The **greenhouse effect** is a naturally occurring process that aids in heating the Earth's surface and atmosphere. It results from the fact that certain atmospheric gases, such as **carbon dioxide**, **water vapor**, and **methane**, are able to change the energy balance of the planet by absorbing **long wave radiation** emitted from the Earth's surface. Without the greenhouse effect life on this planet would probably not exist as the average temperature of the Earth would be a chilly -18° Celsius, rather than the present 15° Celsius.

Some greenhouse gases occur naturally in the atmosphere, while others result from human activities. Naturally occurring greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone (refer Figure 9.4). Certain human activities, however, add to the levels of most of these naturally occurring gases.

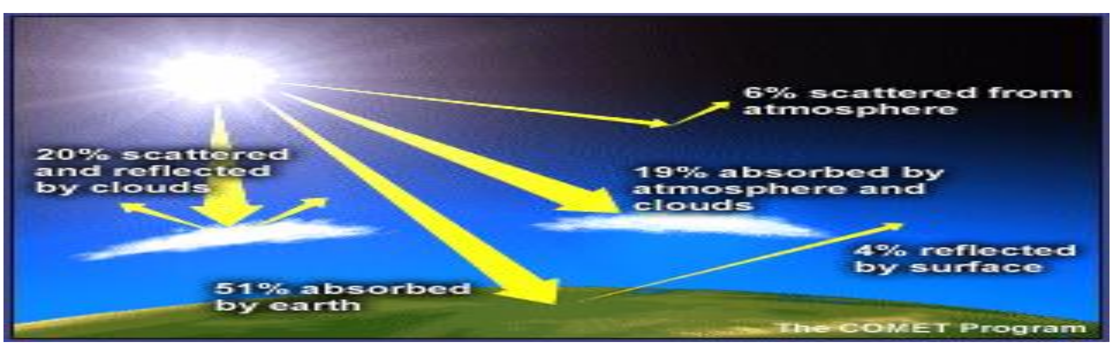
Carbon dioxide is released to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products are burned.

Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from the decomposition of organic wastes in municipal solid waste landfills, and the raising of livestock. Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.

Very powerful greenhouse gases that are not naturally occurring include hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulfur hexafluoride (SF_6), which are generated in a variety of industrial processes.

Often, estimates of greenhouse gas emissions are presented in units of millions of metric tons of carbon equivalents (MMTCE), which weights each gas by its Global Warming Potential or GWP value.

As energy from the Sun passes through the atmosphere a number of things take place. A portion of the energy (26% globally) is **reflected** or **scattered** back to space by clouds and other atmospheric particles. About 19% of the energy available is absorbed by clouds, gases (like **ozone**), and particles in the atmosphere. Of the remaining 55% of the solar energy passing through the Earth's atmosphere, 4% is reflected from the surface back to space. On average, about 51% of the Sun's radiation reaches the surface. This energy is then used in a number of processes, including the heating of the ground surface; the melting of ice and snow and the evaporation of water; and plant photosynthesis.



The heating of the ground by sunlight causes the Earth's surface to become a radiator of energy in the long wave band (sometimes called **infrared radiation**). This emission of energy is generally directed to space . However, only a small portion of this energy actually makes it back to space. The majority of the outgoing infrared radiation is absorbed by the **greenhouse gases**

Absorption of long wave radiation by the atmosphere causes additional heat energy to be added to the Earth's atmospheric system. The now warmer atmospheric greenhouse gas molecules begin radiating long wave energy in all directions. Over 90% of this emission of long wave energy is directed back to the Earth's surface where it once again is absorbed by the surface. The heating of the ground by the long wave radiation causes the ground surface to once again radiate, repeating the cycle described above, again and again, until no more long wave is available for absorption.

