UNIT 10 ATMOSPHERIC POLLUTION

Structure

10.1 INTRODUCTION

In the previous block, you have studied the impact of human activities on environment. You have seen how intensive agriculture on one hand and industrialisation with rapid urbanisation, on the other, have led to the degradation of both the physical and biological resources. Our physical resources, soil, water and atmosphere are highly polluted today.

In this Unit, we will define atmospheric pollution, discuss various sources of air pollutants, their nature as well as harmful effects on animal and plant life. In the subsequent units, we will learn about water pollution, soil pollution and problems related with radioactive wastes and their disposal.

Objectives

After reading this unit, you shall be able to:

- describe the human intervention with the transformation of environment,
- explain various natural as well as man-made factors that affect air pollution.
- give causes and effects of greenhouse effect, acid rain, ozone depletion and photochemical smog,
- list and give examples of corrosive and soiling effects of air pollutants, and
- outline the harmful effects of air pollutants on plant and animal life.

10.2 ATMOSPHERIC CONSTITUENTS

Air is a mixture of gases in varying amounts. It consists of 78% nitrogen, 21% oxygen, argon and other inert gases to the extent of about 1.0%. In addition, carbon dioxide is another important constituent of the atmosphere which varies in amount from 0.1% to 0.3%. The variation is mainly due to combustion photosynthetic processes. The other gases, e.g., sulphur dioxide, nitrogen dioxide, ozone, etc. are found in very small quantities. Water vapour is also an important constituent which varies from region to region.

If we look at the chemical constituents of the atmosphere and the existence of life on the earth, we find that nitrogen, oxygen, and carbon dioxide alongwith the water vapour are the main constituents of the atmosphere associated with life processes. Nitrogen gas is chemically rather inactive in the uncombined form. In the living organisms, it is present in the form of amino acids and proteins. In the soil, nitrogen is found as nitrates, nitrites and ammonium compounds.

The assimilation of nitrates and ammonium salts by living beings is the major process through which inorganic nitrogen enters the living systems. And, once the nitrogen is incorporated or fixed into living systems, it is recycled by a series of interwoven steps. This is called nitrogen cycle, details of which you have already studied in Unit 4.

Atmospheric nitrogen reacts with oxygen under the action of lightening producing oxides of nitrogen which are carried to the earth by rain or snow in the form of nitrous or nitric acid.

Unlike nitrogen, oxygen is a very reactive substance. It is indispensable in life functions of most plants and animals. In fact metabolism can be considered as an efficient oxidation process. During respiration animals and plants take in oxygen and give out carbon dioxide and water vapour. Atmospheric oxygen has resulted from the photosynthetic activity of the plants. Plants take in carbon dioxide in the presence of sunlight and release oxygen.

Carbon dioxide though present in much smaller amounts as compared to nitrogen and oxygen, is crucial for sustaining life. Food chain starts with photosynthesis, in which plants utilise carbon dioxide and water in the presence of sunlight to make sugar and starch. The levels of carbon dioxide in the atmosphere also play a part in determining the global temperature.

Air also carries water vapour. The proportion of water is temperature-dependent and, so, it is exceedingly variable. However, about half the atmospheric moisture remains within one to one and half kilometre of the earth's surface, and it is scarcely found beyond the level of 10 km above the surface of the earth.

In addition to the gases and water vapour, air also carries minute solid particles. These particles when visible are known as dust. Dust particles have terrestrial origin and lie mainly within 1.8 km of the atmosphere from the surface of the earth. The atmosphere acts as a heat insulator and helps in the distribution of heat during day to night temperature changes. The sound vibrations and their transmission is also possible due to the presence of atmosphere. Above all, without atmosphere, there would be no weather, no rain, no vegetative cover, no varying weather phenomena. Without this cover, the earth would have remained exposed to many lethal radiations from sun, thereby creating an adverse situation for any life on the earth.

The percentage proportion of gases remains almost constant throughout the atmosphere, at least upto a height of 24 km. But, this does not hold true in case of the air around large cities and industrial centres, where an increase in carbon dioxide and a decrease in oxygen results due to combustion of fuel in power plants and automobiles and also due to concentration of a large number of human beings.

SAQ 1

State whether the statements are true or false.

i) Atmospheric nitrogen reacts with oxygen under the action of lightening producing oxides of nitrogen which are carried to the earth by rain or snow in the form of nitrous or nitric acid. [ ]

ii) Atmospheric oxygen has resulted from the photosynthetic activity of the plants. [ ]

10.3 TYPES OF AIR POLLUTANTS

Atmospheric pollution is an unwanted change in the quality of earth's atmosphere caused by emission of gases due to burning of fossil fuels, outpouring of ashes and gases from the particulate matter due to soil erosion. Pollen and organic compounds from vegetation and lightening strokes also pollute the atmosphere.

Now, we will study about the different agents that pollute the air. For convenience, air pollutants can be classified into the following three types:

i) Natural Pollutants
ii) Primary Pollutants
iii) Secondary Pollutants

10.3.1 Natural Pollutants

The pollutants which come out from natural sources such as forest fires started by lightening, dispersal of pollen, soil erosion, volcanic eruptions, volatile organic compounds from leaves and trees, decomposition of organic matter and natural radioactivity, etc. are natural pollutants. This type of atmospheric pollution is not a new phenomena. It is perhaps as old as the earth itself. Nature has its own mechanisms of dealing with such pollution. In any case, the concentration of pollutants from the natural sources is often quite low and rarely causes any serious damage.

10.3.2 Primary Pollutants

A primary pollutant can be defined as a harmful chemical that directly enters the air as a result of a natural event or human activities. For example, when coal, oil, natural gas or wood is burnt, carbon dioxide and carbon monoxide are formed, automobiles contributing a large share of carbon monoxide. All these gases enter the atmosphere. Another important pollutant is sulphur dioxide (SO_2) which is added to atmosphere by burning of coal and oil containing sulphur as impurity in electric power plants. Other primary pollutants are oxides of nitrogen, hydrocarbons and suspended particulate matter.

10.3.3 Secondary Pollutants

Secondary pollutants result from harmful chemical reaction between two or more air components. For example, sulphur dioxide, the primary pollutant reacts with oxygen in the atmosphere to form the secondary pollutant, sulphur trioxide (SO_3) ($2SO_2 + O_2 \rightarrow 2SO_3$). The sulphur trioxide can then react with water vapour in air to form droplets of sulphuric acid (H_2SO_4) ($SO_3 + H_2O \rightarrow H_2SO_4$), another secondary pollutant (Fig. 10.1).

