

## INTRODUCTION

The environmental issues are plenty posing threat to mankind but the first and foremost is environmental pollution or may be called biosphere pollution contaminating air, water and soil. Almost all the habitats become polluted due to the influence of human activities; only that natural habitat can be spared which is free from human influence directly or indirectly or that natural habitat can be saved where local people have a primitive way of living without any adverse effect on the natural balance of ecosystem.

Today, the cry of pollution is heard from all the nooks and corners of the globe, and it has become a major threat to the very existence of mankind on the earth. We are unable to breathe fresh air and drink pure safe water. The problem of pollution arose with the civilization of man. When man learned to use fire, the air pollution began.

Pollution increased with the increasing population, and rapid unplanned industrial progress added to the problem further.

In this chapter, different types of pollution and their pollutants along with their sources; specific symptoms of pollutants and their biological effects, and control of pollution will be described. National and international efforts to control/minimise pollution with sustainable development will also be dealt.

A new addition in this chapter is the latest information on 'Climate Change' in Greenland (Denmark) located between the Arctic and Atlantic Ocean. Greenland ice cap is the second largest reservoir of frozen freshwater in the world next only to Antarctica. Nowadays, there is a serious thinking among scientists to avert the coming catastrophe, in case Greenland ice cap melts due to global warming.

## What is Pollution?

Pollution can be defined as an undesirable change in the physical, chemical or biological characteristics of the air, water

or land that may be injurious to life or create a potential health hazard to any living organism.

Any substance that causes pollution is called a **pollutant** which may be any solid, liquid or gaseous substance present in such concentration as may be or tend to be injurious to the environment. Pollutants are of two types :

(1) **Biodegradable** : The biodegradable pollutants are decomposed by the activity of microbes, e.g., sewage, domestic wastes, etc.

(2) **Non-biodegradable** : These pollutants do not degrade or degradation is very slow in nature. Their natural cycling in the ecosystem does not take place. These are of two sub-types:

(a) **Wastes** : Wastes include throw away glass, plastic, aluminium cans and any other material of similar nature.

(b) **Poisons** : Poisons refer to radioactive substances, pesticides, heavy metals like Hg and Pb, long chain phenolics, etc.

## Differences between Biodegradable and Non-biodegradable Pollutants

Biodegradable Pollutants	Non-biodegradable Pollutants
(1) The pollutants are decomposed by microbes.	The pollutants are not degraded by microbes.
(2) The pollutants are accumulated.	These pollutants mostly get accumulated.
(3) The rate of degradation is greater.	The rate of decomposition is very slow.
(4) The pollutants become part of biogeochemical cycles.	The pollutants do not take part in mineral cycling.

These poisons are persistent or semi-persistent in nature and show **biomagnification** (the increase in the concentration of pollutant from one trophic level to another).

Based on nature of release of pollutants and the manner of pollutant dispersion, there are several types of pollution :

(i) **Point Source Pollution** : Pollutants are released from a single point, e.g., chimney, municipal sewer.

(ii) **Line Source Pollution** : Pollutants travel along a narrow belt, e.g., seen on the roads from automobiles.

(iii) **Area Source Pollution** : Pollutants cover specific area, e.g., industrial area, mining area.

(iv) **Diffuse Source Pollution** : Pollutants spread to a large area, e.g., pesticidal spray, agriculture water run-off having fertilizers.

(v) **Fixed Source Pollution** : Pollutants are released from fixed spots covering large or small areas, e.g., large and small industrial units, hydroelectric power plants, smelters.

(vi) **Mobile Source Pollution** : Pollutants move along with the source, e.g., automobiles on the road, aeroplanes in the air.

On the basis of the type of environment being polluted, the pollution is of the following types:

(1) Air pollution, (2) Water pollution, (3) Solid waste pollution, (4) Noise pollution and (5) Radioactive pollution.

## AIR POLLUTION

Air is the most vital component of our biosphere, without which the question of survival does not arise beyond a few minutes. Natural air at mean sea level contains various constituents, as shown is Table 16.1.

