Unit 3

ENVIRONMENTAL CHEMISTRY

General Introduction

The word *environment,* derived from Greek, literally means *surroundings.* The term encompasses the surrounding objects, regions, conditions and especially circumstances of life of all living beings. *Environmental chemistry* deals with the study of chemical phenomena in the environment. It includes the study of the sources, reactions and fates of the chemical species in the air, water and soil environments. It is, in fact, multi-disciplinary in the sense that it embraces chemistry, physics, life sciences, agricultural science, public health and a lot of other disciplines. It is an important part of the general environmental studies and the studies on the effects of human activities upon environmental segments.

The study of the interactions between the different types of living organisms as well as that between the living organisms and the non-living components of the environment is called *ecology* or *environmental biology.*

In his attempt to modify the environment and improve the quality of his life, man has interfered constantly with the environment and this has raised very many environmental issues which threaten the very sustenance of life on earth. It is in this context that *environmental education* assumes importance. It aims at enlightening the public about the grave environmental issues, the importance of protection and conservation of our environment and the need for restraint in all activities which would harm the environment.

Environment

Environment can be defined as the sum total of all social, economical, biological, physical and chemical factors which constitute the surroundings and influence the life of a living organism in its habitat.

Environment consists of the following three components :

1. *Abiotic or non-living component* : This consists of the lithosphere (solid earth), hydrosphere (water component) and atmosphere (gaseous envelope).
2. *Biotic or living component* : This consists of all living organisms.
3. *Energy component* : This includes solar energy, geochemical energy, thermoelectrical energy, hydroelectrical energy, nuclear energy, etc.

Segments of Environment

The environment consists of four segments, namely *atmosphere, hydrosphere, lithosphere* and *biosphere.*

(i) Atmosphere : *Atmosphere* is the protective cover of gases surrounding the earth which sustains life on earth and saves it from the hostile environment of outer space. On account of gravitational force, this envelope has the maximum density at the sea-level, but thins rapidly towards the upper regions. Its major components are nitrogen and oxygen. It also contains some CO_2, argon and ozone as well as traces of He, Ne, CH_4, etc.

The atmosphere serves several functions :

1. It absorbs most of the cosmic rays and all the harmful solar radiations. It allows only the near ultraviolet, near infrared and radiofrequency waves to pass through it towards the earth.
2. It absorbs part of infrared radiation emitted by the sun and also that re-emitted by the earth. It thereby maintains the *thermal balance* of the earth.
3. It acts as the source of oxygen for living organisms, CO_2 for plants and nitrogen for plants, nitrogen-fixing bacteria, etc.
4. It acts as the vital carrier of water from the oceans to land as part of the hydrological cycle.

(ii) Hydrosphere : *Hydrosphere* includes all types of water resources, namely oceans, seas, rivers, lakes, streams, glaciers, polar ice caps, ground water, etc. About 97% of earth's water is in the oceans and about 2% is tied up in the polar ice caps and glaciers. Thus, only about 1% is available in fresh water bodies like the rivers, lakes, streams, etc. and as ground water which is fit for human consumption and for other uses.

(iii) Lithosphere : *Lithosphere* is the outer mantle of solid earth, consisting of minerals occurring in the earth's crust in the form of soil, rocks, etc. *Soil,* in fact, comprises of a mixture of minerals, organic matter, weathered rocks, air and water. Rocks consist of various minerals like asbestos, gypsum, clay, haematite, calcite, quartz, etc.

(iv) Biosphere : *Biosphere* denotes the realm of living organism and their interactions with the environment, namely lithosphere, hydrosphere and atmosphere. Thus, in the biosphere, living organisms, *e.g.* plants and animals, live together being dependent on each other and also interact with other segments of the environment.

ENVIRONMENTAL POLLUTION

Pollution and pollutant

The contamination of any part of our environment, particularly through human activities, by undesirable substances which ultimately have a detrimental effect on the environment is called *environmental pollution.*

Any substance present in nature in quantities greater than natural abundance due to human activities, and which is ultimately harmful to the environment and therefrom to the living systems, is called a *pollutant.* In short, any substance or agent or factor that causes environmental pollution is known as a *pollutant.*

Pollutants may be of several types depending upon where each pollutant acts. Thus, there are *air pollutants, water pollutants, soil pollutants*, etc. *e.g.,* Gases such as CO, SO_2, NO_2, etc. are air pollutants, pesticides, fertilizers, detergents, acids, salts, etc. are water pollutants whereas metals and their compounds, plastics, fertilizers, pesticides, etc. are soil pollutants. One and the same substance may pollute air, water and soil at the same time.

Pollutants may broadly be classified also into the following types.

(i) *Degradable or non-persistent pollutants* are those which are degradable by natural processes. *e.g.,* Vegetable waste, domestic sewage, etc.

(ii) *Slowly degradable or persistent pollutants* are those which remain in the environment in an unchanged form for many decades, *e.g.,* Pesticides such as DDT, plastics, many chemicals, nuclear wastes, etc.

(iii) *Non-degradable pollutants* are those that are not broken down by natural processes and therefore continue to accumulate in the environment from continued release. *e.g.,* Toxic metals like lead, cadmium, mercury, etc.

Environmental pollution is directly related to the unbridled human population explosion and the rapid strides in urbanization and industrialization. It has now assumed global magnitude and its frontiers are no more confined to any particular part of our planet. It poisons the whole biosphere, brings about unfavourable changes in climate and other environmental conditions and poses a serious threat to the normal existence of living organisms.

WATER POLLUTION

Introduction

Water pollution is the contamination of water by foreign substances which unfavourably alter its quality and characteristics such that its normal functions and usefulness in domestic, agricultural, industrial, etc. fields are adversely affected or it constitutes a health hazard to living things.

Water pollution has emerged as one of the most significant environmental problems of recent times. The major reasons for water pollution are none other than human activities. Man has caused the deterioration of the quality of water in all our fresh water bodies by discharging undesired and toxic substances into them. It is a pity that our fresh water streams and rivers have now been turned into mere chemical drains or sewage canals. Pure water, the elixir of life, is now a precious commodity.

The major sources of water pollution include domestic waste from urban and rural areas, industrial effluents, agricultural run-off water, etc. which are discharged into our natural water bodies.

Pollutants of water and their toxic effects

A water pollutant is a substance, agent or factor which degrades the quality of water so as to cause detrimental effects on consumers or on aquatic life.

Examples for water pollutants are sewage, detergents, toxic heavy metals, fertilizers, pesticides, hazardous organic substances, etc.

A brief discussion on some of the water pollutants is attempted here.

a) Water pollution by sewage

Sewage consists of organic and inorganic waste matter of the community carried by water. Broadly, we can say that it consists of less than 1% solids and more than 99% water. Among the solids present, 70% is usually organic materials, namely proteins, carbohydrates, fats, etc. The inorganic fraction consists of grit, salts, metals, etc. in varying proportions.

In most cases, the domestic sewage is generally discharged as such into the nearby water bodies like rivers, lakes or coastal waters where it can cause severe sanitary and other water pollution problems. Some are mentioned below:

1. Sewage induces a foul odour or stench to water, imparts colour to it and causes turbidity.
2. As sewage contains human and animal excreta, it is the carrier of several pathogenic microorganisms. The water pollution by sewage can cause immense harm to public health by spreading diseases. Typhoid, paratyphoid, cholera, polio, etc. are waterborne diseases.
3. Organic pollution of water by sewage causes dissolved oxygen depletion because the microbial degradation of these organic substances consumes dissolved oxygen. This leads to fish kills.
4. Sewage contains huge quantities of nutrients in the form of nitrogen and phosphorus. This leads to *eutrophication* which favours algal growth and results

in algal bloom. [The process of increase in the nutrients of waters which results in a spurt in algal productivity is called *eutrophication* (Greek : meaning 'well-nourished')]. Large amounts of dissolved oxygen gets depleted for algal biological activities and this again leads to destruction of aquatic organisms. Further, the excessive growth of algae and other aquatic weeds presents an unaesthetic scene and disturbs the transportational and recreational uses of water.

Control of pollution by sewage can be achieved to some extent by sewage treatment before discharge. The process involves various steps. Primary treatment removes settleable solids physically or chemically. Secondary treatment or biological treatment using aerobic and anaerobic microorganisms removes organic matter. Tertiary treatment involves advanced biological, chemical and physical treatment and also recycling.

b) Water pollution by industrial effluents

The industrial effluents discharged into our fresh water bodies have the greatest potential to pollute water. The effluent may contain pollutants of all kinds ranging from simple nutrients and organic matter to complex substances and can cause serious problems.

1. Effluents from pulp and paper mills, sugar factories, organic chemical plants, pharmaceutical plants, dairies, tanneries, distilleries, etc. substantially pollute water bodies with organic matter. These organic materials cause the depletion of dissolved oxygen and many of them are highly poisonous to aquatic and terrestrial living organisms including man.
2. The effluents from fertilizer industries release substantial quantities of nutrients into water bodies causing *eutrophication*. Mineral constituents render water excessively hard and make it unsuitable for domestic and industrial purposes.
3. Wastes released into water from metal plating industries contain large quantities of heavy metals and cyanide. These are extremely toxic to all organisms.
4. Effluents from chemical factories contain acidic and alkaline compounds which make water corrosive and are harmful to aquatic organisms.
5. Paper mills release effluents containing mercuric compounds which are used as fungicides. These are highly poisonous and carcinogenic.
6. Radioactive wastes discharged into water from uranium plants and atomic energy plants cause radiation pollution.
7. Wastes from tanneries contain pathogenic bacteria like 'anthrax bacilli' and are very harmful to all organisms.

In order to control water pollution from industrial effluents, it is absolutely nec-

essary that they should be treated before discharged. Treatment involves, primarily, chemical treatment to bring about neutralization coagulation, oxidation, etc. Secondary treatment uses microorganisms and tertiary treatment involves advanced biological, chemical and physical methods and recycling.

c) Water pollution by soaps and detergents

Domestic sewage and effluents from soap and detergent factories introduce a large quantity of soaps and detergents into fresh water bodies. Soaps are easily degraded by microorganisms and pose no serious problems to the receiving water with respect to degradability. However, they are hydrolysed to the corresponding fatty acids which, in turn, increase the organic content of water. This leads to depletion of dissolved oxygen in water destroying aquatic organisms. Soaps also cause turbidity in water.

Detergents belonging to the tetrapropylene benzene sulphonate (TPBS) category have the greatest disadvantage that they are not fully biodegradable by microorganisms. Such detergents do an excellent job of cleaning, but are not degraded in sewage treatment plants and thus make their way from washing buckets and washing machines directly to the water bodies. These when introduced into water will persist for a long time in water, first forming an unstable suspension and then settling to the bottom as sediments. Detergents belonging to the linear alkyl benzene sulphonate (LAS) class and non-ionic esters of sucrose are much more biodegradable.