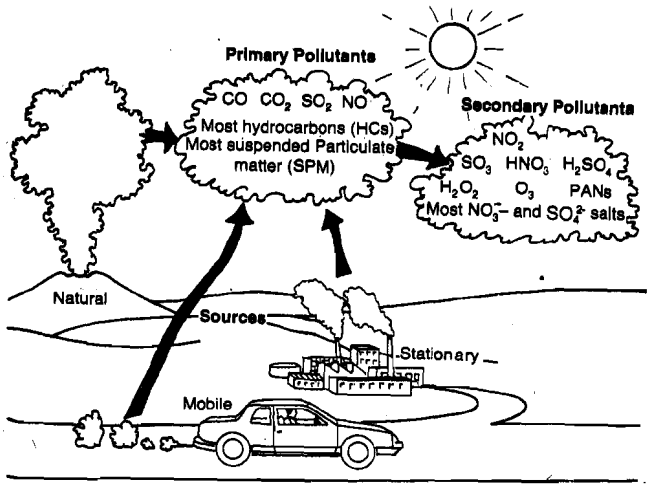


Fig. 10.1 Primary and Secondary air pollutants

SAQ 2

What are known as secondary pollutants? Explain in the space given below.

.....

.....

.....

.....

10.4 SOME MAJOR AIR POLLUTANTS

The major air pollutants are those which are produced in significant amounts and have health and other environmental hazard. We will describe here some of the major air pollutants.

10.4.1 Oxides of Sulphur

The oxides of sulphur have deleterious environmental effects. Electrical power plants which use coal are largely blamed for sulphur dioxide emissions into the atmosphere.

Sulphur dioxide is itself injurious to plant and animal life. It can also react with ozone, hydrogen peroxide, or water vapour in the atmosphere to form sulphuric acid (H_2SO_4). Sulphuric acid is one of the strongest acids known. It corrodes lime stone and metals and destroys clothing. It also has injurious effects on respiratory tissue. Sulphuric acid is considered as one of the most toxic and dangerous air pollutants, being a major component of acid rain. You will read more about acid rain in the later sections of this Unit.

Since most of the sulphur dioxide comes from burning of coal in the power plants, the control of sulphur dioxide emissions into the atmosphere will depend upon the production and use of energy as well as on the quality of the coal used.

10.4.2 Oxides of Nitrogen

Oxides of nitrogen are produced when fuel is burned at high temperatures. Nitrogen, which is, ordinarily inert, combines with oxygen in high temperature flames and tends to stay combined if the exhaust gases are cooled quickly.

Oxides of nitrogen are relatively harmless at ordinary concentrations. They are released into the air mainly from vehicular smoke, electric power plants, industrial establishments, commercial institutions and residential units. The automobile emission is the major contributor of nitrogen oxide, accounting for about 50% of the total. Electric power plants contribute about 33% and the percentage share of the industrial establishments, commercial institutions and residential units is 12%, 14% and 1% respectively. In Indian cities diesel operated vehicles contribute about 90% of the oxides of nitrogen to the air.

Nitric oxide (NO) is the first product of the combination of atmospheric nitrogen with oxygen at high temperatures. At high concentrations, nitric oxide causes asphyxiation.

Further, nitric oxide combines easily with the atmospheric oxygen to form nitrogen dioxide (NO_2). Nitrogen dioxide may create a variety of human ailments, from mere gum inflammation to internal bleeding, pneumonia, lung cancer, etc.

10.4.3 Hydrocarbons

Hydrocarbons are compounds made up of carbon and hydrogen. Some hydrocarbons have direct effect on human beings and are carcinogenic in nature. They are produced during the production of coke and smoldering of refuse piles near coal mines or during improper burning of coal.

10.4.4 Carbon Monoxide

Carbon monoxide (CO) is one of the major pollutants from automobiles comprising 80% of all automobile exhausts. Small amounts are also emitted from volcanoes and

forest fires. Carbon monoxide is a product of incomplete combustion of fuels. Carbon monoxide reduces the oxygen carrying capacity of the blood. It can be fatal at concentrations exceeding 1000 ppm. Therefore, it is not advisable to work in closed rooms with open coal fire.

10.4.5 Carbon dioxide

Carbon dioxide (CO_2) is one of the basic end-products of the burning of fossil fuels, paper, leaves, tobacco and other carbon containing materials. Carbon dioxide is considered relatively innocuous because it has no direct effect on health. But it has several important side effects. It contributes towards acid rain and greenhouse effect.

10.4.6 Lead Pollution

Lead is a chemical pollutant which enters the atmosphere from automobile exhaust. A compound of lead, tetraethyl lead (TEL) is used as an anti-knock agent in petrol or gasoline for smooth and easy running of vehicles. If the octane rating of petrol is low, the fuel and air mixture can ignite prematurely and disturb the smooth running of the engine and cause knocking. Therefore, the octane rating of gasoline is raised by the addition of TEL in concentrations between 0.3 and 0.6 grams per litre. Developed countries have by and large discontinued the use of TEL as an antiknock agent and have increasingly gone over to the use of other methods for raising the octane number of gasoline. It is a matter of concern that we, in India, still use leaded gasoline.

The lead mixed air, if inhaled, may produce injurious effects on the kidneys, blood and liver. It can get mixed up with water and food and can create cumulative poisoning. The effects are far-reaching in case of growing children. The increase in level of lead in children may cause lowering of intelligence. Hence, it forms an important parameter of air pollution.

10.4.7 Suspended Particulate Matter

Any small solid particles and liquid droplets suspended in the air are known as particulate matter. The size and weight, in particular, determine their suspension from a few seconds to months in the atmosphere. Most of such particulate matter is emitted by establishments which use coal as fuel. These air pollutants are also known as aerosols.

The aerosols remain constantly under the influence of gravitational force of earth. The aerosols in the atmosphere are of two kinds: one is the natural, such as fog, bacteria, plant spores, pollen, etc. These usually do not cause any atmospheric pollution. The second type of aerosols, such as cement powder, flue dust from coal dust combustion, quartz and asbestos powder, oil smokes, tobacco smokes and radioactive aerosols are air pollutants due mainly to man's activities and cause constant damage and threat to the atmosphere.

10.4.8 Smoking

The term refers to the smoking of tobacco, but many other substances can also be smoked, for example, opium, dhatura and other herbs.

Cigarette smoking is responsible for many diseases due to the presence of carcinogenic tars in cigarette smoke. The effectiveness of carcinogenic tars is lesser in case of cigar and pipe smoking due to lower temperature at which tobacco is smoked. It is because of the harmful effects that the Government of India has made statutory provisions for cigarette manufacturers in the country to print on every packet of cigarettes a warning saying that "smoking is injurious to health"

Besides, it has also been established that non-smokers whose work conditions lie in smoke-filled rooms are also vulnerable to health problems.

In spite of warnings, cigarette smoking continues, and more and more problems are predicted in future years to come. The most common health problem is the occurrence of cancer of the lungs and larynx. The other health problem associated with smoking is coronary (heart) disease. The well known 'smokers' cough' is of local nature which may bring irritation and bronchitis. Finally, the death rate in middle

aged people, who smoke more than 20 cigarettes a day, is more than twice that of non-smokers, taking all diseases into account.