Table 16.1 Approximate composition of dry air (mainly troposphere) at mean sea level

Gas	% by Volume
Nitrogen	78.084
Oxygen	20.947
Argon	0.934
Carbon dioxide	0.034
Methane	0.0002
Neon, helium, krypton, xenon	Negligible
Other gases [hydrocarbons, nitrogen oxides, hydrogen, ammonia, ozone (in stratosphere), SO <sub>2</sub> , etc.]	Negligible

Besides, water vapour and dust particulates are present in air in various amounts and sizes.

Air pollutants are classified into two types—**primary** and **secondary**.

**Primary pollutants** are those which are produced directly, as for example, burning of fossil fuels by automobiles, or by various industries. Oxides of carbon (CO and CO<sub>2</sub>), sulphur dioxide, oxides of nitrogen, hydrocarbons, aerosols, etc., are **primary pollutants**.

**Secondary pollutants** on the other hand, are produced as a result of interaction between two or more primary pollutants and with other substances. **Smog**, for example, is a secondary pollutant.

There are five major categories of air pollutants :

- Oxides of carbon (carbon monoxide, carbon dioxide)
- Sulphur dioxide
- Oxides of nitrogen
- Hydrocarbons
- Aerosols (dispersion of solid and liquid matter or particles)

The description of various air pollutants with regard to their sources and biological effects are given below.

## SOURCES OF POLLUTION

Air gets polluted largely due to the smoke produced by automobiles, power plants and kitchens and due to the large-scale burning of fossil fuels, such as coal, diesel, petrol, kerosene, and so on.

1. The burning of fossil fuels produces carbon dioxide, carbon monoxide, sulphur dioxide, oxides of nitrogen, hydrocarbons, particulate metallic and metallic traces. Coal produces a lot of smoke and dust while petrol and its products produce more sulphur dioxide.

2. Thermal power plants are coal based. The main pollutants are fly ash, soot and sulphur dioxide.

3. Fertiliser plants produce oxides of sulphur, particulate matter and fluorine. These pollutants come from sulphuric and phosphoric acid units. Ammonia, nitrogen oxides and hydrocarbons come to the atmosphere from nitrogen-based plants.

4. The major pollutants from the textile industry are cotton dust, nitrogen oxides, chlorine, naphtha vapours, smoke and sulphur dioxide.

5. There are thousands of chemical plants and pesticide plants which prepare caustic soda and produce chlorine gas.

6. Steel plants produce carbon monoxide, carbon dioxide, sulphur dioxide, fluorine and dust.

7. Automobiles contribute 60% of the air pollution by releasing compounds like carbon monoxide, oxides of nitrogen, and hydrocarbons. Gases emitted during deceleration and acceleration are more harmful than those produced during constant speed. Incomplete combustion produces a hydrocarbon called 3-4, benzopyrene. On an average every 1,000 gallons of petrol after combustion produce 3,200 pounds of carbon monoxide, 300 of hydrocarbons, 45 of nitrogen oxides, 18 of aldehydes, 17 of sulphur compounds, 2 of organic acids and ammonia and 0.3 pounds of carbon particles.

8. Decomposition of organic waste and municipal garbage produces foul-smelling gases which pollute the air.

## BIOLOGICAL EFFECTS OF AIR POLLUTANTS

**1. Carbon Dioxide (CO<sub>2</sub>) :** At normal concentration, carbon dioxide (CO<sub>2</sub>) is not a pollutant. The concentration of CO<sub>2</sub> has increased from 0.027 to 0.034% (270 ppm to 340 ppm) in the last 150 years. CO<sub>2</sub> is a most important greenhouse gas in the atmosphere which causes **greenhouse effect** and consequently 'global warming'. These two aspects will be discussed in this chapter separately.

**2. Carbon Monoxide (CO) :** Carbonmonoxide is a main pollutant in automobile exhaust (CO = 77.2%, NO<sub>x</sub> = 7.7%, hydrocarbons = 13.7%, other gases = 1.4%). CO combines with haemoglobin to form **carboxyhaemoglobin**. Its capacity to combine with haemoglobin is 210 times faster than O<sub>2</sub>. It causes oxygen deficiency called **hypoxia** that finally leads to death.

