CHAPTER TWELVE

Composition and Structure of the Atmosphere

Syllabus

Composition and Structure of the Atmosphere: *Troposphere, Stratosphere, Ionosphere and Exosphere; Ozone in the Stratosphere, its depletion. Global warming and its impact.*

The earth with its spherical shape is divided into three domains—*Lithosphere*, *Atmosphere* and *Hydrosphere*. These three domains together make up the *Biosphere*. Like matter, these three domains, exist in three states. They occupy space and possess inertia.

The lithosphere exists in solid state, the atmosphere in gaseous state and the hydrosphere in liquid state. Each has a purpose in supporting life on earth. In gaseous state, the atmosphere is characterised by momentum and pressure. It regulates the heat around us.

BLANKET OF AIR

The blanket of air surrounding the earth is known as the *atmosphere*. It exists in several layers, around the earth. These layers become thinner at high altitudes. Therefore, one finds it difficult to breathe as one goes up. This is because less air is pressing down from above. Half of the total mass of air is found below 5 km, touching the surface of the earth. It is held close to the earth by gravity.

The atmosphere protects the earth from harmful ultraviolet and infrared rays of the sun. It has oxygen and nitrogen, the life sustaining gases. It helps in retaining the necessary warmth on the earth and helps in the circulation of water vapour—the source of rainfall.

COMPOSITION OF THE ATMOSPHERE

The atmosphere is a mixture of many gases and tiny solid particles. A clean dry sample of air is made up of 78% of *nitrogen* and 21% of *oxygen*. Oxygen gas helps in burning and breathing. Without breathing oxygen, most living things cannot survive. Nitrogen is a colourless inert gas and has no taste or smell. It dilutes the oxygen and slows down the process of oxidation. It is essential for all living things but they cannot use it directly from the atmosphere. Plants obtain it from the soil and animals obtain nitrogen by eating plants or other animals. These gases are responsible for life on the earth, however, they are insignificant with respect to weather phenomena.

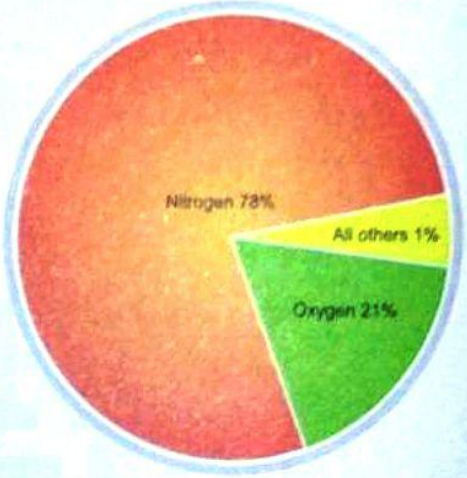

Fig. 12.1. Composition of the Atmosphere

The remaining 1% of air is made up of a number of gases. These include *carbon dioxide, water vapour, helium, hydrogen, argon* etc.

Carbon dioxide (CO_2) is needed by plants for their survival. Water vapour is responsible for all forms of precipitation and hence the circulation of fresh water. Water vapour is added to atmosphere by evaporation from oceans, lakes and rivers, transpiration from vegetation and respiration of animals.

Some particles like pollen from plants, dust from dust storms, ash from meteorites and volcanic eruptions, smoke from fire and salt particles from seas are also present in the lower layer of the atmosphere. These particles act as nuclei for water vapour to form raindrops around them. They also scatter the sun's radiation during sunrise and sunset. The amount of dust varies from place to place.

Functions of the Atmosphere

1. Air has weight and exerts pressure. Being pressed down it always remains in contact with land and water.
2. Due to their physical contact, exchange of gases between air, land and water takes place on a continuous basis.
3. Soil absorbs oxygen and nitrogen due to this contact. Water vapours in air rise from oceans on account of evaporation.
4. Carbon dioxide in air helps in absorption of heat and keeps the earth warm at night.
5. Because of its composition, the atmosphere is the most dynamic entity. Large masses of air are being moved up and down and across the surface of the earth.
6. The energy of the sun is responsible for keeping the atmosphere in a dynamic state.

STRUCTURE OF THE ATMOSPHERE

In the atmosphere, there are concentric layers of air. Each layer has different density. The upper layers press down the lower ones. So, the air of the lower layer is always heavier or denser, while the upper layers are thinner or less dense. In this way about 90 per cent of the mass of air lies within a height of about 20 km from the surface of the earth.