The presence of detergents causes foaming in sewage treatment plants as well as in the receiving waters, thereby reducing the aeration of waters. Aeration rates in rivers is reduced much by the presence of even as low as 0.5 ppm quantities of detergents. This leads to anaerobic conditions and accumulation of toxic substances like H_2S in water. Detergents also temporarily prevent the biodegradation of lipophilic molecules by forming micelles with them. Phosphate containing detergents cause *eutrophication* in receiving waters. Precipitation of calcium salts of detergents impedes the flow of water through soil since they form a gel-like layer.

Most importantly, detergents cause a variety of acute and long term effects on various organisms. They are directly toxic to several species of animals and plants in water and suppress their growth. Many of them impair the selective permeability of cell membranes, interact with enzymes and cause alteration in the infrastructure of the cell. They damage the external sensory organs of many organisms, affecting their food search and capturing capacity.

d) Pesticides

Pesticides like *DDT, chlordane, lindane, malathion, parathion, baygon,* etc. enter our water bodies by a number of ways such as by agricultural run-off, deposition

from air and by direct sprays on water surface to kill mosquitoes and other pests. Once they enter into the aquatic ecosystem, they concentrate in all components of the system. They remain in water persistently in soluble or suspended form or get absorbed on the surface of silt and organic particles which sediment. From there, they enter into the food chain through bacteria, phytoplankton, other aquatic organisms and so on. By the process of *biomagnification*, the concentration of the pesticide residues increases on moving up in the food chain. In organisms placed at the end of the food chains like fish, aquatic birds and man, they are liable to accumulate in a very high concentration. These are highly toxic and lethal to all types of living organisms including animals and plants. They kill and destroy all organisms.

In humans, pesticide residues persist in various parts of the body. The chlorinated hydrocarbons mainly affect the central nervous system while others affect the circulatory or reproductive systems. They accumulate persistently in various parts of the body and exert their toxic influence. They can cause cancers, hypertension, sterility, damage to kidney and death at higher concentrations. Their toxic effects on humans are mentioned below:

1. Excessive concentrations of chlorinated hydrocarbon pesticides in human tissues cause hormonal imbalance, cancer of the organs, leukemia, etc.
2. Organophosphate pesticides interfere with the transmission of nerve impulses, causing unconditioned tremors, spasms, convulsions and paralysis.
3. Pesticides inhibit production and functioning of sex hormones, leading to sterility.
4. Higher concentrations of pesticides in pregnant women may result in abortions, still births and infant deformities.
5. Pesticides cause hypertension and damage to kidneys.
6. In higher concentrations, they cause death.

Pesticides exert their toxicity on microorganisms, aquatic organisms, plants, animals and birds as well, causing death and destruction. Several types of fish, crabs, fish-eating birds, etc. have been wiped out, or their population decreased, in various regions of the earth on account of pesticide pollution.

e) Fertilizers

Modern methods of agriculture, since the so called *green revolution*, use immense quantities of nitrogenous, phosphatic and potash fertilizers. In most cases, a large excess of fertilizer than needed is being added to the fields. As a result, a large quantity of these are carried from the fields by agricultural run-off water into fresh water bodies causing pollution problems.

Contamination of water by fertilizers leads to very undesirable effects. In a large

measure, this contamination results from phosphate and nitrate ions present in fertilizers. These make fresh water bodies *nutrient-rich.* This is called *eutrophication.* This favours massive algal growth. Such algal blooms in a water body cause depletion of dissolved oxygen and thereby tends to choke out other forms of aquatic life, making it a dead pool of water. Further, the excessive growth of algae and other aquatic weeds destroys the natural beauty in and around the water body and obstructively prevent the recreational and transportational uses of water.

When water polluted with nitrates is consumed by humans, nitrates are reduced to nitrites by intestinal bacteria. Nitrites cause the serious child disease *methemoglobinaemia* ('blue baby syndrome') in which nitrite interferes with the oxygen-carrying capacity of blood causing suffocation as well as damage to respiratory and vascular systems.

Control of water pollution by fertilizers can be achieved by the use of *biofertilizers.* These involve the use of efficient strains of microorganisms like *Rhizobium, Azospirillum, Azobacter,* etc. or blue green algae capable of converting atmospheric nitrogen into nitrate or those like *PSM* capable of solubilizing phosphorus from the fixed form. They are cheaper, renewable and pollution-free.

Due to a lack of proper education to the farmers and a lack of proper marketing and distribution methods, biofertilizers are not much used nowadays. But these may replace the chemical fertilizers in future.

f) Heavy metals

Substantial pollution by heavy metals is caused by discharge of effluents from mining and ore-processing, metal plating, chemical, paint, leather and a host of other industries. Heavy metals are discharged into water by domestic sewage, agricultural run-off, water from corroded metal pipes, etc. also.

1. *Lead* : Lead-pollution of natural waters is caused by effluents from a large number of industries such as petroleum, paint, ceramics, battery and plastics, burning of leaded gasoline, use of the pesticide lead arsenate, etc.

Lead is highly toxic to all living organisms. Lead affects aquatic organisms even in very small concentrations. In animals and man, lead accumulates mainly in the bones from where it comes into circulation in the body, particularly at the time of stress or illness. Lead interacts with the –SH group in proteins and enzymes causing their denaturation. This leads to the break down of several enzyme systems. Lead causes anaemia, disruption of haemoglobin synthesis as well as damage to nervous system, kidneys and brain. Lead toxicity is more acute in children than in adults.

2. *Mercury* : Effluents from various industries such as electrochemical industry and those manufacturing batteries, caustic soda, mercury vapour lamps, etc., and efflu-

ents from metallurgical operations introduce substantial amounts of mercury into water.

Mercury is highly toxic to all aquatic as well as terrestrial organisms. It has a tremendous capacity to bioaccumulate in the form of methylmercury. It further tends to biomagnify through food chains, ultimately causing brain damage in consumers at higher trophic levels. This was evidenced when many normally fish-eating people of the Minamata city of Japan died in 1960 by irreversible brain damage. This was caused by the mercury present in the effluents run into the Minamata bay from a chemical factory situated there.

3. *Cadmium* : Cadmium is introduced into natural waters through effluents from electroplating, paint, ink, plastics, etc. industries and from gold jewellery works. Like mercury, cadmium also undergoes biomagnification through food chains reaching its maximum level in man.

Cadmium persistently accumulates in liver, kidneys, pancreas and thyroid in humans. At high levels, it causes damage to lungs, kidney, etc. and causes anaemia and bone marrow depression.

A typical example of cadmium poisoning in the past was the outbreak of *'itai itai'* or 'ouch ouch' disease (so named to indicate the terrible pain associated with it) in the Jintsu River basin in Japan. The disease made bones fragile. Thousands of people died through microfracture of bones and thousands were affected by this bone disease. The disease was caused by the consumption of cadmium-ingested rice from the fields irrigated using water from the Jintsu river. The river was contaminated with cadmium by drainage water from the surrounding mines.

4. *Chromium* : Natural waters get polluted with chromium by effluents from metal plating industries. It is toxic to aquatic and terrestrial organisms. In humans, it causes skin and respiratory disorders and respiratory tract cancer.

5. *Arsenic* : Arsenic pollutes water bodies through pesticides, (*e.g.*, lead arsenate), chemical waste and effluents from mining industries.

It is highly toxic to all types of organisms (as is evidenced by the fact that arsenic compounds have been used as pesticides for hundreds of years). It inhibits the action of enzymes which catalyse cellular reactions. It kills at high levels of concentration and causes cancer on accumulation at lower levels.

Bioaccumulation and biomagnification

Pollutants which can accumulate in organisms are called *persistent substances* or *biologically accumulative substances* and the process is called ***biological accumulation*** or ***bioaccumulation***. *e.g.*, Fairly large quantities of certain heavy metals or

pesticides can accumulate in aquatic organisms on account of the persistent nature of these pollutants.

Biological magnification or ***biomagnification*** is the process in which a stable and non-biodegradable persistent pollutant increases in concentration at each higher trophic (nutritional) level as it is passed successively from one organism to another through the food chain.

Biomagnification occurs when a persistent pollutant gets accumulated in lower organisms and these are consumed by another organism at a higher trophic level. The food is metabolized and excreted, but the persistent pollutant is retained in the larger organism. Since the larger organism feeds upon a large number of such lower organisms in its life span, the persistent pollutant increases in concentration inside the organism. This process continues up into the higher trophic levels in the food chain with a build up of greater concentration of the pollutant in the larger organism at each level. The concentration of the pollutant will be maximum in that organism which is at the topmost position in the food chain. In many cases, man occupies this top position and thus suffers the effect of the toxic pollutant to the maximum extent.

The transition of a persistent pollutant in an aqueous ecosystem along the food chain with biomagnification is schematically represented in Fig. 3.1.

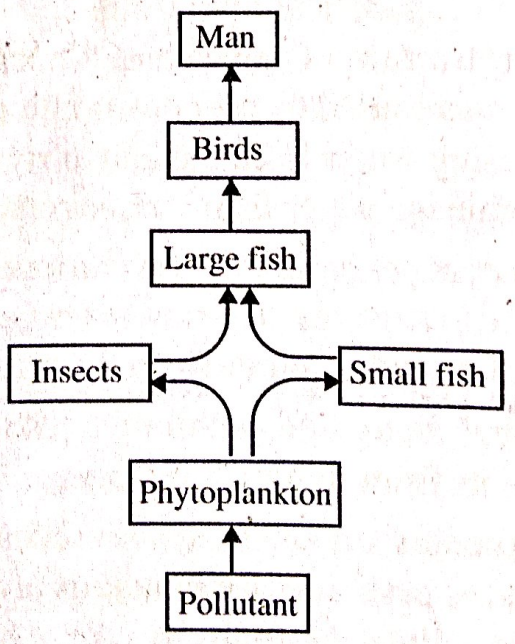

Fig. 3.1 : Schematic representation of biomagnification in the food chain

The residues of many toxic pesticides (like the organochlorine pesticides) and heavy metals become concentrated in humans by biomagnification. Further, the persistent pesticides get distributed even to remote places through food chains. DDT, a persistent pesticide, has been found even in the bodies of penguins of Antartica where it has never been used.

Detrimental effects of water pollution: a synopsis

Some of the important adverse effects of water pollution are summarised below:

1. Water pollution by *domestic sewage* leads to induction of various pathogenic organisms into water and this causes the spreading of various diseases like typhoid, cholera, etc. It also causes *eutrophication* and algal bloom leading to depletion of dissolved oxygen, thereby affecting aquatic life. Further, it causes a foul odour and taste to water.
2. Water pollution by *industrial effluents* leads to a concentration of highly toxic organic, inorganic and metallic components in water and this causes destruction of aquatic population as well as terrestrial plants and animals.
3. Pollution of water by *soaps and detergents* causes *eutrophication,* algal bloom, depletion of dissolved oxygen in water and *foaming.* Further, being toxic, they destroy several organisms.
4. Pollution of water by highly toxic *pesticides* leads to the massive destruction of aquatic organisms and all those who consume pesticide-polluted water.
5. Water pollution by *fertilizers* causes *eutrophication,* algal bloom and the subsequent depletion of dissolved oxygen, leading to the destruction of aquatic population. Water polluted by fertilizers is also highly harmful to humans and causes various diseases such as the 'blue baby syndrome'.
6. Pollution of water by *heavy metal ions* is highly harmful to all organisms. These persistent pollutants enter the food chain and, by the processes of *bioaccumulation* and *biomagnification,* destroy the consumers by their toxic action. Man, at the end of the food chain, suffers the maximum toxic effects of these metal ions.
7. Pollution of water by *radioactive materials* from mining and ore-processing industries, nuclear power plants, etc. and from the use of radioisotopes in industry, medicine, research, etc. is a major radiation hazard to all living organisms.
8. *Oil pollution* destroys marine life, water birds, coastal plants, etc.
9. *Thermal pollution* destroys aquatic life.