The smoking habit, however, can be controlled only by 'will power' and in some cases by substituting disagreeable lozenge for the cigarette.

10.4.9 Radioactivity

You must be aware that radioactive substances disintegrate with emission of radiation. Three kinds of radiation namely alpha, beta and gamma have been identified. These radiations interact with living tissues and damage them. The sources of radiation can be natural, which include both—cosmic and terrestrial, and artificial or man-made. Cosmic rays are the primary source of radiation which enter the atmosphere from outer space. The primary radiation on entering the atmosphere produces secondary radiation through interactions with atoms in the atmosphere.

Terrestrial radioactivity originates from radioactive materials of the earth. A large proportion of this radiation is from radioactive materials, such as uranium, thorium, actinium, potassium and carbon. However, strontium-90 which is a major long-term hazard gets incorporated into vegetation, dairy products and even building materials like bricks, concrete, etc. These materials are believed to have been present in the earth since its inception.

In recent decades radioactive materials have been increasingly used for generation of power, research and medicinal purposes. The radiation from industrial and research units is believed to be absolutely negligible, as these are so shielded by fool-proof measures that the radiation level outside the reactor's core seems to be very much lower than the danger dose. Furthermore, these reactors are so designed that they cannot explode like atomic bombs. The real danger comes from the use of radioactive material for destructive purposes. The world has not yet forgotten the destruction caused by two fission bombs which were dropped in Hiroshima and Nagasaki towards the end of Second World War. Typical radiation exposure levels from various sources are given in Table 10.1.

Table 10.1 : Typical Radiation Exposure Levels

Millirem/year		millirem/year	
From cosmic rays	35	From Coast to Coast Jet Flight	5
From air	5	From colour television	1
From building materials	34	From one chest X'ray	50
From food	25	From living within a 50 miles radius from a nuclear power plant	0.001
From ground	11		

From Table 10.1 it is evident that radiation exposure from natural sources is considerably high as compared to man-made or artificial source, unless there is an accident as happened in Chernobyle or in Three Mile Island.

The harmful effects of radiation, are cancer, gene mutation, damage to the central nervous system, blood forming tissues, eyes, skin, and a host of other organs and systems. Although, at present, the total radiation from all of the man-made sources is considerably low, it may, however, increase in future years with expanded use of radioactive materials. Therefore, the adverse biological effects of the exposure must be evaluated carefully.

10.4.10 Noise Pollution

By definition, noise is "sound without value" or "any noise that is undesired by the recipient". Thus, the kind of environmental impact of noise pollution is slightly different from other kinds of pollution.

Generally, there is much more noise in the urban areas because of larger concentration of population as well as industrial and other activities like

transportation vehicular movements, etc. Non-industrial sources of noise can come from public address systems for religious or political propaganda, recreation, hawkers or other street noise. Noise can also arise from the natural sources like thunder.

Noise as a potent menace can be evaluated in terms of a 'noise level' scale, or in **decibels (dB).** However, the health hazard is a matter of **perceived noise level decibels (pNdB),** which according to the W.H.O.'s prescribed optimum noise level as 45 dB by day and 35 by night; and anything above 80 dB is hazardous. Table 10.2 lists noise sources and their intensity.

Table 10.2 : Noise Source and their Intensity

Noise Source		Noise Scale		Noise Source	Noise Scale
1.	Breathing	10 dB	12.	Traffic Noise	60-90 dB
2.	Winds in the trees	20 dB	13.	Sports car	80-95 dB
3.	Quiet Conversation	20-30 dB	14.	Heavy truck	90-100 dB
4.	Ticking clock	10 dB	15.	Motor cycle	105 dB
5.	House in a quiet street	35 dB	16	Pneumatic drill	90-100 dB
6.	Radio music	50-60 dB	17.	Thunder storm	110 dB
7.	Loud conversation	60 dB	18.	Beat Music (electrically amplified)	120 dB
8.	Office noise	60 dB	19.	Aircraft noise	90-120 dB
9.	Children playing	60-80 dB	20.	Jet take-off (at 100m distance)	120 dB
10.	Lawn mower	60-80 dB	21.	Jet engine (at 25 m distance)	140 dB
11.	Vacum cleaner	80 dB	22.	Space Vehicle launch (from a short distance)	140-170 dB

The hazards of noise pollution are many and varied. For example, people exposed to noise levels reaching 110 db may reveal mental trauma, deafness, physical fatigue and hypertension, cardiovascular disease, insomania, peptic ulcer, eczema and asthama. Psychologists are of the opinion that prolonged exposure to noise for a day alone, may lead to severe mental disorientation, and in a few cases, result in a violent behaviour.

The noise properties and their reasonable level, in general, can be controlled only through enlightened and co-operative authorities. However, in a few cases, noise pollution can be minimised only through rigorous law and conscious efforts of the law enforcement department.

SAQ 3

Fill in the blanks with suitable words.

i) .....is considered as one of the most toxic and dangerous air pollutants, being a major component of acid rain.

ii) .....is a product of incomplete combustion of fuels. It reduces the oxygen carrying capacity of the blood.

iii) Radiations emitted from cosmic rays is.....Millirem per year.

iv) According to the W.H.O. prescribed optimum noise level is.....dB by day and.....dB by night, anything above.....dB is hazardous.

10.5 GEOPHYSICAL INFLUENCES ON AIR POLLUTION

You have learnt that the blanket of gases that makes up the earth's atmosphere, plays a basic role in preserving life as we know it. The upper layer of the

atmosphere, the stratosphere, shields and protects the surface of the earth from meteors, cosmic rays, ultraviolet radiations from the sun, and other harmful radiations and particles that reach our planet. The lower layer of the atmosphere, the troposphere, is a medium for the storage and distribution of various substances. We are all familiar with these functions in relation to water vapour and heat energy, the distribution of which moderates climates.

Troposphere is concerned with the oxygen-carbon dioxide distribution cycle involving all forms of life. It also stores and distributes the various contaminants that we put into it. It is this function that is of primary interest to us in air pollution.

Theoretically, a pollutant can be carried right through the troposphere, but it cannot penetrate the stratosphere. Generally, most air pollution problems are confined to the first hundred metres of atmosphere above the ground level. The behaviour of the atmosphere is the only factor that by itself completely determines whether our pollution will hang around to haunt us, or will blow away to bother someone else!

10.5.1 Geography

Solar energy received by the earth is distributed over a large area near the poles than at the equator (Fig. 10.2). Thus, the amount of energy received per unit area is more at the equator, which is consequently much warmer than the poles. In contrast, the outgoing radiation is distributed much more uniformly with latitude. For both of these situations to exist simultaneously, there must be a major transfer of heat energy from the equatorial regions towards the poles. This is accomplished through the motion of atmosphere known as winds. Pollutants in the air move with these winds. So one nation's pollution can become its neighbours problem.