On the basis of the characteristics of temperature and air pressure there exist four thermal layers of the atmosphere. They are—*Troposphere, Stratosphere, Mesosphere* and *Thermosphere*. The Thermosphere is divided into *Ionosphere* and *Exosphere*.

1. Troposphere

Extent: The troposphere is the lowermost and densest layer. Its height varies from 18 km at the Equator to 8 km at the Poles.

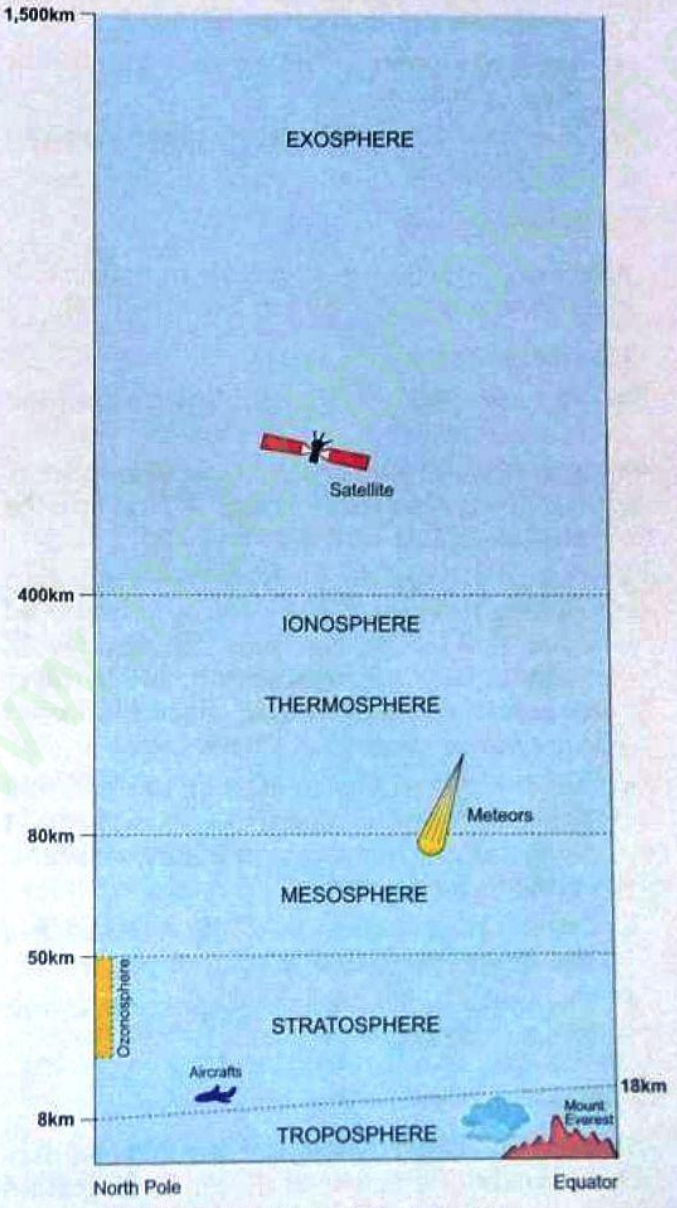

Fig. 12.2. Structure of the Atmosphere

Characteristics

- Seventy-five per cent of the atmosphere is found in the troposphere and its concentration decreases as we go higher from ground level.
- The troposphere is also characterised by regular decrease in temperature with altitude. This decrease in temperature is known as *normal lapse rate*. The average decrease is 1°C for every 166 metre altitude gained. This temperature variation within the troposphere is responsible for many turbulences.
- As a result of these turbulences all weather phenomena take place in this layer.
- The troposphere is heated more from below than from above.
- The upper limit of the troposphere is known as *tropopause*.

2. Stratosphere

Extent: This layer lies above the tropopause. It extends to a height of 50 km from sea level.

Characteristics

- The air is thin, cold and dry. The temperature is about –55°C.
- The *Ozone layer* lies within the stratosphere. Ozone is generally found between the altitudes of 20 and 50 km.
- Ozone absorbs the ultraviolet solar radiation coming from above. The insolation received from the sun is equal to that lost by it. That is why the temperature of the layer is constant. In the higher levels, however, temperature increases with height.
- The lower layer of stratosphere has a virtual absence of water vapour and has constant temperature conditions, therefore, it is ideal for flying jet aircraft.
- Temperature rises from –60°C at the base of the stratosphere to 0°C at stratopause.
- The upper limit of the stratosphere is known as *stratopause*.

