Notes

P.G. DIPLOMA IN ENVIRONMENTAL STUDIES

PHYSICAL SCIENCES

BLOCK - 1 : AIR POLLUTION

BLOCK - 2 : WATER POLLUTION

BLOCK - 3 : SOIL POLLUTION

BLOCK - 4 : PHYSICAL POLLUTION

BLOCK - 5 : POLLUTION MONITORING

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PREFACE

This book deals with Physical Sciences included in the syllabus of P.G. Diploma in Environmental Studies offered by Dr. B.R. Ambedkar Open University. The topics included in this course generally cover the special area of the programme. The syllabus for the sake of convenience is divided into blocks each of which comprises a number of units. Each block generally covers a specific area of the subject. The units are written by the specialists in accordance with a format specially designed to enable the student to read and understand them without much difficulty. Each unit begins with a statement of its contents followed by objectives. Each unit has at its end summary, model answers for the questions given under check your progress and model examination questions. Three assignments are given at the end of the book and the student is expected to submit at least one assignment to the Coordinator/Asst. Director/ Deputy Director of the concerned study centre.

This book deals with various aspects of Air Pollution, Water Pollution, Soil Pollution and Physical Pollution. Special emphasis was given to pollution monitoring and topics such as Remote Sensing and Environmental pollution Monitoring and Analysis.

The University hopes that this material will help the student to get acquainted with principal issues of environment. Critical suggestions for improving the text are most welcome and they will be incorporated in the future edition.

CONTENTS

BLOCK - 1
AIR POLLUTION

UNIT - 1 : SOURCES AND PROBLEMS OF AIR POLLUTION

Contents

1.1. OBJECTIVES

After completing this unit you will be able to :

- define the nature and problems of air pollution,
- list out the factors that influence the air pollution,
- explain the problems of air pollution in Indian context and at global level, and
- describe the monitering of air pollution.

1.2. INTRODUCTION

Air is a loosely defined term used to describe the mixture of gases that exists in a relatively thin layer around the earth. The components of this mixture from ground level upto a height of about 50 miles are remarkably constant.

Table-1.1. The compostion of clean and dry Air.

S.No	Major & Minor Components	Concentration (Vol %)
	Major Components	
1.	Nitrogen (N_2)	78.09
2.	Oxygen (O_2)	20.95
3.	Argon (Ar)	0.93
4.	Carbon Dioxide (CO_2)	0.032

Minor Components

5.	Neon (Ne)	0.0018
6.	Helium (He)	0.00052
7.	Methane (CH_4)	0.00015
8.	Hydrogen (H_2)	0.00005
9.	Nitrous Oxide (N_2O)	0.00002
10.	Carbon Monoxide (CD)	0.00001
11.	Xenon (Xe)	0.000008
12.	Ozone (O_3)	0.000002

As indicated in the table Nitrogen & Oxygen are the predominant gaseous components in the atmosphere and these constitute 99%. Naturally all of the remainder of the atmosphere is made up of Argon (Ar) and Carbondioxide (CO_2). The total volume percent of these four components in the clean air is 99.99.

The minor components of air are numerous and a number result from various natural processes. H_2S, SO_2, CO are all put in to the atmosphere by volcanic action.

1.3. AIR POLLUTANT

The addition of any substance other than the usual components will alter the physical and chemical properties of clean air. Such substances are called as air pollutants.

Pollutants are usually classified as only those substances which are added in amounts sufficients to cause measurable effects on human, animals vegetation or materials. On this basis almost any natural or synthetic substance capable of being air-borne can be classified as a pollutant. Such substances may include solid particles, liquid droplets, gases or as mixture of the aforesaid forms.

Problems : Air pollution is directly influenced by rapid expansion of industries, modern agricultural practice, extensive use of automobiles and indiscriminate waste disposal in urban and semi-urban areas.

Classification of Air Pollutants

Five types of substances known as primary air pollutants, account for more than 90% of the nation wide air pollution problem. These are :

1) Carbon monoxide (CO)
2) Oxides of Nitrogen (NO_x)
3) Oxides of Sulfur (SO_x)
4) Hydrocarbons (CH_x)
5) Particulates (Part)

Sources

1) Transportation
2) Fuel Combustion
3) Industrial Process
4) Waste disposal
5) Agricultural burning

Table 1.2. Sources and amounts.