**3. Sulphur Dioxide (SO<sub>2</sub>) :** The damaging effects of SO<sub>2</sub> are :

- It causes chlorosis and necrosis of vegetation.
- It damages cell membrane.
- The high concentration in the atmosphere causes mutation.
- SO<sub>2</sub> above 1 ppm concentration causes eye irritation and aggravation of bronchitis and asthma.
- It also causes discolouration and degradation of painted surfaces, historical monuments like 'Taj Mahal'. The damage to stone surfaces is called 'stone cancer'.
- Lichens cannot survive in SO<sub>2</sub> rich atmosphere and therefore serve as **plant indicators**.
- SO<sub>2</sub> in the atmosphere also produces **acid rains**.

Different plant species and varieties and even individuals of the same species may vary considerably in their sensitivity to sulphur dioxide. These variations occur because of the differences in geographical location, climate, stage of growth and maturation. The following crop plants are generally considered susceptible to sulphur dioxide : Alfalfa, barley, buckwheat, clover, oats, pumpkin, radish, spinach, squash, and tobacco. Resistant crop plants include *Asparagus*, cabbage, celery, corn, onion and potato.

**4. Nitrogen Oxides (NO<sub>x</sub>) :** Most common oxides of nitrogen in the atmosphere are :

- Nitric Oxide (NO)
- Nitrous Oxide (N<sub>2</sub>O)
- Nitrogen Dioxide (NO<sub>2</sub>)

The damaging effects of NO<sub>x</sub> are as follows :

- They cause **necrosis**, **defoliation**, **die-back disease** of many plants.
- At concentration of 15-50 ppm, NO<sub>x</sub> bring about injury to lungs, liver and kidneys.

(iii) NO<sub>x</sub> are **carcinogenic** and also have **mutagenic** properties.

(iv) NO<sub>x</sub> produced in stratosphere due to solar flares destroy ozone layer.

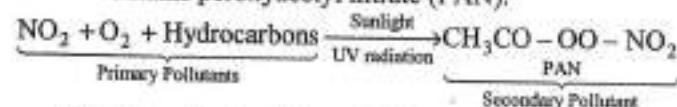


(v) NO<sub>2</sub> causes irritation of alveoli, leading to symptoms resembling **emphysema** upon prolonged exposure to 1 ppm level.

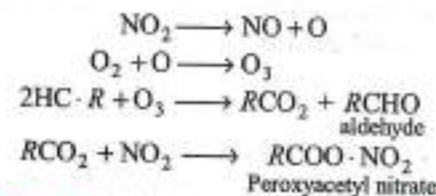
(vi) NO<sub>x</sub> also increases **bronchitis** and **asthma** in men.

(vii) Nitrogen dioxide in atmosphere is also responsible for **acid rains**.

(viii) NO<sub>2</sub> is the chief constituent of **photochemical smog** and smog is formed as a result of reaction with unburned hydrocarbons and NO<sub>2</sub>. Photochemical smog contains peroxyacetyl nitrate (PAN).



The step-wise reactions of the formation of PAN are given below :



**5. Smog :** Dark coloured fog is called **smog** and it is of two types :

**(a) Classical Smog :** Dark coloured smog having excess of sulphur along with smoke, dust, particles and H<sub>2</sub>S. It is also called 'London smog' or 'Sulphurous smog' or 'reducing smog'.

**(b) Photochemical Smog :** Photochemical smog was first discovered in Los Angeles, USA and is, therefore, also called **LOS Angeles smog**. It is a yellowish brown opaque type of air pollutant. High energy rays from sunlight split up nitrogen dioxide to form nascent or reactive oxygen which combines with molecular oxygen to produce **ozone** (O<sub>3</sub>). Photochemical smog is formed as a result of photochemical reaction between NO<sub>2</sub> and hydrocarbons and contain peroxyacetyl nitrate (PAN). The two main pollutants of photochemical smog are PAN and O<sub>3</sub>. Photochemical smog is a mixture of oxidising pollutants and may be called **oxidising smog**.