3. Mesosphere

Extent: This layer lies above the stratosphere and extends to a height of 80 km from ground level.

Characteristics

- The temperature in this layer decreases with height and reaches a minimum of –110°C at the altitude of about 80 km near the *mesopause*, the upper limit of this layer.
- Due to reflected sunlight from meteoric dust particles there are wispy clouds found in this layer.

4. Thermosphere

It extends from mesopause and consists of two layers (a) Ionosphere and (b) Exosphere.

Ionosphere

Extent: It extends up to a height of about 400 km.

Characteristics

- Ionosphere contains electrically charged particles called *ions* which create a sheet like display of light known as *Aurora Borealis* in the Northern Hemisphere and *Aurora Australis* in the Southern Hemisphere.
- Ions reflect radio waves back to the earth's surface. This enables us to have wireless communication.

Exosphere

Extent: It is the uppermost layer in the structure of the atmosphere. It lies between 400 to 1500 km above the earth.

Characteristics

- It merges gradually with interplanetary space.
- In this layer temperature increases with height. We know very little about the atmosphere extending beyond 640 km height from the sea level.
- In the Exosphere density becomes extremely low.
- The main gases here are lighter ones like hydrogen and helium.

From the above it is clear that the atmosphere extends more than a thousand kilometres above the earth's surface. It exercises enormous pressure on the surface of the earth and remains in direct contact with the surface of land as well

as the surface of water on the earth. The contact zone between land, air and water sustains life. The survival of life on earth depends on this contact. The atmosphere acts and influences life through its various elements.

OZONE AND ITS DEPLETION

Ozone is a form of oxygen. It is present in rare amounts in the earth's atmosphere. Approximately one molecule out of every two million present in the atmosphere is Ozone.

In the troposphere, Ozone is generated only in small amounts. But in the stratosphere at 20-50 km above sea level it is present in significant amounts. In the stratosphere, it is produced by the action of high energy radiation from the sun striking some molecules of oxygen and converting them into Ozone. But Ozone decreases by sunlight acting on a number of pollutants in air. These pollutants are emitted by jet aircraft, and by the hydrocarbons from automobile exhausts. The concentration of Ozone in the upper atmosphere is protective, it absorbs the heat of the ultraviolet rays of the sun.

The Ozone layer in the stratosphere also protects the earth and its biosphere from the extra heat. But there is the danger of its depletion through harmful gases and increase in the level of carbon dioxide in the lower atmosphere.

DEPLETION OF OZONE LAYER

Ozone Hole

An 'Ozone hole' is an Ozone depleted area. It was detected through satellite imagery conducted by NASA in the USA. Subsequently much scientific research has been going on. An annual data is being maintained, and efforts by almost every country are being made to reduce the breaking down of Ozone molecules. Many chemicals namely chlorine and bromine are banned which are thought to cause the depletion of the Ozone layer.

Chlorofluorocarbons (CFCs) are regarded as the reason for the Ozone Hole near Antarctica. CFC gases are used in refrigerators, aircraft and air conditioners. CFC compounds escape into the atmosphere and finally break down in the stratosphere. They produce chlorine atoms which destroy the Ozone layer.

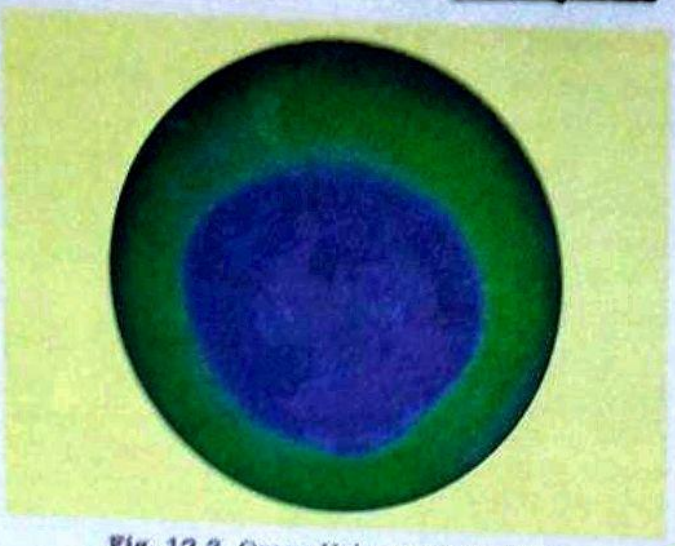

Fig. 12.3. Ozone Hole near Antarctica

Volcanoes play a role in Ozone depletion. Large eruptions give out sulphur dioxide, which speed up destructive chemical reactions. Tropospheric Ozone increases especially in the Northern Hemisphere but it is smaller and localised here.