Control of water pollution

Some of the steps that have to be taken to prevent or control water pollution are given below:

1. Sewage should be first treated in sewage treatment plants before it is let off into water bodies.
2. Treatment of industrial effluents to remove as much pollutants from them as possible should be made compulsory and, instead of discharging them into fresh water bodies, they may be discharged into outer sea.

3. Non-biodegradable detergents should be banned.
4. Use of chemical fertilizers and pesticides should be minimised. As far as possible, *biofertilizers* and less persistent pesticides should be used.
5. Sources of drinking water should be protected from all possible means of infiltration by harmful chemicals and pathogenic organisms.
6. Drainage system in cities, towns and villages should be improved and the seeping of impure water into wells and tanks should be prevented by proper means.
7. Eutrophication and algal blooms leading to depletion of dissolved oxygen should be prevented.
8. Laws should be enforced to ensure harmless disposal of wastes from shops, factories and other enterprises.

Water quality parameters

In order to assess the quality of water, physical, chemical and microbial analysis is very essential.

The quality of water is usually expressed in terms several of its characteristics, such as colour, taste, turbidity, pH, salinity, electrical conductivity, etc. Three of the parameters commonly used to express water quality are (i) *dissolved oxygen* (D.O), *biochemical oxygen demand* (BOD) and *chemical oxygen demand* (COD).

(i) *Dissolved oxygen (D.O)*

Dissolved oxygen is a fundamental requirement for the maintenance of life for aquatic population. It is an important parameter of the extent of water purity or the extent of pollution associated with it. In most waters, varying concentrations of dissolved oxygen are found. This is because the amount depends upon the solubility of oxygen in each type of water which, in turn, is greatly influenced by temperature, pressure, salinity, etc.

Dissolved oxygen (D.O) is expressed as the weight of oxygen in milligrams present per litre of water or as parts per million (ppm).

The optimum value of D.O for good water quality is 4–6 mg/L. This would ensure healthy aquatic life in a water body.

When oxygen demanding substances such as organic matter, reducing agents, etc. are present in water, their oxidation by microorganisms consumes the dissolved oxygen and its level falls. When the level of D.O falls below the minimum critical value required to ensure healthy aquatic life, it indicates pollution of water.

Dissolved oxygen is usually determined iodometrically. D.O is allowed to react with KI to liberate I_2 which is then titrated with standard sodium thiosulphate solu-

tion. Alternatively, D.O may first be treated with Mn^{2+} in strongly alkaline medium to quantitatively precipitate MnO_2. The MnO_2 is then estimated iodometrically in acid medium.

(ii) *Biochemical oxygen demand (BOD)*

Biodegradation of organic matter into simple inorganic molecules by aquatic microorganisms takes place using dissolved oxygen. So, the amount of dissolved oxygen consumed by microorganisms in the process is a measure of the quantity of organic matter present in water or, in other words, a measure of the organic pollution in water. This is expressed as *biochemical oxygen demand* (BOD).

Biochemical oxygen demand (BOD) of a sample of water is the amount of dissolved oxygen used up by suitable aquatic microorganisms for the oxidation of organic matter present in a well-aerated sample of water incubated for a period of five days at 20°C.

BOD of a water sample is determined by finding out the amount of dissolved oxygen in it before and after its incubation for 5 days in the dark at 20°C. The difference between the initial and final values is the actual BOD. Before incubating the sample, it is well aerated to ensure that oxygen is present throughout the period of incubation. In domestic waste waters or surface waters, microorganisms will be sufficiently present, but if the sample is deficient in microorganisms, they have to be introduced before incubation. This is usually done by adding settled domestic waste water stored for 24-36 hours at 20°C.

BOD is usually expressed in mg of oxygen/litre of water or as parts per million (ppm). Water may be considered fairly pure if the BOD is only 1–3 mg L^{-1}. Higher BOD's indicate pollution. Untreated sewage, barnyard run off water, etc. often have BOD's of the order of hundreds or thousands.

BOD test is empirical and semi-quantitative although the result could be considered as an indication of the quality of a water source. The selection of the microorganisms used as 'seed' is very important and the results are often not reproducible.

(iii) *Chemical oxygen demand (COD)*

Chemical oxygen demand (COD) of a sample of water is the oxygen equivalent required for the oxidation of organic matter in water determined with the help of a strong chemical oxidant, usually potassium dichromate in acid medium.

COD test involves boiling the water sample for two hours with excess of standard potassium dichromate in presence of sulphuric acid. The unreacted potassium dichromate is then determined by titration against standard ferrous ammonium sulphate and the oxygen equivalent of the reacted dichromate calculated.

COD is a rapidly measureable parameter for water samples, particularly useful for industrial waste water studies. Since some compounds other than those biologically degradable may get oxidised by dichromate, the COD value is always higher than the BOD of the sample. Any COD value higher than 250 ppm is regarded as indicative of pollution.

PURIFICATION OF WATER

Potable water

The purification of water needed for drinking purposes in towns and cities is a matter of great importance with regard to public health. The actual methods used may vary from one place to another, but all such methods aim at (i) eliminating health hazards and sanitary defects, (ii) removal of colour or turbidity and suspended impurities, (iii) destroying the bacteria and viruses and (iv) restricting the presence of soluble mineral salts within the prescribed limits. The following steps are generally involved in the process.

a) Pre-treatment

(i) ***Storage : Sedimentation of suspended impurities :*** The raw water drawn from a water body is stored for some period in a large tank. This is to improve the quality of water by natural sedimentation of silt and suspended impurities. This also brings about an inactivation of several pathogenic organisms including enteric viruses.

(ii) ***Pre-chlorination :*** If water contains greater quantities of algae and microorganisms, it is chlorinated to improve the water quality. The process will also reduce any colour present in water.

(iii) ***Aeration :*** Aeration is carried out by blowing air through water or by spraying water in air. The suspended organic matter and Fe^{2+}, Mn^{2+}, etc. are oxidised and settle down. The process also eliminates gases like free CO_2, H_2S, etc. present in water and removes disagreeable taste and odour.

b) Coagulation

The impurity particles in the colloidal range are coagulated through promotion of their aggregation by adding a coagulant in required quantities, followed by gentle mechanical agitation. The common coagulant used is *alum.* The aggregated particles are commonly called *floccules* and the bulky precipitate thus formed is called *floc.*

c) Sedimentation

Water containing floc is kept stationary for some time in a sedimentation tank to allow the floccule particles to settle under the influence of gravity.

d) Filtration

Water is then filtered by passing through a porous medium, usually a *sand filter* consisting of a bed of sand. The sand retains all the suspended matter including floc and also removes the microorganisms still present in water. The filters are cleaned periodically of the clogged suspended matter by a *backwash* or reverse flow of water under pressure.

e) Disinfection

The clear filtrate from sand filters may still contain some bacteria and viruses. So, *disinfection* of the water is carried out to reduce the microbial populations to a safe level and to get hygenically safe water. This is commonly done by one of the following methods.

(i) ***Chlorination*** : Addition of liquid chlorine or bleaching powder in minimum required quantities is one of the most effective methods commonly used for sterilizing water. Chlorine yields hypochlorous acid (HOCl) in water which kills bacteria and viruses by oxidising proteins and reversibly denaturing the essential cellular enzymes.

$$CaOCl_2 + H_2O \longrightarrow Ca(OH)_2 + Cl_2$$
$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$
$$HOCl \longrightarrow HCl + [O]$$

Chlorine, however, imparts a rather disagreeable taste and odour to water.

(ii) ***Treatment with ozone*** : Ozonised air is either bubbled through water or it is passed up a tower, divided into compartments by perforated celluloid partitions, down which water is percolating. Ozone, being a very good oxidising agent, oxidises and destroys bacteria, fungi and viruses. The process does not introduce any disagreeable taste or odour to water, but is rather expensive.

(iii) ***Aeration*** : Air is blown through water or water is sprayed in air. On aeration, the organic matter gets oxidised and settle down. The process also eliminates carbon dioxide as well as disagreeable taste and odour.

(iv) ***Other disinfection processes*** : The disinfection of water can be carried out by exposing water to ultraviolet radiation which kills the bacteria and viruses in water quite effectively.

In another technique, electric current is passed through water containing a silver anode and a graphite or stainless steel cathode. The silver ions produced, which have great bactericidal properties, react with most bacteria to form a slime which can be filtered out. These methods are suitable for disinfecting smaller quantities of water.

(v) *Storage and supply* : The potable water thus obtained is stored and supplied to the public. The general steps involved in water purification for drinking purposes are schematically shown in Fig. 3.2.

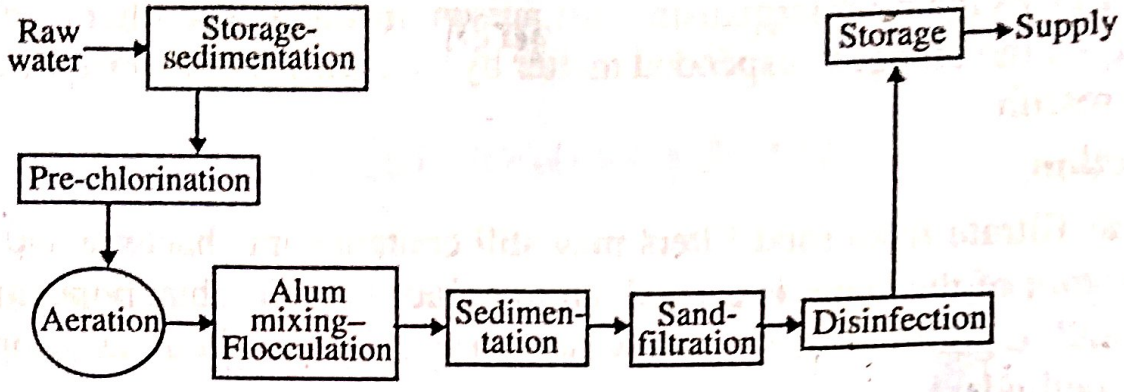

Fig. 3.2 : Important steps involved in purification of water for drinking purposes

Demineralisation (Desalination) of water : The ion-exchange process

The process of removing all the impurity ions present in water is known as *'demineralisation of water'* or *'deionization of water'*. The resulting water is known as *'demineralised water'* or *'deionized water.* Since the process involves the removal of all the saline impurities from water, it is also sometimes called *desalination* or *desalting* of water.

