5.1 GREENHOUSE EFFECT

Troposphere, the lowermost layer of the atmosphere, traps heat by a natural process due to the presence of certain gases. This effect is called **Greenhouse Effect** as it is similar to the warming effect observed in the horticultural greenhouse made of glass (Fig. 5.1). The short-wave-length radiations from the sun can pass through the atmosphere easily to reach the earth. However, the long-wave-length radiations emitted by the warm earth surface are partly absorbed by some gases present in the atmosphere. These gases are called greenhouse gases (GHG). Since long-wave-length radiations are infrared radiations or heat radiations, their absorption by GHG heats the atmosphere which radiates some energy (heat) back to the earth and some to the space. This naturally occurring phenomenon is called Greenhouse Effect. Due to this phenomenon the earth's surface temperature increases. The amount of heat trapped in the atmosphere depends mostly on the concentrations of "heat trapping" or "greenhouse" gases and the length of time they

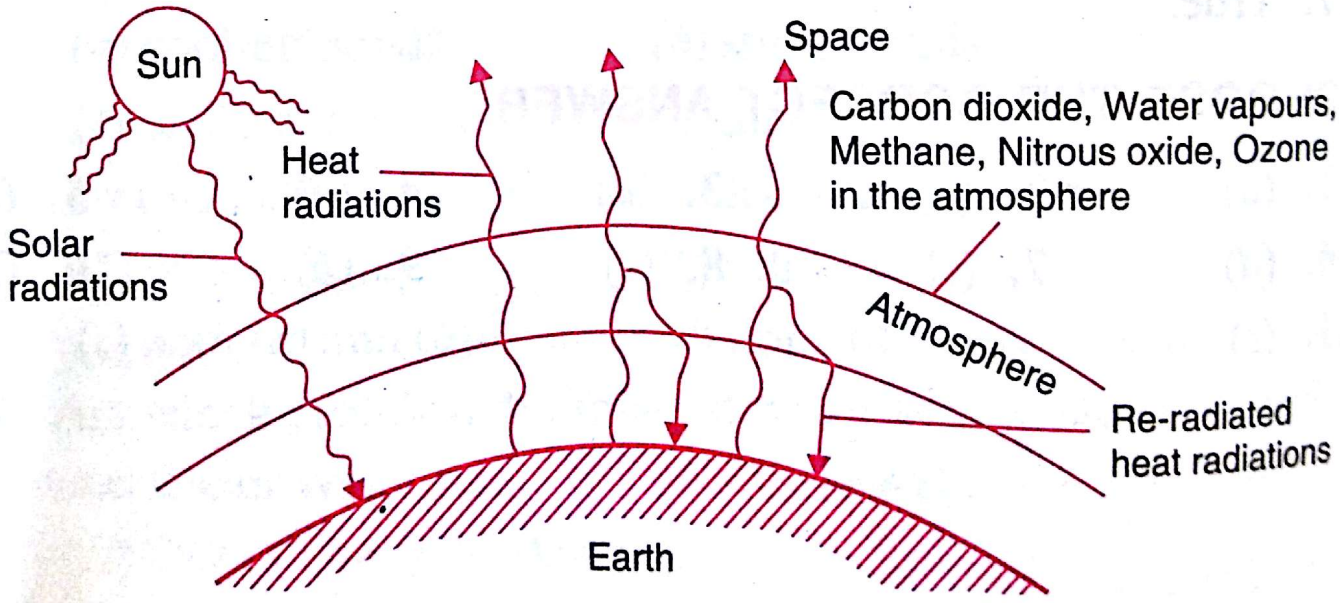

Fig 5.1. The greenhouse effect

stay in the atmosphere. The major greenhouse gases are carbon dioxide, ozone, methane, nitrous oxide, chlorofluorocarbons (CFCs) and water vapours.