Another cause of destruction of Ozone layer, discovered recently, are solar storms. These solar storms consist of coronal mass ejections and solar flares associated with explosions on the surface of the sun.

The largest ozone hole was noticed in September 2000 near Antarctica. The formation of the Ozone hole has been attributed largely to the activities of man. Ozone depletion resulting in Ozone hole is more common to Antarctica where temperatures are the lowest. Due to bitterly cold Antarctic winter, the stratospheric ice clouds promote production of chemically active chlorine and bromine. This, in turn, leads to Ozone destruction when sunlight returns in the Antarctic spring. On the other hand, the Arctic atmosphere though cold, does not get cold enough for the creation of a fully developed Ozone hole.

GLOBAL WARMING

Recent climate studies have shown that the global mean temperature on the earth is rising. This phenomenon known as *Global Warming* is the result of enhanced concentration of greenhouse gases in the atmosphere caused mainly by human activities.

Causes of Global Warming

Some of the chief causes of Global Warming are the following:

1. Destruction of Ozone Layer: We have studied earlier in this chapter that the Ozone layer in the Stratosphere protects the earth from the ultraviolet rays of the sun and its depletion contributes to Global Warming.

2. Greenhouse Effect in the Atmosphere: Excess accumulation of some gases like carbon dioxide, methane, chlorofluorocarbons (CFCs), ozone and water vapour are responsible for disturbing the energy balance and thus increasing heat on the earth. Fossil fuel based industries and the man's lifestyle have resulted in an unprecedented rise of these gases, known as *greenhouse gases*. This is because they act in lower levels of the atmosphere like the glass of a greenhouse. We have seen a greenhouse, which is covered with a glass. It allows the sun's rays to penetrate into the greenhouse but blocks the radiation of heat from the greenhouse, back into the atmosphere.

Greenhouse gases in the atmosphere allow the near infrared rays from the sun to penetrate into the earth. But these gases do not allow the heat radiated by the heated earth to penetrate back into space. Thus, by preventing heat rays to escape into the outer space the greenhouse gases add to the heat already available on the earth's surface. *This increase in temperature due to the concentration of the greenhouse gases is known as the greenhouse effect.*

The greenhouse effect is not confined to a particular region but has a global impact. If unchecked, accumulation of these gases from industry and agriculture could change temperature and rainfall pattern and sea level of the earth. By realising the potential danger of these gases to the earth, the United Nations Environment Programme (UNEP) used the expression, "Global Warming" to alert people about this danger.

3. Deforestation: Clearing away of forests and forest ecosystems on a large scale have posed several dangers to life on earth. Trees are essential for absorbing excess carbon dioxide in air. They are also responsible for maintaining the fertility of the soil. In their absence, winds blow away the top soil as dust into the atmosphere. The dust in the atmosphere plays a key role in reflecting terrestrial radiation back to earth. It may also cause extra cooling at night because bare soils get cooler and warmer more quickly than soils covered with vegetation.

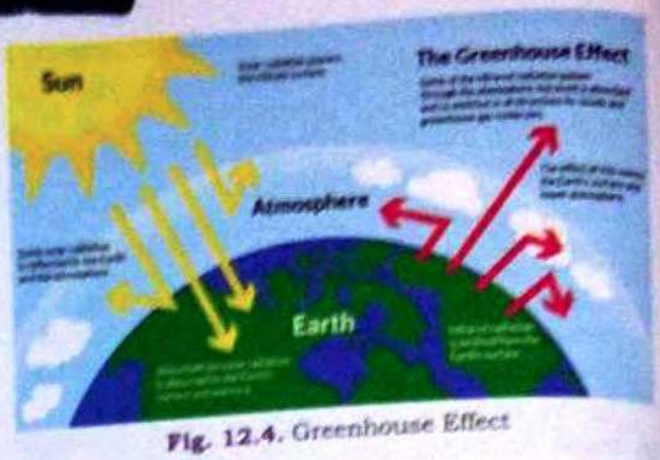

Fig. 12.4. Greenhouse Effect

IMPACT OF GLOBAL WARMING

The atmosphere is being destroyed as a result of Global Warming. This can result in change in the climate of the earth. Already the surface temperature of the earth is on the rise. The global mean temperature increased by approximately 0.6°C in the 20th century. The average temperature of the earth may increase by 1.4 to 5.8°C by the year 2100 from the 1990 level. If the atmosphere is not protected it can have some of the following major impacts:

(i) Rise in Sea Level: Over the last 100 years, because of Global Warming, the ice reserves have melted and the sea level has risen by about 10 to 25 cm. It is predicted that by the year 2100, the oceans are expected to rise between 2.5 and 6.5 feet. It can have disastrous effects on human habitations on sea coasts as one-third of human population lives within 60 km of a coastline. Many towns and cities could even be submerged under water.