A number of gases are involved in the human caused enhancement of the greenhouse effect .These gases include: **carbon dioxide** (CO_2); **methane** (CH_4); **nitrous oxide** (N_2O); **chlorofluorocarbons** (CFxClx); and **tropospheric ozone** (O_3). Of these gases, the single most important gas is **carbon dioxide** which accounts for about 55% of the change in the intensity of the Earth's greenhouse effect. The contributions of the other gases are 25% for **chlorofluorocarbons**, 15% for **methane**, and 5% for **nitrous oxide**. **Ozone's** contribution to the enhancement of green house effect is still yet to be quantified.Average concentrations of atmospheric **carbon dioxide** in the year 2005 were about 380 parts per million .Prior to 1700, levels of carbon dioxide were about 280 parts per million. This increase in carbon dioxide in the atmosphere is primarily due to the activities of humans. Beginning in 1700, societal changes brought about by the **Industrial Revolution** increased the amount of carbon dioxide entering the atmosphere. The major sources of this gas include fossil fuel combustion for industry, transportation, space heating, electricity generation and cooking; and vegetation changes in natural prairie, woodland, and forested ecosystems. Emissions from fossil fuel combustion account for about 65% of the extra carbon dioxide now found in our atmosphere. The remaining 35% is derived from deforestation and the conversion of prairie, woodland, and forested ecosystems primarily into agricultural systems.

Natural ecosystems can hold 20 to 100 times more carbon dioxide per unit area than agricultural systems. Artificially created **chlorofluorocarbons** are the strongest greenhouse gas per molecule. However, low concentrations in the atmosphere reduce their overall importance in the enhancement of the greenhouse effect.

Current measurements in the atmosphere indicate that the concentration of these chemicals may soon begin declining because of reduced emissions. Reports of the development of ozone holes over the North and South Poles and a general decline in global stratospheric ozone levels over the last two decades has caused many nations to cut back on their production and use of these chemicals.

Since 1750, **methane** concentrations in the atmosphere have increased by more than 150%. The primary sources for the additional methane added to the atmosphere (in order of importance) are rice cultivation, domestic grazing animals, termites, landfills, coal mining, and oil and gas extraction. Anaerobic conditions associated with rice paddy flooding results in the formation of methane gas. However, an accurate estimate of how much methane is being produced from rice paddies has been difficult to obtain. More than 60% of all rice paddies are found in India and

China where scientific data concerning emission rates are unavailable. Nevertheless, scientists believe that the contribution of rice paddies is large because this form of crop production has more than doubled since 1950. Grazing animals release methane to the environment as a result of herbaceous digestion. Some researchers believe the addition of methane from this source has more than quadrupled over the last century. Termites also release methane through similar processes. Land-use change in the tropics, due to deforestation, ranching, and farming, may be causing termite numbers to expand. If this assumption is correct, the contribution from these insects may be important. Methane is also released from landfills, coal mines, and gas and oil drilling. Landfills produce methane as organic wastes decompose over time. Coal, oil, and natural gas deposits release methane to the atmosphere when these deposits are excavated or drilled.

The average concentration of **nitrous oxide** in the atmosphere is now increasing at a rate of 0.2 to 0.3% per year. Sources for this increase include land-use conversion; fossil fuel combustion; biomass burning; and soil fertilization. Most of the nitrous oxide added to the atmosphere each year comes from deforestation and the conversion of forest, savanna and grassland ecosystems into agricultural fields and rangeland. Both of these processes reduce the amount of nitrogen stored in living vegetation and soil through the decomposition of organic matter. Nitrous oxide is also released into the atmosphere when fossil fuels and biomass are burned. However, the combined contribution of these sources to the increase of this gas in the atmosphere is thought to be minor. The use of nitrate and ammonium fertilizers to enhance plant growth is another source of nitrous oxide. Accurate measurements of how much nitrous oxide is being released from fertilization have been difficult to obtain. Estimates suggest that the contribution from this source may represent from 50% to 0.2% of nitrous oxide added to the atmosphere annually.