**Synergism :** The occurrence of photochemical smog is a case of **synergism**, involving two pollutants reacting with one another and producing a third pollutant which is even more dangerous to living organisms and the environment than the original pollutants. In this case two primary pollutants are hydrocarbons and NO<sub>2</sub> and the pollutants produced by their reactions is PAN.

**6. Peroxyacetyl Nitrate (PAN) :** The toxic effects of PAN are as under :

- PAN is a potent eye irritant at about 1 ppm or less.
- PAN in a photochemical smog has been found to be 0.04 mg/kg of air. Sensitive plants exhibit damage even at 0.1 mg/kg concentration.
- It also causes damage to leaf tissues.
- It causes death of forest trees.
- It blocks Hill reaction during photosynthesis and also inactivates photosynthetic enzymes.
- PAN is also a cause of respiratory distress in humans.

**7. Ozone (O<sub>3</sub>) :** In the atmosphere, ozone is largely found in the stratosphere (0.10 mg/kg of air) at a height of about 25 km where ozone is concentrated (this zone represents 'ozonosphere'). Ozone absorbs most of the UV radiation of the sun and thus acts as a shield, protecting the living organisms of the earth from health hazards. In troposphere, O<sub>3</sub> has a very low concentration of 0.01 mg/kg of air.

The toxic effect of O<sub>3</sub> are as follows :

- O<sub>3</sub> is a potent eye irritant and also causes respiratory problems similar to PAN.
- It causes **necrosis** of plant tissues.
- It causes tip burn in pine seedlings.
- It hardens rubber.
- O<sub>3</sub> reacts with fibres like nylon, polyester, etc., and degrades their quality.
- Increase in O<sub>3</sub> concentration near the earth's surface reduce crop yields.

Susceptibility to ozone injury is influenced by many environmental and plant growth factors. High relative humidity, optimum soil-nitrogen levels and water availability increase susceptibility. Injury development on broad leaves is also influenced by the stage of maturity. The youngest leaves are resistant. With expansion, they become successively susceptible at middle and basal portions. The leaves become resistant again at complete maturation.

Depletion of ozone is a matter of concern to all of us. This problem will be discussed elsewhere in this chapter.

**8. Aerosols (the Particulates) :** An **aerosol** is defined as a dispersion of solid or liquid matter in the atmosphere. The particles of less than 1.0 μm size are present in aerosol. The particles of more than 1 μm size are called **dust** (if solid) and **mist** (if liquid). The particles of size more than 10 μm are able to settle down or if less than 10 μm remain suspended in the air. The suspended particles are called **Suspended Particulate Matter (SPM)**. **Flyash** is emitted from fossil fuel based plants, e.g., thermal power plant. Cotton dust, cement dust, asbestos particles, silica particles, lead particles, etc., are introduced into the atmosphere from various sources.

The various particles in air such as cotton, coal, flour, etc., produce **pneumoconiosis** or **lung fibrosis** called **byssinosis**

when men come in contact with these particles. Lead particles when inhaled, produce a toxic effect in man. **Asbestosis** is caused by asbestos particles and **silicosis** is caused by silica particles. Asbestos and silica dust may also have carcinogenic effects.

The particulate matter of more than 1.0 μm size like dust settle over the leaves clogging the stomata and also form a thin layer on the leaves to reduce light absorption and hence, the rate of photosynthesis also declines. Spores, pollen grains, etc., suspended in the air cause bronchial problems, allergy and respiratory distress. Such spores and pollen grains are called **aeroallergens**.

## 9. Minor Pollutant Gases :

**(a) Fluorine :** Fluorine occurs in minute quantities in all plants and animals and is one of the elements of protoplasm. In higher doses, fluorine becomes toxic and a pollutant. It occurs in smoke from brick kilns, and iron and aluminium industries. Only 1 ppm is safe but vegetation surrounding iron and aluminium industries may contain about 2000 ppm. If such a vegetation is consumed by animals, they may be seriously affected and die.