One method of demineralising water is by using organic cation-exchange resins and anion-exchange resins. *Ion-exchange resins* are insoluble cross-linked long chain organic polymers having functional groups suitable for the ion-exchange purpose. *Cation-exchange resins* contain acidic functional groups and are capable of exchanging their H^+ ions for other cations. *Anion-exchange resins* contain basic functional groups and are capable of exchanging their anions, say OH^-, for other anions.

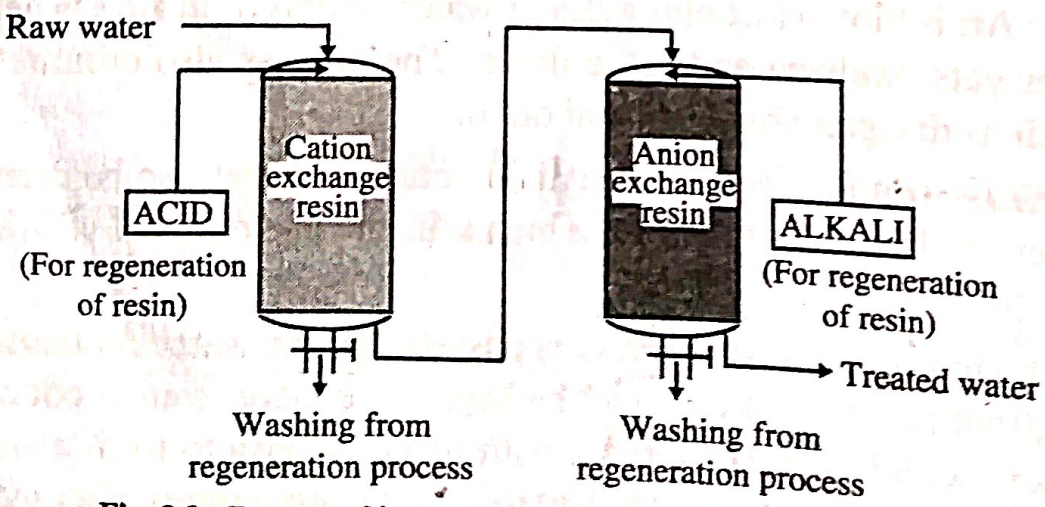

Fig. 3.3 : Process of ion-exchange (Demineralisation of water)

Water containing dissolved ions is passed through a deionizer in which it comes into contact alternatively with a *cation-exchange resin* [$(resin^-)H^+$] and an *anion-exchange resin* [$(resin^+)OH^-$] a number of times.

The cations present such as Ca^{2+}, Mg^{2+}, etc. get exchanged for the H^+ ions of the cation-exchange resin.

$$2\,(Resin^-)H^+ + Ca^{2+} \longrightarrow (Resin^-)_2\,Ca^{2+} + 2H^+$$

$$2\,(Resin^-)H^+ + Mg^{2+} \longrightarrow (Resin^-)_2\,Mg^{2+} + 2H^+$$

The anions such as Cl^-, SO_4^{2-}, etc. present in water get exchanged for the OH^- ions of the anion-exchange resin.

$$(Resin^+)OH^- + Cl^- \longrightarrow (Resin^+)Cl^- + OH^-$$

$$2\,(Resin^+)OH^- + SO_4^{2-} \longrightarrow (Resin^+)_2SO_4 + 2OH^-$$

The H^+ ions and OH^- ions gained by water combine to form water.

$$H^+ + OH^- \longrightarrow H_2O$$

The water coming out of the deionizer is thus free of all the cations and anions, including the hardness causing Ca^{2+} and Mg^{2+} which were previously present.

The exhausted cation-exchange resin and anion-exchange resin can be regenerated by treating with concentrated hydrochloric acid and sodium hydroxide solution respectively.

$$(Resin^-)_2Ca^{2+} + 2HCl \longrightarrow 2\,(Resin^-)H^+ + CaCl_2$$

Exhausted cation-exchange resin → Cation-exchange resin

$$(Resin^+)Cl^- + NaOH \longrightarrow (Resin^+)OH^- + NaCl$$

Exhausted anion-exchange → Anion-exchange resin

The ion-exchange process of demineralizing water is represented in Fig. 3.3.

Desalination or Desalinization or Desalting of sea water

The process of effecting partial or complete demineralization of *sea water* or relatively less saline *brackish water* (frequently found by drilling in arid lands) is known as *desalination* or *desalinization.*

The objective of desalinization is obviously to get potable (drinkable) water from saline waters. This has been tried in various countries, where fresh water is not abundant, like the Middle East Countries.

Some of the methods tried for the purpose are given below:

a) Distillation

Sea water or *brackish water* is distilled and the vapours condensed by cooling with raw water entering the *still* to be distilled. The heat of condensation of steam is thus made use of to pre-heat the water entering the distillation still, thus saving precious energy. The pure condensed water is collected and stored.

b) Electrodialysis

Sea water or *brackish water* is taken in large electrolytic cells divided into three compartments by two *ion-selective* semipermeable membranes. The electrodes are present in the outer compartments. The arrangement is such that the membrane nearer to the cathode is permeable to cations only while that nearer to the anode is permeable to anions only. On applying electricity, the cations and anions move from the central compartment into the two different outer compartments and towards the oppositely charged electrodes. The water in the central compartment gradually gets salt-free. The process is diagrammatically represented in Fig. 3.4.

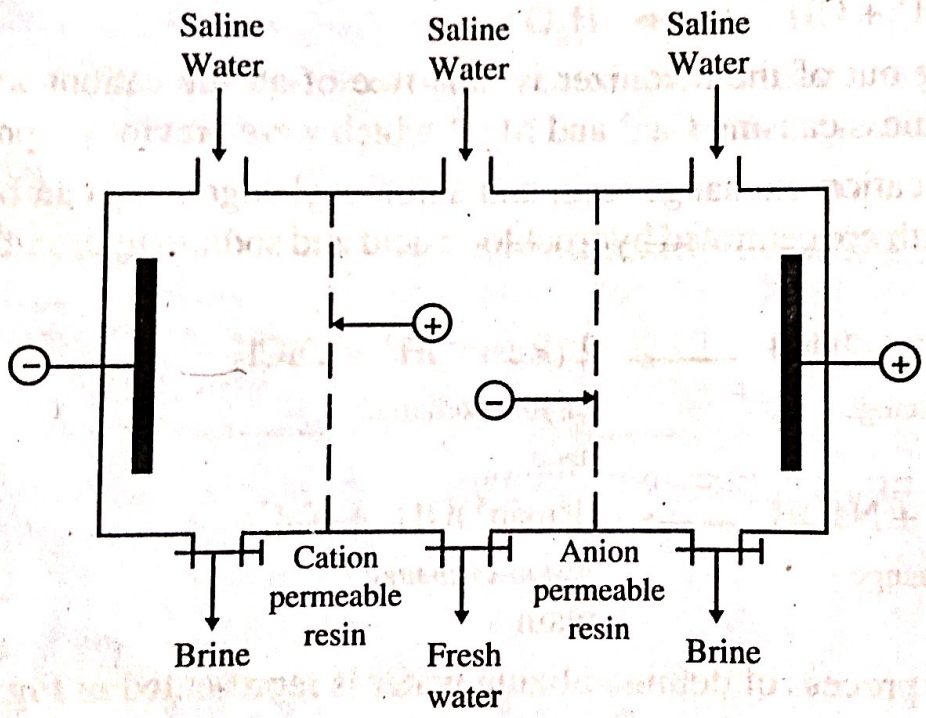

Fig. 3.4: Electrodialysis method of desalination of saline water

c) Reverse osmosis

When saline water is kept separated from a pure sample of water by means of a semipermeable membrane, normally, water will flow into the solution (*i.e.*, saline water) by *osmosis*. However, if a pressure just higher than the osmotic pressure is applied on the saline water, water will flow out from the solution into the pure sample. This process is called *reverse osmosis* and is used to desalinize sea water and brackish water. Membranes specially prepared from nylon, cellulose acetate, etc. are used because they are able to withstand the high pressure needed to be applied. Thus, in

this process, the *water* is forced out of saline water, not the salt. Fresh water can thus be obtained, suitable for drinking purposes. This is schematically represented in Fig. 3.5.

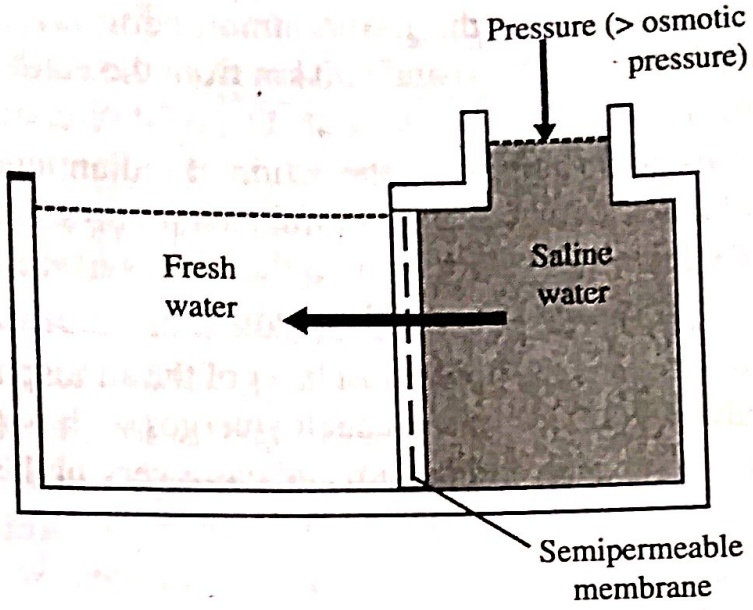

Fig 3.5 : Reverse osmosis method of desalinization of water

AIR POLLUTION

The major regions of atmosphere

Atmosphere is the protective cover of gases that surrounds the earth. It sustains life on earth by protecting it from the hostile environment of outer space.

There are five concentric regions within the atmosphere which can be differentiated on the basis of temperature and other characteristics.

1. Troposphere : The *troposphere* is the lowest layer of atmosphere which extends up to a height of 8 km at the poles and 18 km near the equator. Its temperature decreases with height. It contains 80-90% of the mass of gases in the atmosphere. The major gases present are nitrogen and oxygen. Some argon as well as carbon dioxide and some trace amounts of He, Ne, CH_4, etc. are also present. It is here that living organisms exist. It is a turbulent region having strong air movements and cloud formation.

2. Stratosphere : The *stratosphere* is the region that lies above troposphere extending up to a height of 50 km, its temperature being –55°C to 5°C. It contains nitrogen and oxygen. It also contains ozone which acts as a shield and protects living systems from harmful ultraviolet rays. Due to this absorption of ultraviolet rays, it gets warmer with increasing distance from the earth.

3. Mesosphere : The *mesosphere* is the third atmospheric layer from below. It is the

region that lies approximately between 50 km and 80 km from earth. Its temperature is very low and drops to about –100°C at a level of 80 km from the earth. N_2, O_2, Ozone, etc. are present in this region.

