as 30-40%. When the vortex breaks up, it can send ozone deficient air masses southward to drift over areas of Europe and North America.

- **Environmental Effects of Ozone Depletion**
- Ozone depletion damages some food chains on land and in the oceans and is dangerous to people, increasing the incidence of skin cancers and cataracts, and suppressing immune systems.
- A decrease in ozone can cause an 1-2% increase in uvb radiation and a 2% increase in skin cancer. Because skin cancers have increased globally, health conscious people today are replacing tanning oils with sunblocks and hats, and newspapers in the United States now provide the ultraviolet (uv) index, developed by the National Weather Service and EPA.