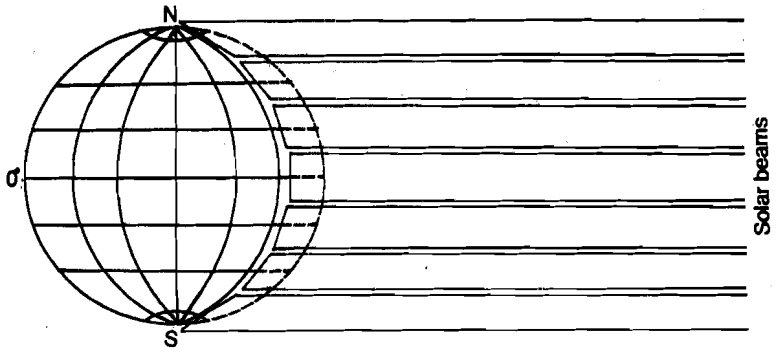


Fig. 10.2 : Variation in the distribution of incoming radiations with latitude

The surface of the earth with its covering, atmosphere and clouds, presents a very mixed reception to incoming solar radiations. Some of the solar energy is absorbed

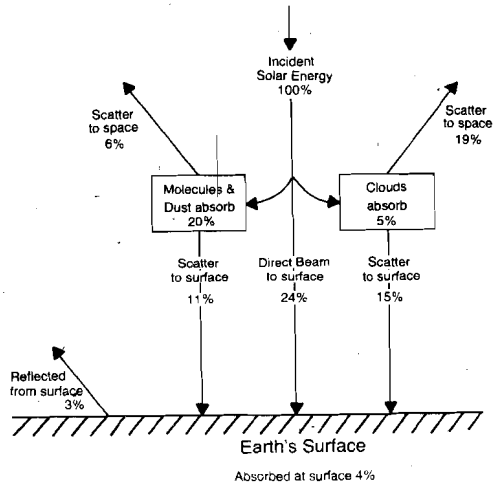


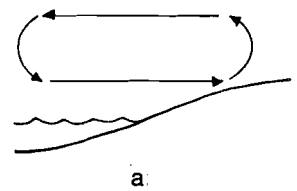
Fig 10.3 : The fate of incoming solar radiation (Global annual average)

by air, some by clouds, some by earth, and some is reflected back into space (Fig. 10.3). You may notice that the major part of the radiation is absorbed by the ground rather than by the atmosphere. This means that air is generally warmed from the bottom, i.e. by contact with the ground and not by direct radiation from the sun. So during daylight hours, the air nearest the ground is usually the warmest.

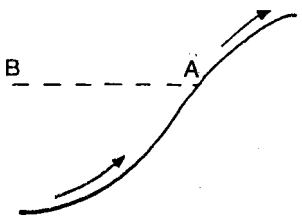
Although the major driving force of the air movements is the temperature difference, the topography of the area also has some effect on air movements and hence on pollution. Here we will discuss two localised phenomena, the land-sea breeze and the mountain-valley wind, which have a significant impact on local air pollution.

Coastal areas develop circulations driven by temperature differences between the land and the ocean. In the morning, the sun warms the land much more rapidly than it does the water. Warmer air over the land tends to rise and is replaced by the cooler air over the ocean creating the sea breeze (Fig. 10.4a). The sea breeze has an impact on air pollution in two ways. First, it can play a major role in carrying pollution generated near the sea to inland areas. Second, if an evening land breeze has carried pollution out to sea, a morning sea breeze can bring the pollution back to the land.

Mountain-valley winds are similar except that the temperature differences which drive the winds are caused by differences in height. In Fig. 10.4b, point A is closer to the surface and so the air there is warmer than at point B. Warm air at A rises creating a morning breeze up the side of the valley. The reverse can occur in the evening. Since pollution sources are often located on valley floors, this pattern of circulation is likely to move pollutants about in unexpected ways.



a



b

Fig. 10.4 (a) Land-sea breeze (b) Mountain-valley wind

10.5.2 Climate

Climate means the average pattern in which weather varies in time. The average is determined over long periods from a month upto decades. The climate of a region depends on the presence or absence of water, the reflection of solar radiation or albedo, the ability to transfer water to the atmosphere (evaporation), the capacity to store heat, and the topography and texture of the region.

Although they constitute only a fraction of the total land area of the earth, metropolitan areas, nevertheless, emit the bulk of all air pollutants. These air pollutants influence temperature, visibility and precipitation as well as other climatic elements.

We are familiar with the fact that cities are often warmer than adjacent rural environments. One of the factors leading to the creation of such a **'microclimate'** is urban heat. This includes the biological heat released by the city population, heat released by some heating devices and industries, automobiles, etc. Other factors are accelerated run-off of precipitation instead of absorption and evaporation, altered albedo and heat storage capacity. These result from replacing forests and fields with concrete buildings and consequently greater surface roughness. Human beings thus exert a dramatic influence on local climates.

Another factor involved in climate changes in a city, is the blanket of pollutants that hangs over it. This blanket absorbs a portion of the upward directed thermal radiation emitted by the earth's surface. Part of this radiation is re-emitted by the pollutants, and the other part warms the ambient air, a process that tends to increase the low level atmospheric stability over the city enhancing the probability of higher pollutant concentrations. Thus, air borne pollutants not only cause a more intense **'heat island'** but also alter the vertical temperature structure in a way that hinders their own dispersion.

The excess carbon dioxide, chlorofluorocarbons and methane gas released by man's industrial activities remain trapped in the earth's atmosphere. They prevent the solar heat re-radiated from the earth's surface from escaping into space causing what is known as the **'Greenhouse Effect'**. Over a prolonged period of time, this can result in a substantial rise in earth's mean temperature. You will read more about greenhouse effect in Section 10.6

Conversely, an increase in particulate matter in the atmosphere, such as smoke and ash, increases the albedo of the atmosphere. This would mean that more of the incoming solar radiation is being reflected back into space before it reaches the

earth's surface. This could result in a drop in the temperature of earth, eventually leading to another glacial period or ice-age for our planet. Prediction of a nuclear winter consequent upon nuclear war is one such scenario predicted by the famous scientist Carl Sagan.

10.5.3 Weather

Weather and climate are not the same thing. Weather refers to the conditions of temperature, cloudiness, windiness, humidity and precipitation that prevail at a given moment or the average of such conditions over time periods ranging from a few hours to a few days. The weather can change from hour to hour, from day to day or from week to week.