4. Ionosphere : The *ionosphere* is the fourth atmospheric layer lying above the mesosphere. It spreads between 80 km and 500 km from the earth. Ionosphere contains ionised gas molecules and atoms like O_2^+, O^+, NO^+, etc. and free electrons. These ions and electrons are produced by the action of radiant energy on gas molecules. This layer protects the earth from harmful cosmic rays. Its particles reflect the radiowaves signalled from the earth back to the earth surface and thus enables the transmission of radio messages around the world.

5. Exosphere : The *exosphere* is the uppermost layer of the atmosphere. It lies above the ionosphere up to about 1600 km and gradually merges with outer space. It contains atomic particles of hydrogen and helium and has a very high temperature due to solar energy.

Air pollution

The contamination of air by undesirable substances having a detrimental effect on living organisms is called *air pollution.*

Any substance or agent that causes pollution of air is called an *air pollutant.*

(i) Carbon monoxide, (ii) nitrogen oxides, (iii) sulphur oxides, (iv) hydrocarbons and (v) particulates (metallic, non-metallic and organic) are the five primary pollutants which together contribute 90% of global air pollution.

Sources of air pollution

The *natural sources* of air pollution are volcanic action, forest fires, etc. which release poisonous gases like CO, H_2S, SO_2, etc. and various particulate matter into the atmosphere. But these contribute very little to air pollution when compared to the *anthropogenic sources* (man-made sources) such as automobiles, industry, electric power plants, etc.

(a) ***Air pollution by automobiles*** : One of the major factors which contributes massively towards air pollution is the use of automobiles fuelled with petrol or diesel. *Automobile exhausts,* in fact, are responsible for more than 55% of total air pollution in the world. The automobiles release huge amounts of poisonous gases into the atmosphere. The major constituent pollutants of automobile exhausts are the following:

(i) *Carbon monoxide,* produced due to the incomplete combustion of the fuel in the engine.

(ii) *Sulphur oxides,* namely SO_2 and SO_3, produced on account of the sulphur content in the burning fuel.

(iii) *Nitrogen oxides,* mainly NO and NO_2, produced during the high temperature combustion of the fuel.

(iv) *Unburnt hydrocarbons* escaping into the atmosphere from the engine, carburetor and other parts of the vehicle.

(v) *Various particulate matter,* particularly the volatile lead compounds produced on account of the use of tetraethyl lead (TEL) as antiknock compound in petrol (in some countries), soot from the incomplete combustion of the fuel, etc.

All the above pollutants are highly injurious to the health of living organisms. Many of them enter into secondary processes in the atmosphere to yield products which can produce disastrous effects. Smog, acid rain, etc. are adverse consequences of such processes.

b) *Air pollution by industries* :Various factories and industrial establishments such as chemical industries, pulp and paper mills, petroleum refineries, metallurgical plants and smelters, cotton mills, synthetic rubber industries, polymer factories, mining industries, asbestos industries, etc. are responsible for about 10-20% of global air pollution. The effluent gases from such industries contain major air pollutants such as CO, SO_2, H_2S, NO, NO_2, acid vapours, smoke, flyash and various other particulates such as asbestos dust. All these gases and particulate matter are injurious to the health of all living organisms. They also produce disastrous secondary consequences such as *smog* and *acid rain.*

c) *Air pollution by electric power plants* : Thermal power plants burning bituminous coal or high sulphur content fuel oils let out large amounts of SO_2 and several tons of flyash into the atmosphere. These constitute major health hazards for humans and animals.

d) *Other sources of air pollution* : Agricultural activities making use of various pesticides cause serious air pollution from these substances. All pesticides are poisons and thereby killers.

The smoke let out from houses contain various air pollutants such as CO, SO_2, NO, NO_2, etc. and soot particles.

The wear and tear of asbestos products like roofing materials, floor tiles, coatings, etc. and the demolition of buildings cause the presence of dangerous asbestos dust and fibre in air.

Incineration of domestic waste, use of freons as refrigerants and in aerosol sprays, tobacco smoking, use of electric power generators, etc. are some other factors which contribute to air pollution.

Another important factor that contributes substantially to air pollution is the fre-

quent occurrence of wars and terrorist activities in various parts of the world. The use of explosives and bombs introduce a large quantity of pollutants into the air.

The radioactive rays that come out of atomic reactors and nuclear explosions constitute a major hazard for all living organisms on the earth.

PHYSIOLOGICAL EFFECTS AND OTHER CONSEQUENCES OF AIR POLLUTION

Air pollution by the oxides of carbon

Carbon monoxide is the most abundant and widely distributed air pollutant. It is produced by the incomplete combustion of carbon or carbon-containing compounds. Automobile exhausts contribute to about 80% of the total CO pollution. It is also produced during the burning of domestic fuel, domestic waste and industrial fuel. It is also formed by the high temperature reduction and decomposition of CO_2.

Incomplete combustion : $2C + O_2 \longrightarrow 2CO$

Reduction of CO_2 at high temperature : $CO_2 + C \longrightarrow 2CO$

Decomposition of CO_2 at high temperature : $CO_2 \rightleftharpoons CO + O$

CO is a very dangerous chemical. Its poisonous effect is due to the fact that it combines with haemoglobin of blood (about 210 times more readily than O_2) to form a stable complex called *carboxyhaemoglobin.* It thereby not only prevents the bonding of O_2 with haemoglobin to form oxyhaemoglobin but also displaces O_2 from the oxyhaemoglobin formed.

$$\underset{\text{Haemoglobin}}{Hb} + CO \longrightarrow \underset{\text{Carboxyhaemoglobin}}{COHb}$$

$$\underset{\text{Oxyhaemoglobin}}{HbO_2} + CO \rightleftharpoons \underset{\text{Carboxyhaemoglobin}}{COHb} + O_2$$

Thus, getting tied up with haemoglobin in this fashion, CO blocks the normal oxygen-transporting ability of blood and thereby causes *asphyxiation.*

Inhalation of CO at levels higher than 100 ppm induces a variety of symptoms ranging from mental aberrations, throbbing headache, dizziness, nausea, vomiting, visual difficulty, breathing difficulty and unconsciousness. In a city during the peak hours of traffic or during the frequent traffic jams, pedestrians, traffic policemen, drivers and shop keepers are all prone to such symptoms due to excessive inhalation of CO. Inhalation of CO above 750 ppm level definitely produces death by asphyxiation. To the weak, anaemic and invalid people and to those suffering from respiratory diseases, CO is lethal at much lower levels. Cigarette smokers and those stand-

ing by (passive smokers) inhale large quantities of CO. The toxic effects of smoking is partly due to CO inhalation.

CO is detrimental to plants also. It causes leaf drops, leaf curling, reduction in leaf size, decrease in chlorophyll content and premature ageing in plants.

CO_2 also becomes an air pollutant when produced in excessive quantities. It then causes *enhanced greenhouse effect* and this leads to *global warming.* [This is discussed at a later stage in this chapter].

Air pollution by the oxides of nitrogen

The oxides of nitrogen, mainly NO along with some NO_2, N_2O, N_2O_3 and N_2O_5, are major air pollutants present in automobile exhausts and effluent gases from electric power industry, fertilizer industry, explosive industry and gold jewellery works. NO is formed by the high temperature combination of N_2 and O_2 and is slowly oxidised to NO_2 and other oxides.

$$N_2 + O_2 \underset{}{\overset{\text{high temperature}}{\rightleftharpoons}} 2NO$$

$$2NO + O_2 \longrightarrow 2NO_2$$

NO, although not a major direct health hazard, produces NO_2 which is fairly toxic to humans.

NO_2 has an irritating effect on mucous membrane and in higher doses causes severe bronchitis and respiratory problems. In a concentration of 3 ppm for 1 hour, it causes bronchioconstriction in man and short exposure at 150-220 ppm levels produces fibroitic changes in the lungs with fatal results. NO_2 disrupts some cellular enzyme systems. It is a pulmonary irritant and causes pulmonary haemorrhage and pulmonary edema leading to death. High levels of NO_2 also cause gum inflammation, pneumonia, internal bleeding and lung cancer. Cigarette smoke contains high levels of NO_2 which causes lung diseases and lung cancer to *active smokers* as well as to *passive smokers.*

The oxides of nitrogen involve in various photochemical reactions with hydrocarbon pollutants in the atmosphere. This gives rise to *'photochemical smog'* which is characterised by brown hazy fumes which irritate eyes, nose, throat and lungs. This smog is a regular feature is some of the major cities of the world. Automobile exhausts are the major culprits in the formation of photochemical smog, which is also known as the *'Los Angeles type smog'* in memory of the terrible smog experienced in Los Angeles in 1944.

The nitrogen oxides also cause the precipitation of nitric acid in the atmosphere and leads to the detrimental phenomenon called *'acid rain'*. [This is discussed at a later stage in this chapter].

The nitrogen oxides affect plants also. Exposure to NO inhibits the metabolic activities in plant tissues leading to decreased photosynthesis. Even low concentrations of NO_2 damage plant leaves, retard photosynthesis and suppress growth.

Air pollution by the oxides of sulphur

The oxides of sulphur SO_2 and SO_3 are produced as a result of the burning of high sulphur content fuels in thermal power plants and industries.

$$S + O_2 \longrightarrow SO_2$$
$$2SO_2 + O_2 \longrightarrow 2SO_3$$

SO_2 and SO_3 are present in automobile exhausts also.

Even at very low levels, SO_2 and SO_3 cause irritation of eyes and damage the respiratory tract producing cough and choking in humans. Inhalation of SO_2 at a level of 5 ppm for one hour causes constriction of the bronchial tubes and inhalation at a level of 10 ppm for one hour can cause severe respiratory distress. Inhalation of SO_2 at higher levels leads to bronchitis, emphysema, chronic asthma and even lung cancer. Inhalation at very high levels causes death by suffocation.

SO_2 is a major factor which causes the formation of *sulphurous smog*. Not only is it a major irritant of eyes, nose, throat and lungs, but also causes pneumonia, bronchitis and allied respiratory problems. This is also called *London smog* in memory of the terrible smog that London experienced in December 1952. The smog had then prevailed in the city for 5 days and had caused the death of 4000-5000 inhabitants, also making thousands ill.

The sulphur oxides cause the precipitation of sulphuric acid in the atmosphere leading to the phenomenon *'acid rain'* which is highly detrimental to living organisms and destroys buildings and sculptures.

The sulphur oxides adversely affect plants also. They are absorbed through the stomata into the mesophyll of the leaves which inactivates the cells. This leads to tissue collapse, bleaching of leaves, dwarfing and destruction of the plants.

Air pollution by hydrocarbons

Various hydrocarbons are let out into the atmosphere through unburnt fuel from automobile exhausts, evaporation from various parts of automobiles, incomplete combustion of coal and wood, refining of petroleum, its transfer and use, leakage of industrial solvents, incomplete incineration of wastes, etc. They are a grave health hazard to humans.