In animals, excess fluorine causes mottling of teeth, knocking knees, weak bones, gastrointestinal and neuromuscular disorders. In plants, excess fluorine causes chlorosis, necrosis of leaves and abscission of fruits.

**(b) Chlorine :** Chlorine is emitted by caustic soda industries and is also an air pollutant. Motor vehicle exhaust contains lead halide aerosols. The photochemical decomposition of the halide products produces chlorine atoms. Chlorine damages leaf stomata and causes breathing problems in man.

**(c) Methyl Isocyanate (MIC) :** A chemical used in the manufacture of pesticide, leaked from the **Union Carbide Plant** in the night of December 2/3, 1984 at **Bhopal**. This gas tragedy resulted in the deaths between 5,000 and 30,000 men, women and children, and maimed several thousand persons.

## Delhi Air Worst in the World

A World Health Organization (WHO) air quality database of 1,600 cities and 91 countries released on **7 May, 2014** shows that concentration of PM 2.5 (particulate matter smaller than 2.5 micrometre) is the highest in Delhi at 153 micrograms per cubic metre (μg/m<sup>3</sup>) when the WHO standard is just about 10 μg/m<sup>3</sup>. The concentration of PM 10 (size 2.5-10 micrometre) in Delhi is 286 μg/m<sup>3</sup>, more than 14 times higher than the WHO annual mean standard of 20. Peshawar (540 μg/m<sup>3</sup>) and Rawalpindi (448 μg/m<sup>3</sup>) in Pakistan fare worse on this parameter. Indian cities with a very high PM 10 level include Gwalior, Raipur and Lucknow.

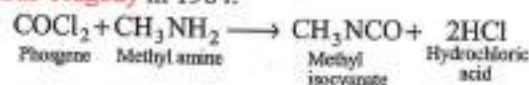
Asian Cities	PM 10	PM 2.5
Delhi	286	153
Karachi	273	117
Dhaka	180	86
Beijing	121	56
Colombo	64	28
Jakarta	48	21
Singapore	27	17

WHO has compared our annual mean levels with its standards. India's annual mean standard for PM 10 is  $60 \mu\text{g}/\text{m}^3$  and for PM 2.5 it is about  $40 \mu\text{g}/\text{m}^3$ . A comparative data was released by WHO for some Asian cities with respect to PM 10 and PM 2.5.

US Environmental Protection Agency document shows that small particles less than 10 micrometres in diameter (both PM 10 and PM 2.5) pose the greatest problems because they can get deep into your lungs, and some may even get into your blood stream. Exposure to such particles can affect both your lungs and your heart. WHO in its statement said that high concentration of these particles cause deaths from heart disease and stroke, as well as respiratory illnesses and cancers.

#### 10. Other Air Pollutants :

- Benzopyrene** is a carcinogen produced in tobacco smoke, automobile exhausts and industrial effluents.
- Ammonia** escapes from fertilizer units, dye, explosive and lacquer industries. It produces irritation and inflammation of upper respiratory tract.
- Phosgene** ( $\text{COCl}_2$ ) is a poisonous suffocating volatile liquid used in dye industry and synthesis of organic compounds like methyl isocyanate (MIC). The release of phosgene and MIC in the atmosphere led to **Bhopal Gas Tragedy** in 1984.



- Aldehydes** are formed as a result of decomposition of oils. The toxic effects include irritation in the gastro-intestinal and respiratory tracts.
- Phenols** cause damage to spleen, kidneys, liver and lungs.
- Hydrocarbons** are also called **Polycyclic Aromatic Hydrocarbons (PAHs)** or **Volatile Organic Carbons (VOCs)**. They are produced naturally (e.g., marsh gas  $\text{CH}_4$ ) as well as due to incomplete oxidation in automobiles. PAH and formaldehyde are carcinogenic, cause irritation of eyes and mucous membranes and also bronchial constriction.  $\text{CH}_4$  gas is produced naturally during decomposition of organic matter and also from paddy fields (40% of the total), cattle, industries, kitchens, etc. Its role as a 'greenhouse gas' will be discussed separately under **Greenhouse Effect**.