Troposphere is the medium in which the phenomenon of weather takes place. The structure of the troposphere with the warmest air at the bottom promotes vertical instability leading to hot air rising and cold air sinking. This is because hot air is lighter than the cold air, hence the troposphere tends to be vertically well mixed. Under certain circumstances, however, the usual temperature profile of the troposphere near the ground is altered so that temperature increases with altitude. In this situation, called an **'inversion'**, with warm light air above and the cold heavy air below, vertical mixing is suppressed over the altitude range where the temperature has increased. Vertical mixing is also suppressed in circumstances where temperature decreases with altitude but not enough to overcome the stratifying effect of density variation. Large quantities of particulate matter in the air can lead to inversion.

Inversions are of special importance in environmental science because they inhibit the dilution of pollution causing what is commonly known as smog. The word **'smog'** was coined in England for the 'smoke-fog' pollution associated with the country. In December 1952, London was covered by smog for ten days. Though deaths occurring at the time were not directly attributed to the smog, later statistics confirmed that 6,000 more people, especially the sick and the elderly, died at that time of the year than usual. This smog was caused not only by fog, smoke and ash particles, but also by the presence of a large quantity of sulphur dioxide gas in the air due to burning of coal in the city for heating and industrial purposes.

The "London smog" is very different from the "Los Angeles smog" or "photochemical smog". The later is a newer variety of smog caused by automobile exhaust. Formation of photochemical smog, is a case of **'synergism'** which in layman's expression, is equivalent to saying two plus two is **greater than** four. Let us

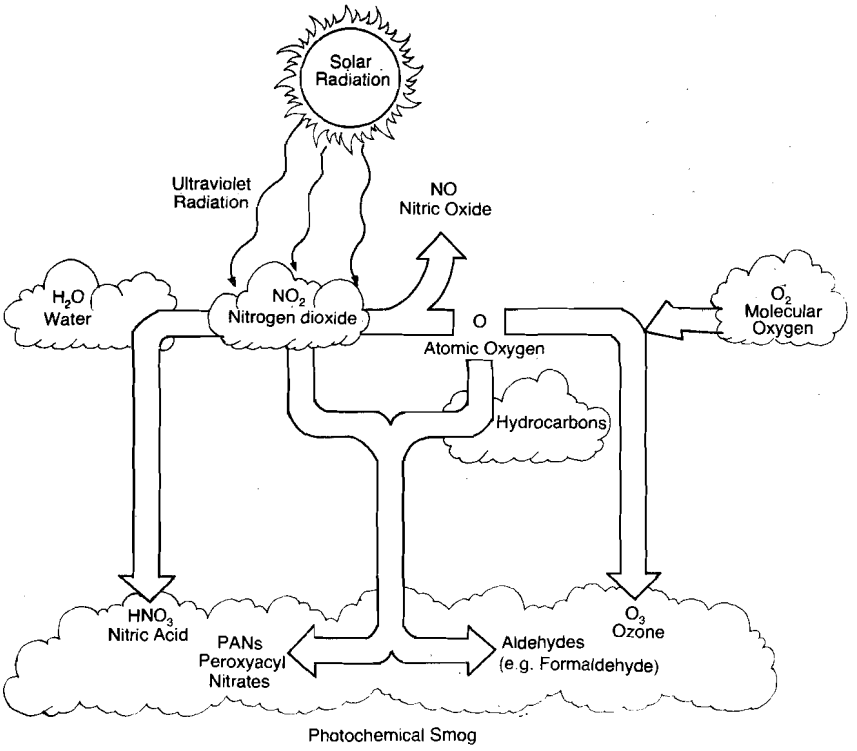


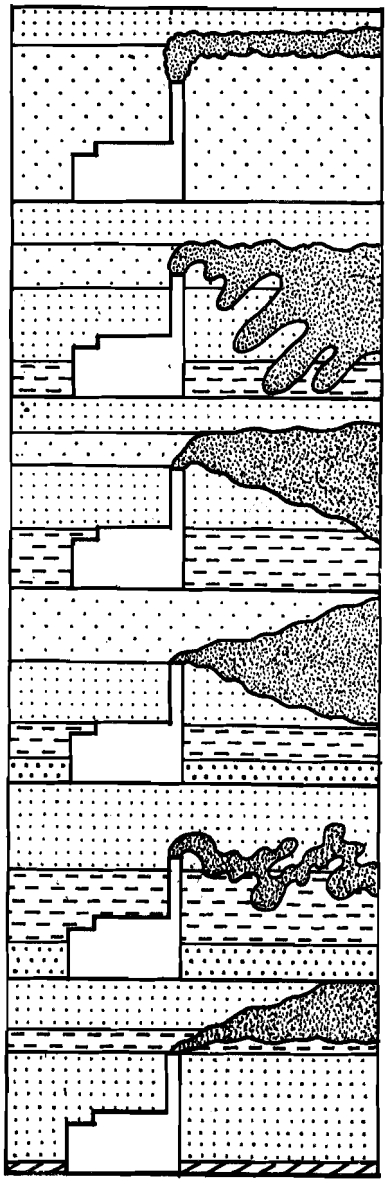
Fig. 10.5 : Simplified scheme of the formation of photochemical smog

now consider synergism in the formation of smog. You know that oxides of nitrogen and unburnt hydrocarbons are both emitted in the automobile exhausts. In the presence of ultraviolet radiations in sunlight, they interact to produce Peroxyacetyl nitrate (PAN) and ozone. PAN and ozone are more harmful than either nitrogen oxides or hydrocarbons or even the two put together. Because of the wind patterns in the eastern Pacific Ocean, and the ring of mountains surrounding the Los Angeles basin, it is an ideal place for the formation of inversions, usually about 2,000 feet above the floor of the basin. Another climatic feature that contributes to Los Angeles air pollution problem is its abundant sunlight which, as discussed above, acts to produce photochemical smog (Fig. 10.5).

Precipitation, i.e. rain, snow, sleet, and hail, too, bring down to the earth's surface. pollutants suspended in the atmosphere. Though pollutants such as chlorofluorocarbons cannot be washed down, sulphur dioxide molecules have a strong affinity for water molecules. They combine to precipitate as **acid rain.** Acid rain is destructive not only to human health and plant and animal life, but also to buildings. You will read more about acid rain in Section 10.6.

10.5.4 Wind

Air pollution affects a far larger number of people than does water or land pollution. Air is a great leveller which does not distinguish between people. We all breath the



During the night, if skies are clear and winds light, warmer air may be found above the layers chilled by the ground (temperature inversion). In these conditions smoke drifts in sheets, or ribbons.

In the morning the warming ground heats the overlying air and begins to break down the inversion. For a short surrounding air may bring the smoke down (fumigation).

The progressive destruction of the inversion from below (the lifting of the inversion) is marked by smoke plumes becoming conical. At first, cones appear to the tilted downwards.

As the normal lapse of temperature with height is set up, the cone becomes more symmetrical.

When the ground is strongly heated by the sun, large, turbulent eddies due to convection currents give smoke plumes a broken up or looping appearance.