5.2 GREENHOUSE GASES (GHG)

The greenhouse gases present in the troposphere and resulting in an increase in the temperature of air and the earth are discussed here:

(*i*) Carbon dioxide: In contributes about 55% to global warming from greenhouse gases produced by human activity. Industrial countries account for about 76% of annual emissions. The main sources are fossil fuel burning (67%) and deforestation, other forms of land clearing and burning (33%). CO_2 stays in the atmosphere for about 500 years. CO_2 concentration in the atmosphere was 355 ppm in 1990 that is increasing at a rate of approximately 1.5 ppm every year. Current CO_2 concentration (in July 2011) is 392 ppm.

(*ii*) Chlorofluorocarbons (CFCs): These are believed to be responsible for 24% of the human contribution to greenhouse gases. They also deplete ozone in the stratosphere. The main sources of CFCs include leaking air conditioners and refrigerators, evaporation of industrial solvents, production of plastic foams, aerosols, propellants etc. CFCs take 10–15 years to reach the stratosphere and generally trap 1500 to 7000 times more heat per molecule than CO_2 while they are in the troposphere. This heating effect in the troposphere may be partially offset by the cooling caused when CFCs deplete ozone during their 65 to 110 years stay in the stratosphere. Atmospheric concentration of CFC is 0.00225 ppm that is increasing at a rate of 0.5% annually.

(*iii*) Methane (CH_4): It accounts for 18% of the greenhouse gases. Methane is produced when bacteria breakdown dead organic matter in moist places that lack oxygen such as swamps, natural wetlands, paddy fields, landfills and digestive tracts of cattle, sheep and termites. Production and use of oil and natural gas and incomplete burning of organic material are also significant sources of methane. Methane stays in the atmosphere for 7–10 years. Each methane molecule traps about 25 times as much heat as a CO_2 molecule. Atmospheric concentration of methane is 1.675 ppm and it is increasing at a rate of 1% annually.

(*iv*) Nitrous oxide (N_2O): It is responsible for 6% of the human input of greenhouse gases. Besides trapping heat in the troposphere it also depletes ozone in the stratosphere. It is released from nylon products, from burning of biomass and nitrogen rich fuels (especially

coal) and from the break-down of nitrogen fertilizers in soil, livestock wastes and nitrate contaminated groundwater. Its life span in the troposphere is 140–190 years and it traps about 230 times as much heat per molecule as a molecule of CO_2. The atmospheric concentration of N_2O is 0.3 ppm and is increasing at a rate of 0.2% annually.

(v) Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6): These are greenhouse gases with lifetime of more than 1000 years. Use of fluorites by man has given rise to significant emissions of these gases. They are removed from atmosphere only by photolysis (destruction by light) or ion reactions in our mesosphere. Hybrid of these two *i.e.*, SF_5CF_3 is the most powerful greenhouse gas till date and its concentration is increasing rapidly.

SF_6 is used in electric equipments. The gas is very stable and very effective for electric insulation.

5.3 GLOBAL WARMING

Due to the presence of greenhouse effect there is heating of the earth and the average global temperature is 15°C. In the absence of greenhouse gases this temperature would have been –18°C. Therefore, Greenhouse Effect contributes a temperature rise to the tune of 33°C. Heat trapped by greenhouse gases in the atmosphere keeps the planet warm enough to allow us and other species to exist. The two predominant greenhouse gases are water vapours, which are controlled by hydrological cycle, and carbon dioxide, which is controlled mostly by the global carbon cycle. While the levels of water vapour in the troposphere have relatively remained constant, the levels of carbon dioxide have increased. Other gases whose levels have increased due to human activities are methane, nitrous oxide and chlorofluorocarbons. Deforestation has further resulted in elevated levels of carbon dioxide due to non-removal of carbon dioxide by plants through photosynthesis.

The phenomenon that worries the environmental scientists is that due to anthropogenic activities there is an increase in the concentration of the greenhouse gases in the air that absorb infrared light containing heat and results in the re-radiation of even more of the outgoing thermal infrared energy, thereby increasing the average surface temperature beyond 15°C. The phenomenon is referred to as the **enhanced greenhouse effect** to distinguish its effect from the one that has been operating naturally for millennia. Enhanced global warming is not good and can cause imbalances in nature.