Inhalation of hydrocarbons even at low levels increases mucous secretion and respiratory tract blockage resulting in breathing difficulty and cough. At higher levels, they cause severe suffocation and, further, many of them are carcinogenic in nature.

The polynuclear hydrocarbon *benzopyrene* present in automobile exhausts and in the smoke from the burning of coal oil and gas industries, cigarettes etc. is a potential carcinogen causing lung cancer.

Hydrocabons enter into a series of photochemical reactions in the presence of NO, NO_2, etc. in the atmosphere and causes *'photochemical smog'*. This causes irritation to eyes, nose, throat and lungs leading to severe respiratory problems. In invalids and old people, the effects are particularly severe.

Hydrocarbons adversely affect plants also. They cause damage to leaf tissues, death of flowering parts and inhibition of their growth.

Air pollution by particulates

Air-borne small solid particles and liquid droplets, commonly known as *particulates,* of inorganic and organic compounds cause considerable air pollution. Automobile exhausts release particulates of oxidised polymeric hydrocarbons, aldehydes, ketones, nitrogenous heterocyclic compounds, etc. as well as soot into the atmosphere. Inhalation of these particulates cause irritation of eyes, nose, throat and lungs [This sensation is often felt when we move through the city in peak hours or get trapped in a traffic jam]. Formaldehyde is highly toxic to humans. Particulates of volatile lead compounds (produced as a result of the usage of the antiknock compound tetraethyl lead in gasoline) present in automobile exhaust is particularly harmful to children resulting in brain damage and cancer.

Asbestos dust in air caused by asbestos industries, wear and tear of asbestos products, etc. can penetrate deeply into the air passages and can stay intact for years in the innermost regions of the lungs. These can cause severe breathing trouble, emphysema and lung cancer.

Small particles of ash called 'flyash' entering the atmosphere from burnt coal in thermal power plants, industries, etc. contain compounds of various elements. These can cause lung disorders, emphysema, etc. and affect formation of red blood cells.

Polycyclic aromatic hydrocarbons (PAH) are highly harmful organic particulate matter. Examples are *benzoypyrene, chrysene,* etc. sorbed on soot particles. They are highly carcinogenic in nature.

HOLES IN THE OZONE LAYER

a) The ozone layer and its importance

Ozone is present in the stratosphere. It is formed from oxygen and decomposed back to oxygen photochemically by various mechanisms. These are represented below:

Formation : $O_2 \xrightarrow[242\ nm]{h\nu} O + O$

$O_2 + O \longrightarrow O_3$

Decomposition: $O_3 \xrightarrow{220\ nm} O_2 + O$

$O + O_3 \longrightarrow O_2 + O_2$

An equilibrium concentration of ozone (~ 10 ppm) is maintained in the stratosphere at an altitude of 25-30 km from the earth. This ozone which envelopes the lower atmosphere is called the *ozone layer.* The stratospheric ozone layer is also referred to as the *ozone umbrella* because it performs the very important function of acting as a *protective radiation shield* for the living organisms on earth against the biologically harmful solar radiations. The ozone layer strongly absorbs ultraviolet light in the region 220-330 nm and thereby protects the animal and plant life on earth from severe radiation damage. Only a small fraction of the harmful ultraviolet rays thus reaches the earth. By this process, it also warms the atmosphere through its exothermic decomposition and thereby maintains the thermal balance of the earth.

b) Holes in the ozone layer (Depletion of ozone of the ozone layer)

One important adverse effect of air pollution by *chlorofluorocarbons* and *nitrogen oxides* is that holes of varying sizes have appeared in the stratospheric ozone umbrella at various regions due to depletion of ozone.

A large hole over Antartica from about 30% of ozone depletion was discovered by scientists in the early eighties. Since then, similar holes have been discovered in the arctic stratosphere and over some of the thickly populated European countries and U.S.A where ozone levels are found varyingly reduced by 3-30%.

The major culprits responsible for ozone depletion in the stratosphere are the *chlorofluorocarbons* (CFC's) or *freons* which are used widely as refrigerants and aerosol can propellants. They are highly stable and inert in the troposphere, but slowly diffuse into the stratosphere where they generate chlorine free radicals ($Cl^{\bullet}$) due to the action of ultraviolet light.

$$CF_2Cl_2(g) \xrightarrow{UV} Cl^{\bullet}(g) + {}^{\bullet}CF_2Cl(g) \qquad \text{----(i)}$$

These chlorine radicals immediately react with stratospheric ozone converting it into O_2 through a chain mechanism.

$$Cl^{\bullet}(g) + O_3(g) \rightarrow ClO^{\bullet}(g) + O_2(g) \qquad \text{----(ii)}$$

$$ClO^{\bullet}(g) + O(g) \rightarrow Cl^{\bullet}(g) + O_2(g) \qquad \text{----(iii)}$$

The chlorine radicals are continuously regenerated and cause the breakdown of ozone. Since, by this mechanism, each chlorine free radical generated can cause the destruction of up to one lakh ozone molecules, a phenomenal depletion of stratospheric ozone is being caused by CFCs.

Other important agents causing ozone depletion in the stratosphere are the nitrogen oxides, NO_x. The supersonic aircrafts, which fly in the stratosphere, discharge large quantities of NO_x in their exhaust gases directly into the stratosphere. Nuclear explosions also increase the NO_x load of the stratosphere. These enter into a series of photochemical reactions with ozone, converting it into oxygen and thereby causing large scale depletion of stratospheric ozone.

c) Impacts of stratospheric ozone depletion

It is the stratospheric ozone umbrella that shields the biotic life on earth from extremely harmful solar rays. So, formation of holes in the ozone umbrella due to air pollution by CFCs and NO_x is a very serious threat to the biological life on earth because harmful ultraviolet radiations can pass through these ozone holes and reach earth.

The most serious impact of ozone depletion on human health is that exposure to ultraviolet-B rays causes *skin cancer*. It is estimated that a 1% reduction in ozone may cause as much as 6% increase in skin cancer cases due to increased exposure to ultraviolet radiation.

Exposure to ultraviolet radiations also leads to *leukemia* and *breast cancer*. These ultraviolet rays are also absorbed by cornea and lens in the eye leading to *photokeratitis* and *cataract* without the person even knowing about it.

Another disastrous impact of stratospheric ozone depletion is that the yields of agricultural crops are reduced due to greater exposure to ultraviolet radiation. In other words, ozone depletion would spell disaster for mankind in terms of large scale damage to food production. Exposure to ultraviolet radiation decreases chlorophyll content of the leaves of plants leading to a decrease in photosynthesis and damage to the leaves.

Ozone depletion causes destruction of aquatic organisms as they are not able to withstand the increased exposure to ultraviolet radiation.

Ozone depletion may also cause serious climatic changes on earth because the ozone umbrella contributes to a great extent towards maintaining the thermal balance on earth.

d) Remedy to prevent ozone depletion

The immediate remedial measure against more ozone depletion is to stop com-

pletely the use of CFCs. A large number of nations including India are collectively on the look out for substitutes for CFCs and the researches have brought forth hopeful results. A number of low cost substitute compounds have been tried out and it is believed that the use of CFCs would be completely stopped in the near future.

GREENHOUSE EFFECT

a) Greenhouse effect and global warming

The **greenhouse effect** *is the progressive warming up of the earth's surface and atmosphere due to the blanketing effect of CO_2 and certain other gases in the atmosphere.*

The earth absorbs solar energy mainly as radiations in the visible region and maintains a steady state or balance by giving off bulk of this energy at the same rate as radiations in the infrared region. Much of the outgoing radiation is absorbed by CO_2 and water vapour present in the atmosphere and is partly re-emitted back to the earth's surface. This leads to a heating up of the earth's surface and atmosphere. This phenomenon is called *greenhouse effect.* It is of great significance in governing the climate of the earth. It is also important in maintaining the heat balance and average surface temperature of the earth within those narrow limits required for optimum climatic conditions to support life on earth.

Carbon dioxide is not usually considered as a pollutant because it is a normal component of the air and directly involved in the give and take relationship between plants and animals. However, there is grave concern over the abnormal increase in its concentration in the atmosphere. Very large quantities of CO_2 are now being introduced into the atmosphere through large scale combustion of fossil fuels in thermal power plants, factories, vehicles, etc. Further, *global deforestation* is also contributing to an increase in the CO_2 content of the atmosphere because trees are essential to maintain a balance in the CO_2 level. The CO_2 gets confined exclusively to the troposphere. Hence, this large scale increase in the atmospheric CO_2 concentration leads to abnormal *global warming* through enhanced greenhouse effect. In other words, CO_2 in large concentrations in the atmosphere absorbs the outgoing infrared radiation to a great extent and re-emits it back to the earth leading to an increase in the average global temperature. Other greenhouse gases like CH_4, N_2O and chlorofluorocarbons (which strongly absorb infrared radiation) also contribute to the increase in the mean global temperature. This is a very serious environmental issue of grave concern. It is estimated that if the input of CO_2 and other greenhouse gases into the atmosphere continues at the present rate, their atmospheric concentrations would double by about year 2050 and this would bring a 3°C rise in the surface temperature of the earth.

b) Consequences of global warming from enhanced greenhouse effect

Some of the probable consequences of an abnormal global warming through *enhanced greenhouse effect* are given below:

1. ***Climatic changes*** : Persistent greenhouse effect and consequent increase in the temperature of the earth's surface and atmosphere would bring about drastic changes in the global climate. Some areas of the world would experience abnormally high evaporation of water and unusual changes in ocean currents and winds. Abnormal changes in weather patterns and seasons as well as increased desertification are bound to ensue. Some regions of the world may lose up to 30% of the annual rain fall while some other regions may experience very high rainfall. The whole climatic pattern of the world would change.

2. ***Drop in agricultural production*** : Climatic changes would obviously affect agricultural production adversely. Since some regions would become increasingly dry and some others increasingly wet, the whole agricultural pattern would be upset with a consequent drop in agricultural produces.

3. ***Sea level rise*** : Increase in oceanic temperature may cause the melting of polar ice caps, leading to an abnormal rise in sea levels around the globe. This may result in the erosion and submergence of low-lying coastal lands and islands.

4. ***Destruction of aquatic organisms*** : Fish and other aquatic organisms may not be able to withstand the high temperature of waters. So, they will perish.

5. ***Refugee problems*** : Climatic changes resulting in either flood or drought, agricultural loss, homelessness and starvation would force people to move within and between countries. These refugees would cause very serious social and economic problems.

c) Control of greenhouse effect

The essential step to control greenhouse effect and to prevent abnormal global warming would obviously be to control and reduce the input of CO_2 into the atmosphere. This control has to be achieved on a global basis and a global policy on industrialization, deforestation, etc. has to be adopted by all the nations of the world. Solar energy may be used as an alternative to the conventional fossil fuels. Planned forestation programmes should be implemented to reduce the CO_2 level, as trees act as natural 'sink' for CO_2 by utilizing it during photosynthesis.