In the early evening, if the [illegible]d are light and the skies cloudless, a temperature inversion (due to radiational cooling of the ground) is established. The upward tilt of the coned plume of smoke shows that dispersion as taking place above the inversion.

Fig. 10.6 : Behaviour of a plume of smoke from a chimney. In this diagram the generalised thermal structure of the air is hyphenated space represent layers of warm air and dotted space, layers of cold air

same air; and wind disperses it to every nook and corner. A great tragedy took place in Bhopal in December 1984 with the accidental escape of 45 tonnes of methyl isocyanate (MIC) gas from the Union Carbide factory. The cool, night-time north wind, spread this poisonous cloud over nearly all of Bhopal. But the concentration was densest in the 1.5 km radius of the factory, resulting in the deaths of about 3,000 people, and life long debilitation and untold suffering for 60,000 more.

In general, the dispersion of gaseous and particulate matter depends on the type of emission and the wind and temperature structure of the atmosphere. Though the latter two are related, it is still possible to make a separate assessment of the role of wind.

Consider a 100 feet tall chimney stack. From its top, pollutant gases and particles emerge at a certain rate, and across the top there is a horizontal wind at a varying rate. The stronger the wind, the larger the amount of air that moves past the chimney. Therefore, the quicker and more rapid is the dispersal of the pollutants. Thus, strong surface winds produce a smoke plume with smaller concentrations of emitted materials than light winds. Fig. 10.6 explains how temperature and wind affect the behaviour of a plume of smoke from a chimney.

10.6 EFFECTS OF POLLUTION ON NON-BIOLOGICAL SYSTEMS

It has long been known that air pollution can affect the local climate, particularly the rainfall. In the recent years there has been considerable debate about the potential impact of air pollution on global climate. Let us examine some of these climatic effects of air pollution.

10.6.1 Climatic Effects

Greenhouse Effect: During the past two centuries, carbon dioxide in the atmosphere has increased dramatically. The probable cause is the burning of fossil fuels and burning of forests by farmers.

Scientists have been worrying that the growing burden of carbon dioxide and other gases may change the earth's climate. In normal circumstances, much of the solar radiation that penetrates the earths' atmosphere is re-radiated as heat from the earth's surface, and dissipates into space. But an increase of carbon dioxide allows most solar radiations to penetrate the atmosphere, but prevents part of the heat re-radiated by the land and water bodies from escaping into space. As carbon dioxide accumulates, enough heat may be trapped to gradually warm the atmosphere.

Other gases that contribute to the greenhouse effect are methane and chlorofluorocarbons. Methane is attributed to release from livestock manure, additional rice fields, and digestion of termites proliferating on dead wood left by worldwide clearing of forests.

Most emissions from industrial plants and factories fall in the areas nearby. Some are carried away by winds to be washed from the sky by snow, rain, or mist. But some chemicals, such as chlorofluorocarbons, do not dissolve or recombine at lower levels. They rise to higher levels and contaminate the stratosphere. Chlorofluorocarbons are used as refrigerants and in some places, still used as 'spray-can propellants'. They add to the greenhouse effect as they drift upwards.

Researchers estimate that the expected rise in atmospheric temperature would be $2^{0}C$ by the end of the century if the greenhouse gases continue to increase at current rates. Higher global temperature would cause glaciers to melt, and also lead to an expansion of the oceans because warm water occupies larger volume than cold water. If the levels of greenhouse gases in the atmosphere double, sea level will rise; estimates of the average rise vary between 0.5 to 2.5 metres. This is expected to occur gradually in the next century affecting coastal areas where about a billion people, a quarter of the world's population now live. Further, marine ecosystem will also be greatly affected (Fig. 10.7).

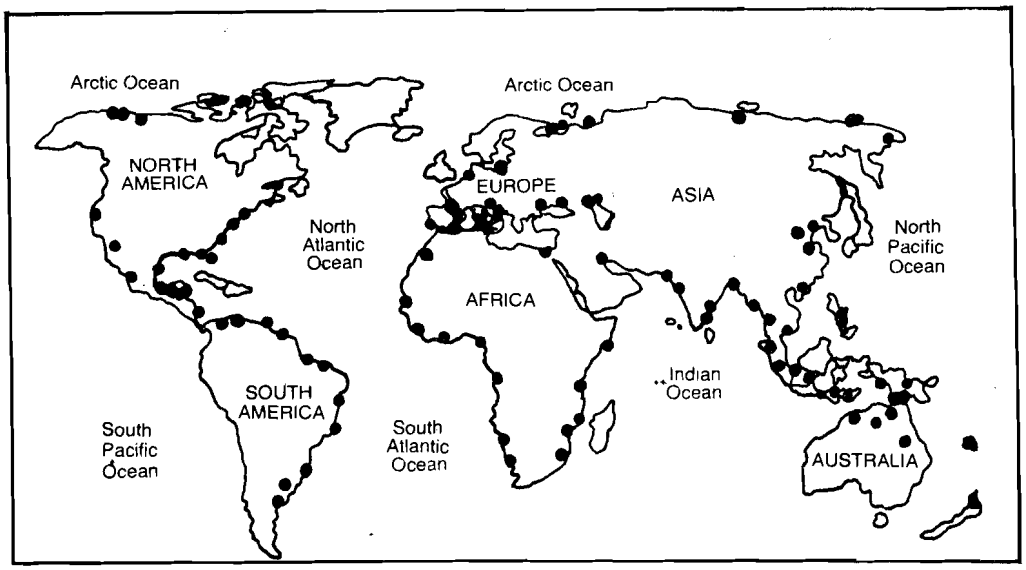


Fig. 10.7 : Places vulnerable to global warming

Acid Rain : Sulphur dioxide released from coal burning power plants, industrial boilers and smelters, is normally carried away and gets oxidised in the atmosphere. But when it gets absorbed in suspended particulate matter in the air such as dust, fly ash, etc. and comes in contact with moisture droplets, it turns into sulphuric acid. The same thing can happen when it comes in contact with the moist tissue in the lungs. Similarly, nitrogen dioxide gas from motor vehicle exhaust is converted into nitric acid. Unless they are neutralised in reaction with alkaline compounds in the atmosphere, these strong acids eventually return to the earth as 'acid rain'.

Rainfall in unpolluted areas is usually slightly acidic with a pH between 5.5 and 6.5 because water and carbon dioxide combine in the atmosphere to form a weak acid, carbonic acid. The pH of acid rain is often less than 4, even 3 to 3.5 is not unusual.

Acid rain corrodes metals and limestone, causing extensive damage. It damages vegetation and wildlife, etches car finish and erodes buildings and bridges. Moreover, acid rain is seldom localised. These pollutants can travel hundreds, even thousands of kilometres to rain far away with no respect for state or national boundaries.