Warming or cooling by more than 2°C over the past few decades may prove to be disastrous for various ecosystems on the earth including humans, as it would alter the conditions faster than some species could adapt or migrate. Some areas will become inhabitable because of drought or floods following a rise in average sea level.

5.4 SEA LEVEL RISE

Global temperature increase would accelerate rise in sea level from the current level (Fig. 5.2). In the last century sea level rise of 10–15 cm occurred. There is consensus that long term sea level rise in ocean would occur in future also. The Intergovernmental Panel on Climate Change (IPCC, 2007*d*) projected sea level rise of between 18 and 59 cm. Sea level rise is due to two main reasons (*i*) thermal expansion (Water expands on becoming warm). Global rise in temperature will cause thermal expansion. (*ii*) melting of land based ice (glaciers and ice-sheets) reaching the sea. More recent publications project one meter sea level rise. By the end of 21st century, the sea level rise is expected to be between 0.56 and 2 m. Melting of ice-sheets may result in higher sea level. Partial melting of the Greenland and West Antarctica Ice sheets may result in sea level rise up to 6 metres or more.

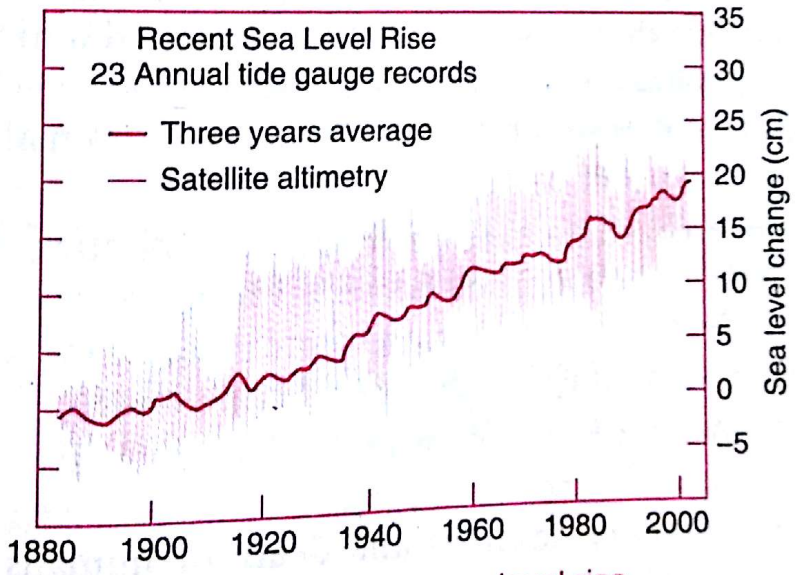

Fig 5.2. Recent sea level rise

Water evaporated from the oceans reach Antarctica and Greenland ice sheets. The same amount of water generally returns to the sea in the form of icebergs and ice melting from the edges.

Sea level rise would cause:

(*i*) Flooding of coastal area with large human population, Bangladesh, Mumbai, Lakshadweep etc. will be affected.

(*ii*) Disturb many commercially important spawning grounds.
(*iii*) Disturb many world's coastal fisheries.
(*iv*) Flooding agriculture lowlands and deltas.
(*v*) Accelerate coastal erosion.
(*vi*) Increase salinity of estuaries and coastal aquifers.
(*vii*) Inundate large area of wetlands.

5.5 CLIMATE CHANGE

Climate is the average weather of an area. It is general weather conditions, seasonal variations and extremes of weather in a region. Such conditions which average over a long period—at least 30 years is called climate.

The **Intergovernmental Panel on Climate Change (IPCC)** in 1990 and 1992 published the best available evidence about past climate change, the greenhouse effect, and recent changes in global temperature. It is observed that earth's temperature has changed considerably during the geological times. It has experienced several glacial and interglacial periods. However, during the past 10,000 years of the current interglacial period the mean average temperature has fluctuated by 0.5–1°C over 100 to 200 year period. We have relatively stable climate for thousands of years due to which we have practised agriculture and increased in population. Even small changes in climatic conditions may disturb agriculture that would lead to migration of animals including humans.