Pollutant Source	Millions of tonnes					
	CO	NO_x	CH_x	SO_x	Particulates	Total
Transportation	111.0	11.7	19.5	1.0	0.7	143.9
Fuel combustion	0.8	10.0	0.6	26.5	6.8	44.7
Industrial process	11.4	0.2	5.5	6.0	13.1	36.2
Solid waste disposal	7.2	0.4	2.0	0.1	1.4	11.1
Miscellaneous	16.8	0.4	7.1	0.3	3.4	28.0

Transportation is the main source of air pollution

Carbon Monoxide

Carbon Monoxide (CO) is the most abundent and widely distributed air pollution found in the lower atmosphere. It is a gas with boiling point of - 192°C and is colourless, odourless and tasteless. It has a density of 96.5% like that of air. It is flammable and burns with a blue flame.

Sources : Both natural and anthropogenic sources contribute to atmospheric levels of CO. The principal source of carbon monoxide in the environment are incomplete combustion, combination of hydroxyl radicals with methane derived from decomposition of living matter, the oceans, and the growth and decomposition of plants containing chlorophyl. The presence of CO in automobile exhaust resulting from poor combustion. The environmental effects of CO has been studied intensively. Approximately ten times of as much CO enters the atmosphere from natural sources than from all human activities.

Effects of CO Air pollution

Carbon monoxide has not been shown detrimental effects on higher plant life for several weeks at exposure levels below 115 mg/m^3. It does inhibit nitrogen-fixing bacteria in clover roots when such levels are maintained continuously for a month or more. The principal effect of carbon monoxide on humans and other animals is its interference with the transfer of oxygen through the body. By forming a coordination complex with hemoglobin (Hb) in the red blood cells, carbon monoxide displaces oxygen and prevents the latter from being transported through the bloodstream :

$$Hb + O_2 \rightleftharpoons HbO_2 \text{ --- } (1)$$

$$HbO_2 + CO \rightarrow COHb + O_2 \text{ --- } (2)$$

Increased COHb in the blood has the effect of depriving various organs, especially the brain, of needed oxygen. This results in impairment of corresponding physical abilities.

Carbon monoxide in the atmosphere may also cause chronic health effects. For instance, a study done in Los Angles showed a strong correlation between carbon monoxide concentration and the mortality rate. 20ppm CO could account for 11 extra deaths per day in the Los Angels area when compared with the mean yearly concentration of about 7 ppm.

Analysis of CO

The most commonly used method for determining atmospheric CO concentrations is nondispersive infrared (NDIR) analysis. This differs from the usual spectrophotometric IR measurements in that no grating or prism is used – all IR wavelengths pass through the sample and reference cells alternately. The radiation is absorbed by a detector, raising the temperature of the latter in proportion to intensity. Use of gaseous carbon monoxide in the detector is an ingenious way to insure that it will have maximum sensitivity at wavelengths corresponding to CO's absorption spectrum. If the intensity of radiation passing through the sample cell is decreased because of the presence of CO, the sample side of the detector will not be as warm as the reference side. The resultant pressure differential is measured by distension of a flexible diaphragm. With proper calibration a direct meter or recorder readout of CO concentration is possible.

Commercially availble instruments with cell path lengths of a meter or more can measure a range of 1-115 mg/m^3 with response times of 1-5 min. This permits essentially continuous monitoring. Once the high initial investment is paid, a NDIR analyzer can be operated by in experienced personnel, requires no wet chemicals, and is reasonably in sensitive to changes in flow rate and ambient temperatures. Carbon dioxide and water vapor, which absorb strongly in the infrared are the chief interferences, and their effects may be minimized by means of filter cells which remove the wavelengths which they absorb from sample and reference beams.

1.4. OXIDES OF NITROGEN

Eight different nitrogen oxides are known, but only three viz., nitrous oxide (N_2O), Nitric oxide (NO) and nitrogen dioxide (NO_2) are important. There are several natural sources of nitrogen-containing compounds (other than N_2) in the atmosphere, Ammonia, nitrous oxide and nitric oxide are all released by microbial process.

Nitrous oxide is also quite stable in the troposphere and is present in much higher concentrations than other nitrogen compounds. Most of it is removed by biological sinks, but a small quantity difuses to the stratosphere where its reaction with atomic oxygen produce NO.

Check Your Progress - 1

What are the compounds of Nitrogen released in microbial process?