ACID RAIN

a) Formation of acid rain

The acids, mainly HNO_3 and H_2SO_4, formed in the atmosphere from the air pol-

lutants nitrogen oxides and sulphur oxides respectively, are brought down to the earth as constituents of rain, snow, hail, etc. This acid precipitation is known as **acid rain.**

Tremendous amounts of nitrogen oxides and sulphur oxides are discharged into the atmosphere as a result of the combustion of huge amounts of petroleum products and other fossil fuels. These pollutants are converted into acids, namely HNO_3 and H_2SO_4, through a series of chemical reactions in the presence of light, water, oxygen, heavy metal ions, organic oxidants, etc. in the atmosphere. These acids then come down to the earth during rain, snow, hail, etc. and constitute what is known as the *acid rain.* It is thus a major secondary effect of air pollution.

The reactions leading to the formation of HNO_3 and H_2SO_4 are summarised below :

Formation of HNO_3 :

$$NO + O_3 \longrightarrow NO_2 + O_2$$

$$NO_2 + O_3 \longrightarrow NO_3^* + O_2$$

$$NO_3^* + NO_2 \longrightarrow N_2O_5$$

$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

Formation of H_2SO_4 :

$$SO_2 + \tfrac{1}{2}O_2 + H_2O \xrightarrow[\text{Soot particles}]{NO} H_2SO_4$$

The acid droplets formed get suspended in water vapour to form 'acid fog' which gets dispersed far and wide by air currents. In a cool weather, the acid fog precipitates as *'acid rain'.*

b) Adverse effects of acid rain

Acid rain has severe ecological impacts and is now a serious pollution problem in several areas. Some of its adverse effects are given below:

1. Acid rain increases the acidity of the soil and thereby causes serious damage to agricultural crops. Cadmium absorption of plants increases posing a grave health hazard to plants and humans.
2. It damages leaves of trees, reduces their photosynthetic capability and retard their growth, thereby destroying forests. Thus, the natural resources for the production of wood pulp, paper, etc. are decreased.
3. Acid rain makes the water in tanks, ponds, lakes and rivers so much acidic that fish and other aquatic life are eliminated in such regions.

4. The acid droplets in air as well as acid-contaminated potable water cause neurological, digestive and respiratory diseases in humans.
5. Acid rain causes extensive damage to buildings, statues, monuments, etc. The acids in the rain attack the sculptural materials of marble, lime stone, slate, mortar, etc. to form soluble sulphates and nitrates.

   e.g., $CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2$

   As a result, the structures become pitted as the soluble salts formed are leached out by rain water. [Several invaluable stone statues and monuments in Greece, Italy and other parts of the world have been dissolved partially by acid rain. The Taj Mahal in Agra faces such a threat at present].
6. Acid rain destroys materials like fabric, paper, etc.

c) Control of acid rain

Short-term control of acid deposition problem can be achieved by using *lime* in acid-polluted soils and fresh water bodies. However, this is not a solution to the acid rain problem. The only remedy to acid rain is to reduce air-borne nitrogen oxides and sulphur oxides. This needs basic changes in the patterns of using fossil fuels. Advanced research and tough legislation are required to reduce the emissions of NO_x and SO_x. Solar energy should be made use of wherever possible in place of fossil fuels.

Control of air pollution

Some of the steps that have to be taken to control air pollution are given below:

1. Better automobile engines should be designed to ensure complete combustion of the fuel so that the toxic pollutants carbon monoxide and hydrocarbons would not be present in the exhaust gases.
2. In order to avoid the presence of volatile lead compounds in automobile exhaust gases, the use of leaded petrol should be completely banned. Only the use of unleaded petrol must be permitted.
3. Use of gaseous fuels in automobiles would ensure more or less complete combustion of the fuel and thereby reduce emission of toxic pollutants like CO and hydrocarbons.
4. Entry of noxious waste products into air from industries and power plants should be prevented by using proper equipments such as filters, electrostatic precipitators, dust traps, adsorbent columns containing activated carbon, etc.
5. The heights of chimneys of factories should be raised for allowing atmospheric dilution of the effluent gases.

6. Only furnace fuels of low sulphur content should be used in power plants, industries, etc. so that pollution by sulphur oxides can be minimised.
7. Soluble gaseous pollutants like SO_2 in industrial effluent gases may be dissolved away by passing through a device called 'scrubber' in which a fine spray of water is used.
8. Excessive use of pesticides and chlorofluorocarbons should be prevented.
9. The use of asbestos should be totally banned in order to prevent air pollution by the highly harmful asbestos dust.
10. Cigarette smoking should be banned in all public places.
11. Trees, which can serve as natural 'sinks' for various pollutants should be planted on a large scale around industrial centres.

TOXICITY AND ENVIRONMENTAL HAZARDS OF PESTICIDES

Pesticides are chemicals which are extensively used for killing pest populations that destroy economic crops, biological products etc. and cause diseases. Pesticides include insecticides, rodenticides, herbicides and fungicides. Pesticides have been in use since very early times, *e.g.*, the use of arsenic compounds as insecticides dates back to 70 A.D. Since 1940, synthetic organic pesticides have been extensively used. Some examples of pesticides are given in Table 3.1.

Table 3.1 : Basic groups of pesticides

Group	*Examples*
1. Insecticides and acaricides	Chlorinated hydrocarbons (DDT, BHC aldrin, endrin, heptachlor, toxaphene, etc.), organic phosphorus chemicals (malathion, parathion, etc.), carbamates (pyrolan, isodan, etc.), inorganic chemicals ($CuSO_4$, lead arsenate, etc.)
2. Rodenticides	Pival, warfarin, thallium, sodium fluoroacetate, strychnine.
3. Herbicides	Sodium arsenite, 2, 4-D, 2, 4, 5-T, dalapon, methyl bromide
4. Fungicides	Mercuric chloride, Nabam, Ziram, Captan.

Pesticides were once considered as the *achievement* of the twentieth century. Paul Herman Mueller of Switzerland, who prepared the first synthetic organochlorine pesticide DDT, was later awarded *Nobel peace prize*. They were responsible for the boost in agricultural crops and the eradication of various diseases. However,

now they have become the *curse* of modern times on account of the pollution they had caused since the very time of their introduction and the pollution they cause presently.

Pesticide pollution and the environmental hazards

Contamination of the environment with harmful pesticides is known as *pesticide pollution.*

Pesticides are applied as aerial sprays or directly to the soil. After getting deposited, most of them (almost all organic pesticides) undergo biochemical modifications by heat, light and water to yield derivatives commonly known as *pesticide residues.* Many of these residues are stable, non-biodegradable and persistent in nature. They can survive for long periods of time. DDT, BHC, chlordane, aldrin, etc. are examples. The persistence periods of some of the pesticides in the soil are given in Table 3.2.

Table 3.2 : Persistence of pesticides in soil

Pesticide	*Persistence*
Parathion	3-6 months
2, 4, 5-T	6 months
Diuron	16 months
Toxaphene	6 years
Heptachlor	9 years
Aldrin	9 years
DDT	10 years
BHC	11 years
Clordane	12 years

The pesticides do not stay in their points of deposition. They move through the components of environment. A portion of pesticide residues in soil gets vapourised either directly or along with moisture into air. A portion seeps into the ground water. A significant portion moves in agricultural run-off water to reach lakes, streams, rivers and oceans. Then, they concentrate in the food chains. By the process of *biomagnification,* the concentration of the pesticide residues increases on moving up in the food chain, finally reaching the ultimate consumer, namely *man,* in the most concentrated form. Presently, residues of pesticides (*e.g.,* DDT) are widely distributed. They are everywhere from the tissues of organisms to oceans and polar

ice caps, exerting their toxic influence and they will continue to do so for many more years to come.

Another important environmental consequence of the use of pesticides is that pests develop resistance to them with time. The population of such resistant pests grow faster, necessitating the invention and application of more and more newer and stronger pesticides, thereby creating more and more pollution problems.

Further, pesticides not only kill the targeted organisms (pests) but also other beneficial organisms such as microorganisms of soil and phytoplankton of water.

Pesticides have thus become a grave environmental issue faced by man of modern times.

Toxic effects of pesticides

All synthetic pesticides are highly toxic to all plants and animals. They kill and destroy all organisms. They can enter the human body orally, through skin or by inhalation. The chlorinated hydrocarbons mainly affect the central nervous system while others affect the circulatory or reproductive systems. They accumulate persistently in various parts of the body and exert their toxic influence. They can cause cancer, blood cancer, hypertension, sterility, damage to kidney and death at higher concentrations. Their toxic effects, in a very general sense, on humans are mentioned below:

1. Excessive concentrations of chlorinated hydrocarbon pesticides in human tissues cause hormonal imbalance, cancer of the organs, leukemia, etc.
2. Organophosphate pesticides interfere with the transmission of nerve impulses, causing unconditioned tremors, spasms, convulsions and paralysis.
3. Pesticides inhibit production and functioning of sex hormones, leading to sterility.
4. Higher concentrations of pesticides in pregnant woman may result in abortions, still births and infant deformities.
5. Pesticides cause hypertension and damage to kidneys.
6. In higher concentrations, they cause death.

They exert their toxicity on microorganisms, aquatic organisms, plants, animals and birds as well, causing death and destruction. Several types of fish, crabs, fish-eating birds, etc. have been wiped out, or their population decreased, in various regions of the earth on account of pesticide pollution.

Control of pesticide pollution

Some steps which have been suggested for control of pesticides are the following:

1. The use of highly persistent pesticides should be replaced by less persistent pesticides.
2. Wherever the use of a persistent pesticide is necessitated, it should not be used excessively; only the minimum required amount should be used, strictly localised to that area.
3. Effluents from pesticide factories should be treated by suitable methods before they are released to a water body.
4. Predators and parasites of pests can be released for the biological control of pests, so that the use of pesticides can be minimised.
5. Spraying synthetic pheromones and sex stimulants in non-cultivated areas can be tried to attract the pests from the cultivated areas and thereby the use of pesticides can be avoided.
6. Natural pesticides like the petroleum products (kerosene, petrol, etc.) or plant products (tobacco preparation, neem and turmeric extracts, etc.) can be used as far as possible in place of synthetic pesticides.

RADIATION POLLUTION

a) What is radiation pollution?

The pollution of the environment caused by extremely dangerous radiations from sources introduced into the environment by human activities is called *radiation pollution.* The main radiation hazard comes from ionising radiations (α-rays, β-rays, γ-rays, X-rays, etc.) which cause genetic mutations in living organisms. They form positive and negative ion pairs as they pass through the protoplasm which is the chief cause of damage in the living organisms.

The chief type of radiation pollution is *radioactive pollution* caused by radionuclides which contaminate air, water and soil and seriously endanger our planet's ecological equilibrium. These radionuclides, introduced into the biosphere, cause radiation damage to living organisms not only externally, but also internally because they inevitably find their way into the bodies of the living organisms. This type of radiation pollution is unique in the sense that it not only produces direct effects on the individual affected, but also brings physiological changes in the generations to come. The menace of radiation pollution has raised substantially as a result of the techniques harnessing nuclear energy for both constructive purposes (*e.g.*, generation of electric power) and destructive purposes (atom bombs, nuclear explosions, etc.)

b) Anthropogenic sources of radiation pollution

Some of the *man-made sources* of radiation pollution are briefly given below:

(i) ***Medical diagnosis using X-rays*** : The use of X-rays for medical diagnosis constitutes an important source of radiation pollution as they are highly penetrating in nature.