- Mercury** is liberated in vapour form during burning of coal and smelting. **Lead** is released by automobile exhausts. The other metals released into the atmosphere in the form of vapours or particles from various metallurgical operations include **arsenic, cadmium, etc.** Their toxic effects will be discussed in water pollution.

There are three major issues related to air pollution—**Greenhouse Effect, Acid Rain and Depletion of Ozone.**

### GREENHOUSE EFFECT

Greenhouse is a small glass house for growing plants especially during winter. The sunlight enters into the green house through glass panels but the heat cannot escape out. It results in warming up of green house. A similar effect is also observed in nature where warming up of atmosphere occurs due to increased concentration of some gases like **carbon dioxide ( $\text{CO}_2$ )**, **methane ( $\text{CH}_4$ )**, **chlorofluorocarbons (CFCs)** and **nitrous oxide ( $\text{N}_2\text{O}$ )**. Hence, the warm up effect is called **greenhouse effect** and these gases are called **greenhouse gases**.

The relative proportion of these greenhouse gases reveal that  $\text{CO}_2$  contributes maximum (60%) followed by  $\text{CH}_4$ , CFCs and  $\text{N}_2\text{O}$  (Fig. 16.1). Due to its major share,  $\text{CO}_2$  is considered the most important greenhouse gas. However, CFCs are about 1500 times more active in warming than  $\text{CO}_2$ , and  $\text{N}_2\text{O}$  is

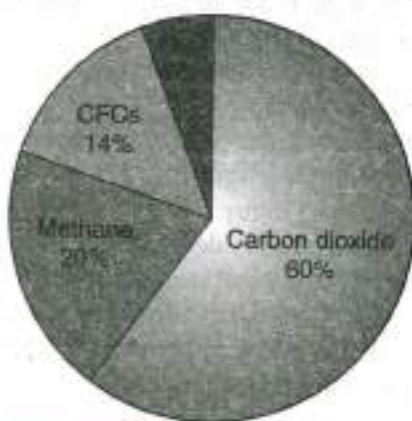


Fig. 16.1 Relative contribution of various greenhouse gases to total global warming

roughly has 25 times more heat trapping potential than  $\text{CO}_2$ .

It is believed that without greenhouse effect the average temperature at surface of earth would have been around  $-18^\circ\text{C}$  than the present average of  $15^\circ\text{C}$ .

It has been estimated that 48% incoming solar radiation falls on earth's surface and about 52% is held back in the upper atmosphere. The incoming solar radiation heats the earth's surface, and a small portion of it is reflected back. Earth's surface reemits heat in the form of long wave infrared radiation. A part of this infrared radiation does not escape into

space and major fraction of it is absorbed by greenhouse gases. The molecules of these gases radiate heat energy, and a major part again comes to earth's surface, and it is again heated up (Fig. 16.2). This cycle is repeated many a times causing increase in temperatures of earth. In simple terms, **greenhouse effect refers to interception of long wave infrared radiation (emitted from Earth) by greenhouse gases and reradiation of heat energy by the molecules of these gases toward the earth.** Consequently, earth is heated up once again.

**Effects and Sources of Greenhouse Gases :** The impact of greenhouse gases is described as below :

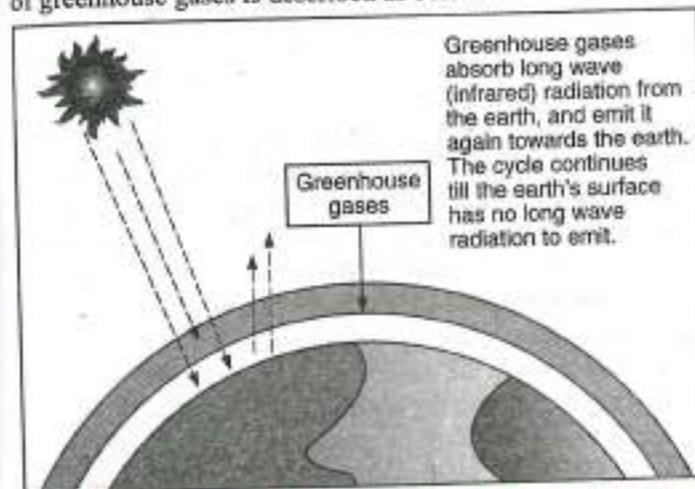


Fig. 16.2 The role of greenhouse gases in warming up of the atmosphere (greenhouse effect)