(ii) Precipitation Change: Warming of atmosphere will considerably increase its moisture carrying capacity. While the troposphere warms up, the stratosphere will cool down. This would cause widespread changes in rainfall patterns due to changed pattern of air-mass movements. Rainfall is expected to

increase at higher latitudes in both summer and winter and in southern and eastern Asia in summer. However, winter rainfall may decrease at lower latitudes.

These changes in rainfall patterns are expected to lead to flooding in some areas, drought in others. Monsoon flooding is expected to cause great loss of life in India, Bangladesh and South-East Asian countries.

(iii) Radiation Imbalance: It is the balance between radiation coming into the atmosphere and radiation going out. Any change in this balance can have rapid impact on lifeforms on earth because it will have an impact on the sensitivity, adaptability and vulnerability of the whole biospheric system. With increasing global warming many species are expected to shift slowly poleward or towards high elevations in mountain areas. Since trees are sensitive to temperature changes, an increase in temperature may cause large-scale death of trees and their replacement by scrub vegetation. Many species may not be able to migrate fast enough to track temperature changes and may disappear.

(iv) Agriculture: Climate change will bring about substantial changes in cereal production specially in the Tropics. In the Tropics, cereals dominate the food sources and are the mainstay of agriculture. There will be more shortages of cereals.

(v) Water Resources: There is a great deal of controversy over the likely impact on water resources. However, all agree that the global freshwater conditions may worsen by 2025 more due to population pressure than due to climatic factors.

(vi) Diseases: Temperature and precipitation are two important causative factors of diseases like malaria which may reappear in different forms as a result of change in the climate.

The earth in the past has had several phases of warm climates followed by Ice Ages. In the past, these changes took place over several thousand years. Such changes may now take place over a few decades or a century. Further, during such changes in the past, life forms, landforms and waterbodies have changed. We can now expect such changes taking place within a few centuries, if we do not protect our atmosphere.

Terms to Remember

Ozone Layer : A layer in the stratosphere of the atmosphere which keeps temperature constant in the lower levels and absorbs ultraviolet rays of the sun.

Global Warming : The rise in average mean temperature of the earth on account of enhanced concentration of greenhouse gases in the atmosphere.

CFCs : Chlorofluorocarbons.

EXERCISES

I. Short Answer Questions

1. What is known as atmosphere?
2. State the gaseous composition of the atmosphere.
3. Name the four layers of the atmosphere.
4. What is known as troposphere?
5. Mention the chief characteristics of stratosphere.

6. In which layer of atmosphere do all the weather conditions occur?
7. Name the constituent gases of atmosphere which scientists consider responsible for climate change.
8. What is known as Ozone Layer?
9. What is leading to depletion of Ozone Layer in the atmosphere?
10. What is known as Global Warming?
11. Name important Greenhouse gases.

II. Explain the following terms/processes:

1. Global Warming.
2. Greenhouse Effect.
3. Normal Lapse Rate of Temperature.
4. CFCs.

III. Structured Questions

1. (a) Define atmosphere. Name the four layers of atmosphere.
   (b) Mention any two functions of the atmosphere.
   (c) Give a reason for each of the following:
      (i) We find it difficult to breathe when we climb mountains.
      (ii) The atmosphere is the most dynamic entity.
      (iii) All the weather phenomena takes place in the troposphere.
   (d) Draw a well labelled diagram of the structure of the earth's atmosphere.
2. (a) Describe the structure of the atmosphere.
   (b) Explain the factors responsible for depletion of Ozone in atmosphere.
   (c) State any three factors that lead to Global Warming.
   (d) Draw a well labelled diagram to explain the Greenhouse Effect.

IV. Project Work

Forest fires are becoming more frequent and disastrous sparking a global outrage. Prepare a project report on the causes and the effects, both short term and long term, of forest fires.

❑❑❑