Anthropogenic (man-made) activities are upsetting the delicate balance that has been established between various components of the environment. Greenhouse gases are increasing in the atmosphere resulting in increase in the average global temperature.

This may upset the hydrological cycle, result in floods and droughts in different regions of the world, cause sea level rise, changes in agriculture productivity, famines and death of humans as well as livestock.

The global change in temperature will not be uniform everywhere and will fluctuate in different regions. The places at higher latitudes will be warmed up more during late autumn and winter than the places in tropics. Poles may experience 2 to 3 times more warming than the global average, while warming in the tropics may be only 50 to 100% on an average. The increased warming at poles will reduce the thermal

gradient between the equator and high latitude regions decreasing the energy available to the heat engine that drives the global weather machine. This will disturb the global pattern of winds and ocean currents as well as the timing and distribution of rainfall. Shifting of ocean currents may change the climate of Iceland and Britain and may result in cooling at a time when rest of the world warms. By a temperature increase of 1.5 to 4.5°C the global hydrological cycle is expected to intensify by 5 to 10%. Disturbed rainfall will result in some areas becoming wetter and the others drier. Although rainfall may increase, higher temperatures will result in more evapo-transpiration leading to annual water deficit in crop fields.

IPCC Report, 2007

The Report of the United Nations Intergovernmental Panel on Climate Change (IPCC), 2007 has been prepared by more than 3000 scientific expert researchers from various countries. The report highlights the unequal availability of water *i.e.* excess or lack of water leading to increase in droughts and floods. Glaciers in Himalayas will melt and the size and number of glacial lakes will increase. The mid latitude and semi arid regions of the world will experience drier years. Africa will experience water stress. There will be increased availability of water in moist tropics and high latitudes. Rain dependent agricultural produce will get a boost in North America. Sea level and human activities together will contribute to loss of coastal wetlands. Fresh water availability will decrease by 2050. More than a billion people will be at greater risk. The report assesses that 40 per cent species will become extinct. Human health will be affected. There will be increase in number of deaths, diseases like diarrhoea, cardiovascular diseases, etc.

The IPCC headed by Dr. R.K. Pachauri jointly with former US vice-president Al Gore was awarded Nobel Peace Prize for 2007.

Impact on Human Environment

The enhanced greenhouse effect will not only cause global warming but will also affect various other climatic and natural processes.

(*i*) **Global temperature increase:** It is estimated that the earth's mean temperature will rise between 1.5 to 5.5°C by 2050 if input of

greenhouse gases continues to rise at the present rate. Even at the lower value, earth would be warmer than it has been for 10,000 years.

(*ii*) **Rise in sea level:** With the increase in global temperature sea water will expand. Heating will melt the polar ice sheets and glaciers resulting in further rise in sea level. Current models indicate that an increase in the average atmospheric temperature of 3°C would raise the average global sea level by 0.2–1.5 meters over the next 50–100 years.

One meter rise in sea level will inundate low lying areas of cities like Shanghai, Cairo, Bangkok, Sydney, Hamburg and Venice as well as agricultural lowlands and deltas in Egypt, Bangladesh, India, China and will affect rice productivity. This will also disturb many commercially important spawning grounds, and would probably increase the frequency of storm damage to lagoons, estuaries and coral reefs.

In India, the Lakshadweep Islands with a maximum height of 4 metres above the sea level may be vulnerable. Some of the most beautiful cities like Mumbai may be saved by heavy investment on embankment to prevent inundation.

Life of millions of people will be affected by the sea level rise who have built homes in the deltas of the Ganges, the Nile, the Mekong, the Yangtze and the Mississippi rivers.

(*iii*) **Effects on human health:** The global warming will lead to changes in the rainfall pattern in many areas, thereby affecting the distribution of vector-borne diseases like malaria, filariasis, elephantiasis, etc.