Ozone's role in the enhancement of the greenhouse effect has been difficult to determine scientifically. Accurate measurements of past long-term (more than 25 years in the past) levels of this gas in the atmosphere are currently unavailable. Concentrations of ozone gas are found in two different regions of the Earth's atmosphere. The majority of the ozone (about 97%) found in the atmosphere is localized in the **stratosphere** at an altitude of 15 to 55 kilometers above the Earth's surface. In recent years, the concentration of the **stratospheric ozone** has been decreasing because of the buildup of **chlorofluorocarbons** in the atmosphere. Since the late 1970s, scientists have discovered that **total column ozone** amounts over Antarctica in the springtime have decreased by as much as 70%. Satellite measurements have indicated that the zone from 65° North to 65° South latitude has had a 3% decrease in stratospheric ozone since 1978. Ozone is also highly concentrated at the Earth's surface. Most of this ozone is created as an artificial by product of **photochemical smog**.

Global Warming (Climate Change) Implications

Rise in global temperature

Observations show that global temperatures have risen by about 0.6 °C over the 20th century. There is strong evidence now that most of the observed warming over the last 50 years is caused by human activities. Climate models predict that the global temperature will rise by about 6 °C by the year 2100.

Rise in sea level

In general, the faster the climate change, the greater will be the risk of damage. The mean sea level is expected to rise 9 - 88 cm by the year 2100, causing flooding of low lying areas and other damages.

Food shortages and hunger

Water resources will be affected as precipitation and evaporation patterns change around the world. This will affect agricultural output. Food security is likely to be threatened and some regions are likely to experience food shortages and hunger.

3.4.6 ACID RAIN

Oxides of sulfur and nitrogen originating from industrial operations and fossil fuel combustion are the major sources of acid forming gases. Acid forming gases are oxidized over several days by which time they travel several thousand kilometers. In the atmosphere these gases are ultimately converted into sulfuric and nitric acids. Hydrogen chloride emission forms hydrochloric acid. These acids cause acidic rain. Acid rain is only one component of acidic deposition. Acidic decomposition is the total wet acidic deposition (acid rain) and dry deposition. Rain water is turned acidic when its pH falls below 5.6. In fact clean or natural rain water has a pH of 5.6 at 20˚ c because of formation of carbonic acid due to dissolution of CO2 in water. In absence of rain, dry deposition of acid may occur. Acid forming gases like oxides of sulphur and nitrogen and acid aerosols get deposited on the surface of water bodies, vegetation, soil and other materials. On moist surfaces or in liquids these acid forming gases can dissolve an form acids similar to that formed in acid rain.

Effects of acid rain:

Acid rain causes a number of harmful effects below pH 5.1. The effects are visible in the aquatic even at pH less than 5.5.

1. It causes deterioration of buildings especially made of marble e.g. monuments like Taj Mahal. Crystals of calcium and magnesium sulphate are formed as a result of corrosion caused by acid rain.
2. It damages stone statues. Priceless stone statues in Greece and Italy have been partially dissolved by acid rain.
3. It damages metals and car finishes.
4. Aquatic life especially fish are badly affected by lake acidification
5. Aquatic animals suffer from toxicity of metals such as aluminium, mercury, manganese, zinc and lead which leak from the surrounding rocks due to acid rain.
6. It results in reproductive failure, and killing of fish.
7. Many lakes of Sweden, Norway, and Canada have become fishless due to acid rain.
8. It damages foliage and weakens trees
9. It makes trees more susceptible to stresses like cold temperature, drought, etc . Many insects and fungi are more tolerant to acidic conditions and hence they can attack the susceptible trees and cause diseases.

Control measures:

1. Emission of SO_2 and NO_2 from industries and power plants should be reduced by using pollution control equipments.
2. Liming of lakes and soils should be done to correct the adverse effects of acid rain.
3. A coating of protective layer of inert polymer should be given in the interior of water pipes for drinking water

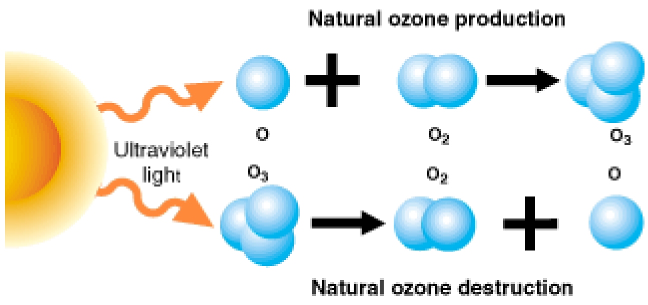
3.4.7 OZONE LAYER DEPLETION

As early as 1896, the Swedish scientist Svante Arrhenius had predicted that human activities would interfere with the way the sun interacts with the earth, resulting in global warming and climate change. His prediction has become true and climate change is now disrupting global environmental stability. The last few decades have seen many treaties, conventions, and protocols for the cause of global environmental protection.
Few examples of environmental issues of global significance are:

- Ozone layer depletion
- Global warming

One of the most important characteristics of this environmental degradation is that it affects all mankind on a global scale without regard to any particular country, region, or race. The whole world is a stakeholder and this raises issues on who should do what to combat environmental degradation.

Earth's atmosphere is divided into three regions, namely troposphere, stratosphere and mesosphere. The stratosphere extends from 10 to 50 kms from the Earth's surface. This region is concentrated with slightly pungent smelling, light bluish ozone gas. The ozone gas is made up of molecules each containing three atoms of oxygen; its chemical formula is O_3.
The ozone layer, in the stratosphere acts as an efficient filter for harmful solar Ultraviolet B (UV-B) rays Ozone is produced and destroyed naturally in the atmosphere and until recently, this resulted in a well-balanced equilibrium .



Ozone is formed when oxygen molecules absorb ultraviolet radiation with wavelengths less than 240 nanometres and is destroyed when it absorbs ultraviolet radiation with wavelengths greater than 290 nanometres. In recent years, scientists have measured a seasonal thinning of the ozone layer primarily at the South Pole. This phenomenon is being called the ozone hole.

Ozone Depletion Process

Ozone is highly reactive and easily broken down by man-made chlorine and bromine compounds. These compounds are found to be most responsible for most of ozone layer depletion.

The ozone depletion process begins when CFCs (used in refrigerator and air conditioners) and other ozone-depleting substances (ODS) are emitted into the atmosphere. Winds efficiently mix and evenly distribute the ODS in the troposphere. These ODS compounds do not dissolve in rain, are extremely stable, and have a long life span. After several years, they reach the stratosphere by diffusion.

Strong UV light breaks apart the ODS molecules. CFCs, HCFCs, carbon tetrachloride, methyl chloroform release chlorine atoms, and halons and methyl bromide release bromine atoms. It is the chlorine and bromine atom that actually destroys ozone, not the intact ODS molecule. It is estimated that one chlorine atom can destroy from 10,000 to 100,000 ozone molecules before it is finally removed from the stratosphere.

Chemistry of Ozone Depletion

When ultraviolet light waves (UV) strike CFC* ($CFCl_3$) molecules in the upper atmosphere, a carbon-chlorine bond breaks, producing a chlorine (Cl) atom. The chlorine atom then reacts with an ozone (O_3) molecule breaking it apart and so destroying the ozone. This forms an ordinary oxygen molecule (O_2) and a chlorine monoxide (ClO) molecule. Then a free oxygen** atom breaks up the chlorine monoxide. The chlorine is free to repeat the process of destroying more ozone molecules. A single CFC molecule can destroy 100,000 ozone molecules.
* CFC - chlorofluorocarbon: it contains chlorine, fluorine and carbon atoms. ** UV radiation breaks oxygen molecules (O_2) into single oxygen atoms.

Effects of Ozone Layer Depletion

1) Effects on Human and Animal Health: Increased penetration of solar UV-B radiation is likely to have high impact on human health with potential risks of eye diseases, skin cancer and infectious diseases.

2) Effects on Terrestrial Plants: In forests and grasslands, increased radiation is likely to change species composition thus altering the bio-diversity in different ecosystems. It could also may affect the plant community.

3) Effects on Aquatic Ecosystems: High levels of radiation exposure in tropics and subtropics may affect the distribution of Phytoplankton’s, which form the foundation of aquatic food webs. It can also cause damage to early development stages of fish, shrimp, crab, amphibians and other animals, the most severe effects being decreased reproductive capacity and impaired larval development.