The overall effect of acid, rains on ecosystems is not well understood, but it has the potential for serious damage. Sweden's forests have suffered a reduction in growth rate, starting in the 1950s, thought to be due to acid rains. The fish like salmon and trout have disappeared from Swedish lakes and streams where the pH has fallen much below 5. The origin of acid rain in Sweden has been traced to Western Europe, especially the United Kingdom. Acid rain has also taken its toll on the conifer forests of West Germany. As acids leach nutrients from their leaves and soil, spruce and fir trees are dying. Aluminium and heavy metals such as cadmium, are present in many soils but generally remain immobile. In Germany, they have become mobile in the presence of acids and are sucked up by trees into their systems causing more damage to already weakened trees. Acid rains can also affect soil micro-organisms, especially those responsible for nitrogen fixation. They can influence the behaviour of bacterial and fungal pathogens.

10.6.2 Corrosive and Soiling Effects

Buildings, bridges and other man-made structures can be soiled and damaged extensively by pollution. The accumulation of dirt and organisms that utilise polluted products can alter the appearance of a building. But most damage is caused by acids present both in the air and in rain-water. Stone work may get corroded. A case in point is the marble Parthenon in Athens. Sulphur oxides in the smog over Athens chemically transform marble into gypsum, causing it to crack and flake off. This has caused more erosion of the frieze panels of the Parthenon in the past twenty four years than had occurred in twenty four centuries. The Westminster Abbey in London, and the ancient Roman Colloseum have also suffered such damage due to acid deposition.

In India, acid rain threatens our famous monument, the Taj Mahal. Crude-oil refineries situated in nearby Mathura, spew out vast quantities of sulphur dioxide into the atmosphere. This sulphur dioxide is carried by winds to Agra, among other places, where it gets adsorbed by water droplets and rains down on the Taj Mahal. The Taj Mahal, made only of marble slabs, is susceptible to corrosion. The damage to this majestic monument, once it takes place, will be irreversible. Therefore, there is a need to monitor both the quality of the sulphur dioxide emissions from the refinery as well as the wind direction in the area. It is essential, in any case, that suitable measures should be taken for the removal of sulphur dioxide from refinery emissions.

10.6.3 Ozone Depletion

The stratospheric pool of ozone is continually being produced and destroyed. Production takes place when molecular oxygen O_2 is split by ultraviolet (uv) solar radiation and the resulting oxygen atoms, 'O', attach themselves to other O_2 molecules:

$O_2 \rightarrow O+O$
$O+O_2 \rightarrow O_3$ (Ozone)
The net result of destruction is
$2O_3 \rightarrow 3O_2$

Ozone can impair vision and breathing when it occurs in smog. But, in the upper atmosphere, 12 to 30 miles above the ground, it protects life on earth by intercepting the sun's damaging uv radiations. During the past ten years, however, this protective layer of ozone has become thinner over the South Pole. From 1979 to the present, the hole has deepened within which ozone concentration has fallen by almost 40%.

Some scientists believe that the ozone was attacked by chlorine released by chlorofluorocarbons, widely used as industrial chemicals. When chlorofluorocarbons, which drift upwards, reach the stratosphere, they react destructively with ozone. Ozone can also be destroyed by nitric oxides from emissions of supersonic jets. It is also possible that ozone was pushed aside by the upwellings of air from lower levels of the atmosphere. Whatever the cause, the potential effects could be serious. If the ozone that protects us from excessive uv radiations, continues to disappear, it would result in an increase in melanomas and skin cancer incidents as well as a reduction in crop yield.

10.7 EFFECTS OF POLLUTION ON BIOLOGICAL SYSTEMS

In the previous section, you have studied about the effect of pollution on non-biological systems. In this section, we will study about the effect of air pollution on the biological systems.

10.7.1 On Plants

Plants are not immune to the pollution we produce. In fact, being the only organisms capable of producing food and thus sustaining life on earth, they are liable to pass on whatever pollution they pick up. Crop yield may be greatly affected with serious consequences to the human race.

Photochemical smog has a deleterious effect on plants. As described earlier, in the presence of sunlight, various pollutants combine to form ozone and peroxyacetyl nitrate (PAN). Ozone is extremely damaging to plants. It enters leaves through the stomata which are used for normal gas exchange, and alters the permeability of the membranes of the stomata. This causes nutrient—and electrolyte—imbalances resulting in the death of the cells. In effect, ozone increases respiration of leaves, killing the plant by depleting its food. Chronic exposure to ozone may weaken plants and make them more susceptible to disease, or age them prematurely, reducing crop yields without signs of outward injury.

PAN, the other component of photochemical smog, is phyto-toxic. It blocks the process of photosynthesis killing the plant by shutting down food production.

Sulphur dioxide has a potential for serious damage to plants by contributing to acid rains. As said earlier, these rains leach nutrients from soil and foliage, and affect soil organisms responsible for nitrogen fixation. Acids enhance the uptake by plants, of toxic heavy metals from soil. This has seriously effected the existing conifer forests in Europe and Western United States.

10.7.2 On Animals

Though many pollutants are absorbed by animal tissues from the contaminated food eaten. Animals can be directly affected by pollutants in the air. The following discussion will concentrate on the effects of air pollutants on man, since the effects on animals is much the same as on man.

An average adult breathes approximately 14,000 litres of air per day. This air is cleared by various filtering devices in the nasal passage and lungs. Large particles breathed in, are trapped by hair in the nose. Soft spiral bones in the nasal passage break the air into narrow whirling streams from which smaller particles are forced against the sticky walls of the passage. Other impurities are caught in the trachea and bronchi by a thin layer of mucous which is propelled like an undulating blanket towards the throat, where both mucous and impurities are spat out. In the lungs, the tiny air sacs or alveoli are protected by scavenger cells that engulf many of the smaller particles that penetrate this system of defence.

These filtering mechanisms work well enough in the normal atmospheric conditions. But, in many cities the atmosphere is so charged with pollutants that these mechanisms are put under intolerable strain. Moreover, many of the most dangerous pollutants are attached to dust particles of so small size that they evade the filtering mechanisms altogether, while others in the gaseous form eventually pass into the blood. One of the most serious effects of certain pollutants is to slow down the rate at which oxygen is passed from the alveoli into the blood stream. This puts an additional load, not only on the lungs, but also on the heart. That is why protracted smog is fatal to people with heart and respiratory diseases (Fig. 10.8).

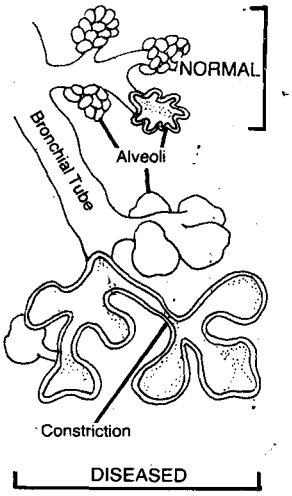


Fig. 10.8 Bronchitis-emphysema, a disease caused or aggravated by air pollution. In the normal lung, the bronchial tubes branch into millions of alveoli where transfer of oxygen to blood takes place. In a diseased lung, alveoli coalesce reducing the area for oxygen transfer. Also, bronchi are constricted reducing the rate at which air is exchanged.