Areas which are presently free from diseases like malaria, schistosomiasis, etc. may become the breeding grounds for the vectors of such diseases. The areas likely to be affected in this manner are Ethiopia, Kenya and Indonesia. Warmer temperature and more water stagnation would favour the breeding of mosquitoes, snails and some insects, which are the vectors of such diseases.

Higher temperature and humidity will increase/aggravate respiratory and skin diseases.

(*iv*) **Effects on agriculture:** There are different views regarding the effect of global warming on agriculture. It may show positive or negative effects on various types of crops in different regions of the world. Tropical and subtropical regions will be more affected since the average temperature in these regions is already on the higher side. Even a rise

of 2°C may be quite harmful to crops. Soil moisture will decrease and evapo-transpiration will increase, which may drastically affect wheat and maize production.

Increase in temperature and humidity will increase pest growth like the growth of vectors of various diseases. Pests will adapt to such changes better than the crops.

To cope up with the changing situation, drought resistant, heat resistant and pest resistant varieties of crops have to be developed.

5.6 OZONE LAYER DEPLETION

For the last 450 million years the earth has had a natural sunscreen in the stratosphere called the ozone layer. This layer filters out harmful ultraviolet radiations from the sunlight and thus protects various life forms on the earth.

Ozone is a form of oxygen. The molecule of oxygen contains two atoms whereas that of ozone contains three (O_3). In the stratosphere ozone is continuously being created by the absorption of short wavelength ultraviolet (UV) radiations. Ultraviolet radiations less than 242 nanometers decompose molecular oxygen into atomic oxygen (O) by photolytic decomposition.

$$O_2 + h\nu \longrightarrow O + O$$

The atomic oxygen rapidly reacts with molecular oxygen to form ozone.

$$O + O_2 + M \longrightarrow O_3 + M$$

(M is a third body necessary to carry away the energy released in the reaction).

Ozone thus formed distributes itself in the stratosphere and absorbs harmful ultraviolet radiations (200 to 320 nm) and is continuously being converted back to molecular oxygen.

$$O_3 + h\nu \longrightarrow O_2 + O$$

Absorption of UV radiations results in heating of the stratosphere.

The net result of the above reactions is an equilibrium concentration of ozone. Ozone concentration in about 24 km of the stratosphere *i.e.*, from 16 km to 40 km away from earth is about 10 ppm (as compared to 0.05 ppm concentration of harmful tropospheric ozone). This equilibrium is disturbed by reactive atoms of chlorine,

bromine, etc. which destroy ozone molecules and result is thinning of ozone layer generally called ozone hole.

The amount of atmospheric ozone is measured by 'Dobson Spectrometer' and is expressed in **Dobson units (DU)**. One DU is equivalent to a 0.01 mm thickness of pure ozone at the density it would possess if it were brought to ground level (1 atm) pressure. Normally over temperate latitude its concentration is about 350 DU, over tropics it is 250 DU whereas at subpolar regions (except when ozone thinning occurs) it is on an average 450 DU. It is because of the stratospheric winds which transport ozone from tropical towards polar regions.

Thinning of Ozone Layer

The Antarctic ozone hole was discovered by Dr Joe C. Farman and his colleagues in the British Antarctic Survey who had been recording ozone levels over this region since 1957. During spring season of south pole *i.e.*, September to November each year ozone depletion is observed. Steep decline has been observed since mid-1970s with a record low concentration of 90 DU in early October of 1993.