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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Ammonia returns to the soil or water environment by gaseous deposition or by precipitation of aerosols involving ammonium compounds. Sulfate and nitrate salts are important in this respect, because of their water solubility they are often found in reinfall, and in such cases ammonia helps to neutralise acid rain.

Sources

Natural and anthropogenic sources both contribute to current atmospheric levels of nitrogen oxides. The emision percentage from natural and anthropogenic sources differs markedly for the three oxides. Almost all atmospheric N_2O comes from natural sources. NO is produced by both natural(80%) and anthropogenic (20%) sources, while nearly all NO_2 emitted into the atmosphere is of an anthrpogenic origin.

Problems of Atmospheric NO_x

A major process responsible for the removal of NO_x, from the atmosphere involves the conversions of the oxides to nitric acid (HNO_3). The HNO_3 from NO_x has not been completely determined. However it is known that the direct reaction of NO_2 with H_2O is

$$2NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$$

A reaction between NO_2 and atmospheric Ozone generates the intermediate N_2O_5. The intermediate then dissolves in water to give nitric acid. The presence of NO_x in the atmosphere does lead to plant injury and damage.

1.5. ANALYSIS OF OXIDES OF NITROGEN

Chemiluminescent methods are used for detection and determination of oxides of Nitrogen. In the method ozone is made to react with nitric oxide to produce NO_2 in an excited state. When the latter decays to the ground state the luminescence emitted will be proportional to original concentration of NO. This method also can be used to determine total quantity of NO and NO_2 by treating the incoming sample with O, and then converting NO_2 to NO + O_2.

The Griess - Saltzman method is based on reaction of NO_2 with sulfanilic acid to form a diazonium salt. The later then couples with N-(1-naphthyl)- ethylene diamine dihydrochloride to form an azo-dye whose absorption at 550 nano meters may be measured spectrophotometrically. Analysis must be completed with in a hour of sample collection. The method can be used to determine atmospheric concentration of NO_2 from 40 to 1500 $\mu g/m^3$ (0.02 - 0.75 ppm). High concentration of SO_2 may bleech the reagent, giving low results, and stoichiometry of the process is not completely clear, but it can be calibrated using permeation tubes and is easily modified for automated analysis.

Oxides of Sulfur

The sulfur oxides emitted into the atmosphere in the largest quantities is SO_2, a small amount of SO_3.

Sources : On a world wide, 146 million tonnes of SO_2 enter the atmosphere annually in a direct way. In addition 194 million tonnes of SO_2 are annually generated with in the atmosphere as a result of the oxidation of H_2 S. This is a secondary process (H_2 S oxidation) rather than direct emissions, accounts for the majority of atmospheric SO_2.

$$H_2S + O_3 \longrightarrow H_2O + SO_2$$

Fate of Atmospheric SO_x

A large part of the atmospheric SO_2 is oxidized to SO_3 which then reacts with water vapour to form H_2SO_4.

$$SO_2 \xrightarrow{O_3} SO_3 \xrightarrow{H_2O} H_2SO_4$$

The sulfuric acid reacts with other available substances to form sulfates. For example ammonium sulfate results when the acid reacts with ammonia.

Effects of SO_x

Plants are injured by SO_2 in one of the two ways depending on SO_2 concentration. They cause chronic injury by a gradual yellowing of the leaves. On human health they cause irritation of the respiratory system.

Oxides of Sulfur

SO_x are monitored by bubbling a gas sample through 0.3M $H_2 O_2$ at a P^H of 5. This converts SO_2 & SO_3 to $H_2 SO_4$ which can be titrated with a base. The presence of other acidic (HCl) or alkaline (NH_3) gases in the sample can lead to erroneous results, but the method is simple and inexpensive.

Check Your Progress - 2

Name the sulphur oxides which can get more pollution in the atmosphere to the longer extent

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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1.6. HYDROCARBONS AND PHOTOCHEMICAL OXIDANDTS

Hydrocarbons and photochemical oxidants are two separate but related categories of pollutant compounds. Hydrocarbons are primary pollutants because they are introduced directly in to the air. Photochemical oxidants are secondary pollutants originating in the atmosphere from reactions involving primary pollutants.

Hydrocarbons : As their name implies contain only the elements hydrogen and carbon. They are found in all three physical states (gas, liquid and solid) at room temperature.