Ozone and PAN, both components of photochemical smog, irritate eyes, impair vision, make breathing difficult, and aggravate asthama.

SO_2 in the air, obstructs breathing and irritates eyes. But, its effect is far greater when it gets adsorbed on moist tissues in the lungs. It forms sulphuric acid which burns into the lungs and causes respiratory ailments. Nitric acid, similarly formed, also causes respiratory ailments in a like manner. Both NO_2 and SO_2 contribute to acid rain. Acid rain can have a very adverse effect on aquatic life. Certain fish cannot tolerate even small fluctuations in pH, with the result that acid rain over streams and lakes has greatly affected fish populations. As mentioned earlier, in Swedish streams, salmon and trout have disappeared where the pH has fallen below 5.

Lead is poured into the atmosphere through automobile exhaust. When inhaled, it accumulates in bones and other tissues, threatening to cause irreversible brain and kidney damage. Young children are most vulnerable because their nervous systems are still developing. Excessive absorption of lead can decrease a child's intelligence, shorten his or her attention span, cause learning disabilities or cause hyperactivity. Elevated blood lead levels in adult males have been linked to high blood pressures indicating that many heart attacks may be brought on by lead in the systems.

Carbon monoxide (CO), is encountered in auto exhaust fumes and incomplete burning of any organic material. The gas is colourless and odourless, but very poisonous to living things. CO reduces the oxygen carrying capacity of the blood by combining with haemoglobin to form carboxyhaemoglobin. And thus it brings about asphyxiation. In minute quantities, it can cause breathlessness and tiredness.

SAQ 4

Tick (√) for the right answers.

i) Temperature inversions are responsible for the occurrence of
   a) the greenhouse effect

b) microclimates
c) smog
d) heat islands

ii) Which of the following is held responsible for the depletion of earth's ozone layer?
a) Chlorofluorocarbons
b) Methane
c) Carbon dioxide
d) Sulfuric acid

iii) Peroxyacetyl nitrate (PAN) kills plants by
a) aging them prematurely
b) shutting down photosynthesis
c) depleting their food
d) leaching its nutrients

iv) Lead in the atmosphere can cause
a) brain damage
b) respiratory ailments
c) itching eyes
d) breathlessness

10.8 SUMMARY

In this Unit you have learnt that :

- the air consists of 78% of nitrogen, 21% of oxygen, and 1.0% of argon and other inert gases. The amount of carbon dioxide in the atmosphere varies from 0.1% to 0.3%. The other gases such as sulphur dioxide, nitrogen dioxide, ozone, etc. are found in very small quantities. Atmospheric pollution, is an unwanted change in the quality of the earth's atmosphere.

- human activities are the main contributors to air pollution. These are stationary combustion sources, mobile combustion sources and manufacturing sources. Significant pollutants include sulphur oxides, nitrogen oxides, carbon monoxide, and particulate matter.

- radiation from radioactive substances is also creating a large scale environmental problem. It has several biological ill effects including genetic damage. Besides the small doses of radioactive emissions we are regularly exposed to natural and man-made sources, the threat of dangerous levels and large amounts of radiation released by nuclear accidents also exists. A serious environmental problem is to do with the safe and proper disposal of radioactive wastes.

- noise defined as unwanted sound is becoming a menace these days. It is also a pollutor of atmosphere, though in a different sense. It causes anxiety, stress, fright, loss of hearing and other physiological and psychological effects.

- under average meteorological conditions, air temperature drops steadily with altitude. However, if the upper air is warmer than the air beneath it, the atmosphere becomes very stable, and pollutants are trapped under the warm air. This condition is referred to as **atmospheric inversion.**

- air pollution can affect global temperature. The increased concentration of carbon dioxide, methane and other gases absorb infrared radiation from earth and prevent its escape and may thus cause a warming known as the **Greenhouse effect.**

- another air pollutant which is causing much concern these days is—chlorofluorocarbons, they reach upto ozone layer and destroy the ozone layer by catalysing its decomposition to oxygen. Since ozone acts as a shield against the harmful ultraviolet rays reaching earth's surface, ozone depletion loss may result in increase in human skin cancer and other stresses on biosphere.

- oxides of nitrogen and of sulphur react in the atmosphere to produce strong acids. which precipitate in the form of acid rain, snow or dust. This acidic precipitation

has caused extensive destruction of forests and fisheries, as well as damage to masonry, metals and other materials. Automobile exhaust in the presence of sunlight forms photochemical smog. The photochemical smog has several adverse effects on biological systems.

- air pollution in general affects biological systems in different ways, ultimately killing sensitive plants and animals.

10.9 TERMINAL QUESTIONS

1) State whether the following statements are true or false.
   a) Air in its natural state is pure.
   b) Natural air consists of gases, dust and water-vapour.
   c) Air is polluted mainly through combustion.
   b) Chlorofluorocarbons accelerates the breaking process of ozone.
   e) Chlorofluorocarbons accelerates the breaking and making process of ozone.

2) Write answers in four or five lines.
   a) Distinguish between London-smog and photochemical smog.

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   b) What is the greenhouse effect?

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   c) What is acid rain?

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   d) How is the Taj Mahal affected by acid rain?

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   e) How would depletion of ozone from the stratosphere affect human life?

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10.10 ANSWERS

Self Assessment Questions

1) i) T ii) T

2) Please refer Section 10.3.3

3) i) Sulphur dioxide
ii) Carbon monoxide
iii) 35
iv) 45, 35, 80

4) i) c ii) a iii) b iv) a

Terminal Questions

1) a) T b) T c) T d) F e) T

2) a) London-smog is a mixture of smoke, fog, ash, dust and sulphur dioxide. Photochemical smog is the result of interaction between hydrocarbons and nitrogen oxides from auto exhaust, in the presence of sunlight. Ozone and PAN, the products of this synergistic reaction, are capable of causing more damage than the original reactants.

b) Carbon dioxide produced from burning coal, remains trapped in our atmosphere. It prevents solar energy reflected from the earth's surface from re-radiating into space. This warms the earth's atmosphere, resulting in what is known as the greenhouse effect.

c) Sulphur dioxide gas released into the atmosphere by industrial plants absorbs on water droplets and moist dust particles. These condense and precipitate as acid rain.

d) Sulphur dioxide emitted by the Mathura crude-oil refineries are the source of acid rain on the Taj Mahal. Acid rain is causing corrosion and flaking of the marble of which the Taj Mahal is built.

e) If the protective layer of ozone in the stratosphere is destroyed, ultraviolet radiations from the sun would penetrate the earth's atmosphere. This would result in an increase in skin cancers and melanomas.