Chlorofluorocarbons (CFC) are mainly responsible for ozone depletion in the stratosphere. CFCs are a group of synthetic chemicals first discovered by Thomas Midgley Jr. in 1930. CFC-11 and CFC-12 are the CFCs most commonly used. CFCs are used as coolants in refrigerators and air conditioners, as propellants, cleaning solvents, sterilant and in styrofoam etc. CFCs released in the troposphere reach the stratosphere and remain there for 65–110 years destroying O_3 molecules. In 1974, Rowland and Molina warned that CFCs are lowering the concentration of ozone in the stratosphere and predicted severe consequences. It was however, in 1985 that scientists for the first time discovered that 50% (98% in some areas) of upper stratospheric ozone over Antarctica was destroyed during the Antarctic spring and early summer (September–December). At Antarctic region the temperature during winter drops to – 90°C. The winds blowing in a circular pattern over earth's poles create polar vortices. Water droplets in clouds when enter these vortices form ice crystals. CFCs get collected on the surfaces of these ice crystals and destroy ozone much faster. Similar destruction of ozone over North Pole occurs during Arctic spring and early summer (February–June). The depletion is 10–25% and it is less than that observed at south pole.

Nitrous oxide emitted by supersonic aircrafts during combustion of fossil fuel, and use of nitrogen fertilizers breaks ozone molecules. Chlorine liberated from chlorofluorocarbons also break ozone molecules. The chain reaction started in Antarctic spring *i.e.*, August/September continues till nitrogen dioxide is liberated from nitric acid formed in the stratosphere by photolysis (breakdown by sunlight). Nitrogen dioxide combines with chlorine and stops further destruction of ozone.

ARCTIC OZONE HOLE

Levels of ozone above the Arctic on 19 March 2010 (left) and 26 March, 2011 (right), (Source of photograph: OMI/Aura/NASA)

For the fist time above the Arctic, a very large hole (thinning of ozone beyond certain level), almost five times the size of California, has been reported during early 2011. This time it is comparable to that in the Antarctic ozone hole. Chemically induced destruction of ozone occurs over both the pole and the hole above the Arctic was always much smaller than that reported over Antarctic. In March 2011 unusually long-lasting intense cold temperatures and powerful wind patterns in the Arctic lower stratosphere created the right conditions for already-present, ozone-destroying forms of chlorine to cause more than 80 per cent ozone loss over an altitude of 18–20 kilometres. The findings, published on 3th October in the journal Nature reveal that the hole is formed over northern Russia, parts of Greenland, and Norway. This means that people in these areas are likely to be exposed to high levels of UV radiations. The risk of UV exposure in these areas would increase if occurrence of similar Arctic hole becomes an annual feature.

Effects of Ozone Depletion

- Ozone depletion in the stratosphere will result in more UV radiation reaching the earth especially UV-B (280–320 nm). The UV-B radiations affect DNA and the photosynthetic chemicals.

Any change in DNA can result in mutation and cancer. Cases of skin cancer (basal and squamous cell carcinoma) which do not cause death but cause disfigurement will increase.

- Easy absorption of UV rays by the lens and cornea of eye will result in increase in incidents of cataract.
- Melanin producing cells of the epidermis (important for human immune system) will be destroyed by UV-rays resulting in immuno-suppression. Fair people (who cannot produce enough melanin) will be at a greater risk of UV exposure.
- Phytoplanktons are sensitive to UV exposure. Ozone depletion will result in decrease in their population thereby affecting the population of zooplankton, fish, marine animals, in fact the whole aquatic food chain.
- Yield of vital crops like corn, rice, soybean, cotton, bean, pea, sorghum and wheat will decrease.
- Degradation of paints, plastics and other polymer material will result in economic loss due to effects of UV radiation resulting from ozone depletion.

5.7 OZONE DEPLETING SUBSTANCES (ODSs)

Ozone depleting substances (ODSs): Those substances which deplete the ozone layer. These are widely used in refrigerators, air-conditioners, in dry cleaning, as solvents for cleaning, electronic equipment, fire extinguishers and as agricultural fumigants.

Ozone depleting substances as per Montreal Protocol are:

- Chlorofluorocarbons (CFCs)
- Halon
- Carbon tetrachloride (CCl_4), Methyl chloroform (CH_3CCl_3)
- Hydrobromofluorocarbons (HBFCs)
- Hydrochlorofluorocarbons (HCFCs)
- Methyl bromide (CH_3Br)
- Bromochloromethane (CH_2BrCl)

There are other ozone depleting substances, but their ozone depleting effects are very small in comparison to these controlled substances.