Hydrocarbons most important in air pollution are those that are gases at normal atmospheric temperatures or those that are highly volatile at such temperatures. Most of these compounds have relatively simple structures containing twelve or less carbon atoms per molecule.

These may be classified as aliphatic or aromatic on the basis of their molecular structures. These are further classified as saturated or unsaturated. The number of hydrocarbons involved in air pollution is fairly large.

Photochemical Oxidants : The term photochemical oxident is used to describe an atmospheric substance produced by a photochemical process (a chemical process that involves light) which will oxidize materials not readily oxidized by gaseous oxygen. These substances are secondary pollutants produced by an interaction of primary pollutants with light. The most studied photochemical oxidants found in the atmosphere are ozone.

Sources of Hydrocarbons : Most hydrocarbons enter the atmospher from natural sources. These are coal, natural gas and petroleum fields. Methane the simplest of all hydrocarbons is emitted in to the atmosphere in quantities larger than any other hydrocarbon.

Hydrocarbons : Hydrocarbons in air are monitored using Gas- Chromatograhy.

Sources of particulate matter : Historically the oldest air pollution problem is that of smoke and soot - particulate matter. Particulates may contain a variety of chemical compounds depending on the sources from which they are emitted. All have the common property of consisting of finely divided solid particles suspended in the atmosphere.

There is a variety of sources of atmospheric suspended solids. Spray from Ocean waves evaporates, leaving salt particles whose average diameter lies between 1 and 10 μm. These may reach altitudes well above 500 m over the oceans and have been detected as much as 1500 Km inland.

Volcanoes are another important, if intermittent source. In some explosive eruptions particles have been injected into the stratosphere as well as the troposphere. Even monor eruptions may produce haze 3000 Km away and there is evidence that the explosion of Krakatoa in the East Indies may have effected climate for several years.

A third important less massive source is biological. Spores, pollen, viruses or bacteria have been found as high as the stratosphere and photochemical decomposition of terpenes derived from tree results in haze of the type that gives the great smoky mountains of the southeastern United States. Forest, grass and brush fires, some of man-made origin produce as many as 5×10^{18} particles per square meter and smoke from major conflagrations can travel around the world. Dust and sand storms, which produce mainly large and giant particles.

Mans activities unfortunately are compararble in magnitude to the sources listed above. In USA fuel combustion and industrial processes both emit more suspended solids than forest fires. The former produce large quantities of fly ash containing carbon, oxides of silicon, iron, aluminum, calcium, nickel or phosphorous and sulfates.

Particulates : Particulates in Air sample are monitored by densitometry. Air is passed through a filter usually a continuous strip of paper which is automatically moved past the collection site at constant intervals. The particles collected during each time incriment appear as a dark spot whose reflectance will be proportional to the concentration of particulates.

1.7. OTHER INDUSTRIAL AIR POLLUTANTS

A variety of substances are emitted to the atmosphere by industrial processes in addition to the five major air plollutants listed in Table 1. Some of them are reaching levels high enough to affect materials, plants or animals deleteriously. /Sources, yearly emmissions, and health effects of a number of such air pollutants are listed in Table 2. Although not all inclusive, it gives a general impression of the problems which will remain after the five major air pollutants have been adequately controlled. The paragraphs which follow will examine a few representative examples from Table - 2 in detail.

Table 1.3. Sources, Annual Emissions and Health Effects of Minor Air Pollutants (USA).

Sl.No.	Substance	Source	Health effects
1.	Lead	Auto-exhaust, industry, solid waste disposal, coal combustion, paints	Brain damage, behavioral disorders, convulsions, death.
2.	Fluorides	Industry, Coal combustion	Mottled teeth, weakening of bone, weight loss, thyroid and kidney injury, death.
3.	Vanadium	Coal and petroleum combustion, industry	Inhibits formation of phospholipids and S-containing aminoacids.
4.	Manganese	Industry, Coal combustion	Fever, Pneumonia
5.	Arsenic	Industry	Dermatitis, melanosis perforation of nasal septum possible carcinogen
6.	Nickel	Coal combustion, industry	Dermatitis, dizziness, headaches, nausea and carcinogenesis
7.	Asbestos	Industry	Scarring of lungs, lung cancer
8.	Cadmium	Industry	Gastrointestinal disorder, respiratory tract disturbances, carcinogenic and mutagenic
9.	Mercury	Coal combustion, commercial, industry	Tremor, skin eruption, hallucinations
10.	Berellium	Coal combustion, industry	Lung damage, enlargement of lymph glands.
11.	Selenium	Ore refining, sulfuric acid manufacture, coal combustion	Depression, jaundice, nose bleed, dizziness, headaches

Check Your Progress - 3

What are the main substances and sources for health effects like lung damage, jaundice and skin effects ?