4)Effects on Bio-geo-chemical Cycles: Increased solar UV radiation could affect terrestrial and aquatic bio-geo-chemical cycles thus altering both sources and sinks of greenhouse and important trace gases, e.g. carbon dioxide (CO_2), carbon monoxide (CO), carbonyl sulfide (COS), etc. These changes would contribute to biosphere-atmosphere feedbacks responsible for the atmosphere build-up of these greenhouse gases.

5) Effects on Air Quality: Reduction of stratospheric ozone and increased penetration of UV-B radiation result in higher photo dissociation rates of key trace gases that control the chemical reactivity of the troposphere. This can increase both production and destruction of ozone and related oxidants such as hydrogen peroxide, which are known to have adverse effects on human health, terrestrial plants and outdoor materials.

The ozone layer, therefore, is highly beneficial to plant and animal life on earth filtering out the dangerous part of sun's radiation and allowing only the beneficial part to reach earth. Any disturbance or depletion of this layer would result in an increase of harmful radiation reaching the earth's surface leading to dangerous consequences.

3.4.8 NUCLEAR HOLOCOST AND NUCLEAR ACCIDENTS

Nuclear holocaust refers to a possible nearly complete annihilation of human civilization by nuclear warfare. Under such a scenario, all or most of the Earth is made uninhabitable by nuclear weapons in future world wars.

Nuclear physicists and others have speculated that nuclear holocaust could result in an end to human life, or at least to modern civilization on Earth due to the immediate effects of nuclear fallout, the loss of much modern technology due to electromagnetic pulses, or nuclear winter and resulting extinctions. Since 1947, the Doomsday Clock of the Bulletin of the Atomic Scientists visualizes how far the world is from a nuclear holocaust.

The threat of a nuclear holocaust plays an important role in the popular perception of nuclear weapons. It features in the security concept of mutually assured destruction (MAD) and is a common scenario in survivalism. Nuclear holocaust is a common feature in literature, especially in speculative genres such as science fiction, dystopian and post-apocalyptic fiction.

The English word "holocaust", derived from the Greek term "holokaustos" meaning "completely burnt", is commonly defined as "a great destruction resulting in the extensive loss of life, especially by fire."

Case study: Chernobyl reactor

A mishandled reactor safety test led to an uncontrolled power excursion, causing a severe steam explosion, meltdown and release of radioactive material at the Chernobyl nuclear power plant located approximately 100 kilometers north-northwest of Kiev. Approximately fifty fatalities resulted from the accident and the immediate aftermath most of these being cleanup personnel. An additional nine fatal cases of thyroid cancer in children in the Chernobyl area have been attributed to the accident. The explosion and combustion of the graphite reactor core spread radioactive material over much of Europe. 100,000 people were evacuated from the areas immediately surrounding Chernobyl in addition to 300,000 from the areas of heavy fallout in Ukraine, Belarus and Russia. An "Exclusion Zone" was created surrounding the site encompassing approximately 1,000 mi² (3,000 km²) and deemed off-limits for human habitation for an indefinite period. Several studies by governments, UN agencies and environmental groups have estimated the consequences and eventual number of casualties. Their findings are subject to controversy.

Nuclear weapons causes holocaust:

If all the nuclear weapons in the world were used, then all of humanity would most like be destroyed. This is for several reasons. Firstly, most major cities would be destroyed by incoming warheads. However, this would leave some areas untouched. Thes e areas would most likely be reached by radioactive fall-out blown by the wind. These would be the immediate repurcussions. Later, the world would go into what is called "Nuclear Winter". Global temperatures would drop significantly, as well as the amount of sunlight received by the earth. This is very similar to what is believed happened to the dinosaurs. It is believed that a large asteroid collided with the earth, and stirred up a lot of dust into the atmosphere. This blotted out the sun, and plants died. With very few plants to eat, the dinosaurs (and many other animals) went extinct. Nuclear winter would be a lot like this. The only difference is that there the dust would be raised up by impacting nuclear warheads and their explosions. Additionally, the dust would be radioactive. The combination of radioactivity, lack of food, and lowering temperatures cause a Nuclear Holocaust, with the chances of humans surviving it very low.