**1. Carbon dioxide ( $\text{CO}_2$ ) :** Photosynthetic activity of the existing vegetation and crop plants is unable to metabolise the high amount of atmospheric  $\text{CO}_2$ . In 1987, 5900 million tonnes of  $\text{CO}_2$  was added into the atmosphere. The amount of  $\text{CO}_2$  measured in 1998 was 6300 million tonnes. The data released by Mauna Loa Observatory, USA had shown that  $\text{CO}_2$  concentration of the atmosphere has been rising rapidly since 1959. If this trend continues, the concentration of  $\text{CO}_2$  may become 540-970 ppm by the end of 21<sup>st</sup> century. The rise in  $\text{CO}_2$  concentration had been due to (i) Deforestation, (ii) Changes in land use, (iii) Excessive combustion of fossil fuels and biomass burning. The atmospheric life time is 5-200 years.

**$\text{CO}_2$  Fertilization Effect on Plants :** Increase in  $\text{CO}_2$  concentration has a negative impact globally but productivity and stress tolerance in plants is increased. This phenomenon is termed  **$\text{CO}_2$ -fertilization**. The  $\text{CO}_2$  compensation point is higher for  $\text{C}_3$  plants and the atmospheric  $\text{CO}_2$  concentration is limiting for photosynthesis. Doubling the  $\text{CO}_2$  concentration increases the growth of  $\text{C}_3$  plants by 30% provided the other controlling factors of growth are favourable. The optimum  $\text{CO}_2$  concentration for photosynthesis had been calculated as

20 times than the normal concentration of  $\text{CO}_2$  (0.03%) and it comes out to be 0.6%. However, this concentration may be still lesser. At greater concentration than this leads to partial closure of stomata. It does not affect diffusion of gases but the rate of transpiration is reduced. As a result water use efficiency of plants is increased and drought tolerance in plants is induced.

The increased photosynthesis may also show better root growth accompanied by mycorrhizal association for higher absorption. In legumes, nodulation in roots may also be more and it helps in  $\text{N}_2$ -fixation. Thus plants will be able to grow in nutrient deficient soils. However, the negative effects of increased  $\text{CO}_2$  concentration are much greater than positive effects on plant growth.

### New High of Greenhouse Gas Levels

At a time when India witnessed the impact of climate change in the form of extreme weather events one after the other, the World Meteorological Organization (WMO) on 9.9.2014 came out with an alarming disclosure. The level of greenhouse gases in the atmosphere reached a record high in 2013, propelled by a surge in levels of carbon dioxide, it said in a survey.

"In 2013, concentration of  $\text{CO}_2$  in the atmosphere was 142% of the pre-industrial era (1750), and of methane and nitrous oxide 253% and 121% respectively. The report said, "The observations from WMO's Global Atmosphere Watch network showed that  $\text{CO}_2$  levels increased more between 2012 and 2013 than during any other year since 1984. Preliminary data indicated that this was possibly related to reduced  $\text{CO}_2$  uptake by the Earth's biosphere in addition to the steadily increasing  $\text{CO}_2$  emissions."

" $\text{CO}_2$  emissions becoming more extreme due to human activities such as the burning of fossil fuels," said WMO secretary general Michel Jarraud. "The greenhouse gas Bulletin shows that, far from falling, the concentration of  $\text{CO}_2$  in the atmosphere actually increased last year at the fastest rate for nearly 30 years. We must reverse this trend by cutting emissions of  $\text{CO}_2$  and other greenhouse gases across the world," he said.

The shocking disclosure is part of the WMO's annual Greenhouse Gas Bulletin, released in Geneva, which also said the oceans that absorb these emissions have become more acidic than ever—yet another dangerous fact that has the potential to affect marine life.