(ii) ***Radiotherapy*** : Radionuclides used in radiotherapy of diseases like cancer constitute a source of radiation pollution as they are often indiscriminately used and improperly handled.

(iii) ***Nuclear tests and radioactive fall out*** : Nuclear explosion tests carried out by various countries pose a major radiation threat to all living organisms as they introduce a large quantity of long-lived radionuclides to the environment which get distributed all over the globe.

The radioactive dust that falls to the earth after a nuclear explosion is called *radioactive fall out.* It becomes suspended up to heights of 7-8 km above the earth's surface and are carried by air currents around the world. The dust contains radionuclides which usually settle down with rain and pollute soil and water. From the soil, they enter into plants and thereby enter the food chain. Once they enter the body of a living organism, they radiate internally throughout its life-span.

(iv) ***Nuclear reactors*** : The leakage of nuclear radiation from nuclear reactors contributes considerably to radiation pollution.

(v) ***Nuclear power plants*** : The nuclear power plants set up in various parts of the world to produce electric power have become a major radiation threat to the whole world. The Three Mile Island power plant leakage in USA in 1979 and the Chernobyl power plant leakage in U.S.S.R in 1986 are examples for the disastrous power plant accidents which caused the death of thousands of innocent people and radiation damage to millions.

(vi) ***Radioactive waste*** : The radioactive waste from nuclear reactors and power plants contain a very large number of radionuclides. The storage, transportation and disposal of these wastes are major problems of the present nuclear industry and they cause wide-spread radiation damage from wherever they are deposited irrespective of whether it is deep under the earth's surface or in the deepest portions of the oceans.

(vii) ***Radioactive ore-processing*** : Radionuclides from the mining and processing units of radioactive ores pollute soil, water and air and cause extensive radiation pollution.

(viii) ***Industrial and medical research*** : Researches in the industrial and medical fields often include the use of radionuclides and produce radiation effects which damage the environment.

(ix) ***Other sources*** : Advanced technological implements such as colour televisions,

X-ray fluoroscopes, radars, etc. and even luminous dials of watches and clocks cause radiation pollution.

c) Hazards of radiation pollution

Radiation pollution manifests its disastrous effects on all kinds of living organisms. Radiation damage depends upon the type of radiation, period and frequency of exposure. Some very general effects of exposure to ionizing radiations are given below:

1. Sub-lethal doses of radiations can cause symptoms like nausea, vomiting, diarrhoea, loss of apetite and general weakness within a few hours of exposure.
2. Exposure to acute doses (*i.e.*, ~ 600 Rad) would produce symptoms of nausea vomiting, diarrhoea, etc. initially and would cause death within a few weeks.
3. Long term exposure to even small quantities of radiations would cause cancer in different parts of the body or leukemia.
4. Even short-term exposure to slightly larger quantities of radiation can cause cancer of the breast, thyroid, lung or even brain.
5. Radiations can break down enzymes, proteins and nucleic acids and thereby cause various metabolic disorders.
6. Radiations can cause internal bleeding and blood vessel damage which become evident as red spots in the skin.
7. Radiations can damage eye cells and induce cataract.
8. Radiations can cause bone marrow depression, kidney and liver disorders, damage to reproductive organs and gastrointestinal disorders.
9. Radiations produce genetic effects including gene mutations and chromosome abnormalities which are transmitted to the next generation.
10. Exposure to radiations kills plant cells and thereby destroy vegetation.
11. Water pollution by radioactive materials destroy aquatic population through radiation effects.

d) Control of radiation pollution

Some control over radiation pollution and its hazards can be achieved by preventive and saftey measures.

1. X-rays for diagnostic purposes and radiations for therapy should be used as sparingly as possible and adequate protection should be made available to the persons who carry out these operations.
2. High chimneys and high ventilators should be used at places where radioactive contamination is high.

3. While working with radionuclides, hoods, gloves and masks made of protective materials should be used.
4. Production of radioisotopes should be minimized.
5. Extreme care should be exercised during the disposal of radioactive waste.
6. All safety precautions should be taken to prevent leakage of radiation from nuclear reactors and power plants
7. The number of nuclear installations should be minimized.
8. Nuclear explosion tests and production of nuclear weapons should be stopped completely because a nuclear war would obviously wipe out the entire human race from the surface of the earth.

NOISE POLLUTION

a) What is noise pollution ?

Noise pollution means pollution of the environment with unpleasant and undesirable sound, through human activities thereby causing adverse effects in all recepients.

Noise is a pollutant which is as harmful to humans and animals as any other pollutant. With the development of technology, machinery and industry, noise has now become a global meance to human peace and tranquility.

b) Sources of noise pollution

Some of the man-made sources of noise pollution are mentioned below:

1. Industries, factories and machinery.
2. Vehicles such as trains, buses cars, scooters, etc. and the hooting of horns.
3. Loud speakers and audio systems used in social gatherings, celebrations, etc.
4. Domestic appliances such as grinders, mixies, vacuum cleaners, audio systems, etc.
5. Various construction works. 7) Fire works, explosion
6. Sirens from factroies, etc.

The menace of noise pollution is growing day by day due to the population explosion, urbanization and rapid industrialization.

c) Adverse effects of noise pollution

Noise in an average living room would be about 40 decibels (db) and normal conversational speech would be about 50 db. Noise level up to 70 decibels (*e.g.*, that in a running bus) is more or less harmless to humans and up to 85 db, it is tolerable. However, higher levels of noise would become a health hazard to humans. The noise level would be about 80-90 db from the beating of a drum, 75-90 db inside a cinema hall, 80 db from a mixie, 120 db from an exploding cracker, 130 db from the hoot of

a train, 150 db from a siren, and so on. Some of the adverse effects produced by *noise pollution* on humans are mentioned below:

1. It induces hormonal imbalances, anxiety, and fright.
2. It affects the hearing capacity and at higher levels, damages ear drum causing deafness.
3. It may induce emotional disturbances, psychological disorders, nervous break down and even insanity.
4. It disturbs sleep and cause fatigue and frustration.
5. It increases heart beats and raises blood pressure.
6. It aggravates gastric disorders and stomach ulcers.
7. It may affect the functioning of brain, kidneys and liver.
8. It disturbs man's methods of communication such as normal and telephonic conversations.
9. It causes headache nausea and fatigue as well as affects work performance.
10. It induces abortions and causes physical abnormalities in young children.
11. It encourages addiction to sleeping pills, drugs and alcohol.
12. At very high levels, it may kill a person inducing heart attack or cerebral haemorrhage.

d) Control of noise pollution

Although noise pollution cannot be totally eliminated, it can be reduced and its effects minimised by taking some preventive or safety measures. Some such measures are mentioned below:

1. Ear-protective aids such as ear plugs must be issued to workers in noisy factories.
2. Walls and ceilings of factories must be insulated with sound-absorbing materials.
3. Old noisy factory machines should be replaced by new ones fitted with silencers.
4. For houses and office buildings in the middle of busy cities, the doors and windows should be designed properly using adequate sound-proofing techniques.
5. Noise-creating operations should not be conducted in enclosed spaces but only in large open spaces.
6. Vehicles producing high rattling sounds should not be allowed on the road.
7. The use of air horns should be prohibited in cities and towns and near hospitals, schools, etc.
8. The use of blaring loud speakers in thickly populated areas should be prohibited.

9. By growing trees around factories and places of gathering, the impact of noises can be reduced.
10. Busy bus stations, railway stations, aerodromes, etc. should be away from heavily populated areas.

UNIVERSITY MODEL QUESTIONS

Section A (Very short answer)

1. What is the name given to that segment of the environment that includes all types of water resources ?
2. What does a higher BOD for a water sample from a pond indicate ?
3. What is a *pollutant* ?
4. What is a *water pollutant* ?
5. Name two water pollutants.
6. What is meant by *eutrophication* ?
7. Name a factor that causes eutrophication.
8. Name one important source of water pollution.
9. Which heavy metal pollution caused the so called *Minamata disease* ?
10. Name the heavy metal pollutant that caused the so called *itai itai disease*.
11. What is meant by *bioaccumulation* ?
12. What is meant by *biomagnification* ?
13. Name one method of disinfecting water for drinking purposes.
14. What is meant by *demineralisation of water* ?
15. Suggest a process for the *demineralisation of water*.
16. What is an *air pollutant* ?
17. Name the region of atmosphere immediately above troposphere.
18. Name two air pollutants.
19. Which pollutant causes the so called *London smog* ?
20. Name a pollutant that causes *photochemical smog*.
21. Which are the major culprits for stratospheric ozone depletion ?
22. What is *greenhouse effect* ?
23. What is the major detrimental consequence of enhanced greenhouse effect ?
24. Name two *greenhouse gases*.
25. Name two important acid components of acid rain.
26. Name two pollutant gases that cause acid rain.
27. What are *pesticides* ?

28. What is meant by *pesticide pollution.*
29. Name one chlorinated hydrocarbon insecticide.
30. What is *noise pollution* ?
31. What is known as *radiation pollution* ?
32. What is the lowermost layer of atmosphere called ?
33. What does *hydrosphere* consist of ?
34. What is *lithosphere* ?
35. What is meant by *ozone umbrella* ?
36. Mention an important detrimental consequence of ozone layer depletion.

Section B (Short answer)

1. How is D.O in water expressed ? What happens when D.O falls very low ?
2. Define : (i) Pollution; (ii) Pollutant.
3. What are the two major environmental imbalances caused by deforestation ?
4. How do fertilizers pollute water ? What are the adverse effects ?
5. How does lead pollution occur ? What are the toxic effects of lead ?
6. What is meant by acid rain ?
7. What are the chief components causing air pollution ?
8. What is meant by *bioaccumulation* ? What is its consequence ?
9. What is meant by *biodegradability* ?
10. Define the terms i) Eutrophication; ii) COD.
11. Name the four segments of environment.
12. Explain the term *biomagnification.*
13. What is meant by BOD ? How does it differ from COD ?
14. What is meant by *environmental pollution* ?
15. Name the different types of pollution.
16. How do industrial effluents pollute water ?
17. How is water polluted by soaps and detergents ?
18. How do pesticides pollute the environment ?
19. Name some chlorinated hydrocarbons used as pesticides.
20. What are the chief causes of water pollution ?
21. Why is it said that long term use of synthetic fertilizers destroys the quality of soil ?
22. Name the most toxic heavy metal ions causing water pollution.
23. Explain the significance of determining the Dissolved Oxygen in a water sample.
24. What are the toxic effects of mercury and cadmium ?
25. Give a schematic representation of biomagnification in the food chain.
26. What are the important stages involved in the purification of water to make it potable ?