**2. Methane ( $\text{CH}_4$ ) :** The contribution of methane towards greenhouse effect is 20%. Its concentration in the atmosphere is more than doubled between pre-industrial time and 2000 AD., from 700 ppb to 1750 ppb. It is produced by the activity of methane bacteria under anaerobic conditions that cause

incomplete decomposition. The major sources of methane are freshwater wetlands, enteric fermentation in cattle, flooded paddy fields and incomplete combustion of biomass. At present, there is large cultivation on paddy fields and an enormous increase in cattle population causing a rise in methane concentration by almost 1% every year. The atmospheric life time is 12 years.

**3. Chlorofluorocarbons (CFCs) :** These are the compounds of carbon and halogen (chlorine and fluorine). CFCs escape into the atmosphere from leakage of air conditioners, refrigerators, evaporation of industrial solvents, foaming agents and aerosols. The concentration of CFCs had already reached 282 ppt (parts per trillion). The atmospheric life time is the highest (45-260 years) among greenhouse gases. There is 14% impact of this gas on greenhouse effect. CFCs also cause ozone depletion and therefore most widely used CFC-11 and others are being replaced by hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs, e.g., HFC-23).

**4. Nitrous oxide ( $N_2O$ ) :** It contributes 6% to the greenhouse effect. The concentration of  $N_2O$  from pre-industrial period had increased to about from 270 ppb-316 ppb in 2000AD. The various sources of  $N_2O$  in the atmosphere include :

- (i) Burning of nitrogen rich fuels including livestock wastes and biomass burning.
- (ii) In agriculture, it is produced from degradation of nitrogen fertilizers and denitrification in water-logged soils.
- (iii) Nitrate contaminated ground water, and
- (iv) From industrial nylon production.

### Global Warming

Due to increasing pollution, the level of greenhouse gases particularly  $CO_2$  had increased on global basis causing considerable heating of earth leading to **global warming**. During the past century, more so during the last three decades, the temperature of the earth had an average increase of  $0.6^\circ C$ . The effect of global warming brings about odd climate changes in the environment and one of these is '**El-Nino Effect**' that disturbs the pattern of rainfall every 5-8 years due to warming up of sea.

Rise in atmospheric temperature has been confirmed by Intergovernmental Panel on Climatic Change (IPCC, 1991, 1992). It is feared that by the year 2100, the average temperature of Earth may rise by  $1.5^\circ - 5.6^\circ C$  over 1990 level. The rise in temperature may be greatest in polar regions followed by middle latitudes and then tropics as reported by **World Climate Programme (WCP, 1988)**. In tundra regions, the temperature had already increased considerably. The major effects of **global warming** are being described as ahead :

- (i) The most important effect would be **increased melting of polar ice caps** as well as of other places like the Himalayan snow caps. Over many years, this will result in a **rise in sea level** that can submerge many coastal areas. It shall affect human population as 60% of human population lives within 60 km of coast line. Many habitats like coastal salt marshes and estuaries, wetlands, drylands, etc., will suffer an adverse impact and it will also endanger the life in these habitats.
- (ii) Rise in temperature may increase crop productivity in temperate areas if the rise is small.
- (iii) The amount of rainfall at higher latitudes both in summer and winter may increase. The greater rainfall may be experienced in southern and eastern Asia in summer. It may lead to floods leading to further worsening of conditions.
- (iv) Increase in temperature in troposphere is accompanied by cooling of upper atmosphere which had already shrunk by 8 km. This cooling of upper atmosphere will result in ozone depletion thereby increasing the ozone hole (to be discussed separately under ozone depletion).

**Control of Global Warming :** The following strategies can be adopted to control global warming :

- (a) Reduction in the consumption of fossil fuel.
- (b) Improvement in the efficiency of energy usage.
- (c) Deforestation must be checked and more vegetation is to be planted for greater use of  $CO_2$  in photosynthesis.
- (d) Increase in human population has to be checked.
- (e) The use of chlorofluorocarbons is to be substituted by alternate analogues which do not contribute to global warming.
- (f) The rational use of nitrogen fertilizers and greater use of legumes of increase fertility of soil through  $N_2$ -fixation.