Note : (a) Write your answer in the space provided below

(b) Compare your answer with the one given at the end of this unit.

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1.8. ACID RAIN

Once sulfuric has formed it may react with ammonia or metal salts (such as sodium chloride from sea particulates) to plroduce sulfates (XSO_4). Sulfuric acid or sulfates then precipitate with rain. Sulfurous and sulfuric acids, HCl produced by above reaction and hydrolysis of ammonium sulfate all reduce the P^H of rain water.

In both Europe and the United States acid rain with P^H values ranging from 5.0 to as low as 2.1 is common. Because of dissolution of atmospheric CO_2 to form $H_2\ CO_3$ the P^H of natural rain is some what below 7.0 averaging around 5.7 (Carbon dioxide dissolved in rain water reacts to generate carbonic acid. This causes rain water to be slightly acidic as indicated by the normal P^H of 5.7).

1.9. SUMMARY

Air is loosely defined term used to describe the mixture of gases that exists in a relatively thin layer around the earth. The addition of any substance other than the usual components will alter the physical and chemical properties of clean air. Such substances are called as air pollutants.

Carbon monoxide, oxides of nitrogen, oxides of sulfur, hydrocarbons and particulates are known as primary air pollutants. Carbon monoxide is the most abundent and widely distributed air pollutant found in the lower atmosphere. Nitrous oxide is also quite stable in the troposphere and is present in much higher concentrations than other nitrogen compounds. Hydrocarbons are found in all three physical elements (gas, liquid and solid) at room temperature. Carbon dioxide dissolved in rain water reacts to generate carbonic acid. This causes rain water to be slightly acidic as indicated by the normal pH of 5.7.

1.10. CHECK YOUR PROGRESS : MODEL ANSWERS

1. NH_3, N_2O and NO.
2. Sulfur dioxide (SO_2)
3. Berellium - Commercial Industry

   Selenium - Ore refining

   Mercury - Commercial Industry.

1.11. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Explain the primary and secondary pollutants.
2. Write briefly about the Industrial Air Pollution.

II. Answer the following questions in about 10 lines each.

1. How do you classify Air Pollutants ?
2. Write the main effects of carbon monoxide in Air Pollution.
3. How is Ammonium Sulphate formed in the air ?

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UNIT - 2 : METEOROLOGY AND AIR POLLUTION

Contents

2.1. OBJECTIVES

After completing this unit you will be able to:

- describe the changes occurring in the climate,
- explain the effects of air pollutants on weather conditions, and
- describe the hazardous human activities taking place mostly because of ignorance of people

2.2. INTRODUCTION

The lives of all of us are affected by the weather. For example what we eat and drink, what we wear, how we behave and what our homes are like, are all influenced by the weather conditions, weather even shapes the land scape. Weather is with us all the time. *The state of air at any particular place and time is called the weather.* It can be hot or cold, windy or still, wet or dry. In some places it changes from day to day, in other places it stays much the same all year round. *The usual weather of a place is called its climate.* The climate of an area generally depends on its portion on the earth's surface. Places near the equator have hot climate and places far away from the equator will have cold climate.

But the world's climates are always changing. The revolutionary changes that took place in the recent times in the conditions of weather and climate forced the meteorologists to realise that the present climate too is unreliable. There was also a growing recognition that human activity such as burning fossil fuels, stirring up dust, falling forests and covering large areas with huge buildings and roads has reached a scale which could not but effect the climate. The air pollution problems would have been probably less serious had the weather been consistent. *The science dealing with the predictions of the weather conditions is called meteorology.* Air pollution meteorology is therefore becoming an increasingly important scientific activity these days. We shall discuss briefly some aspects of this air pollution meteorology in this unit.

2.3. CLIMATIC CHANGES AND METEOROLOGY

A reassessment of the earlier knowledge of the past climate changes which explained the Ice ages now forced the meteorologists to realise that the present climate is unreliable. Climate change has not ceased. There was a growing realisation that human activity and the climate change are more closely related than believed or anticipated. Therefore meteorology gained greater importance in these days than in the earlier days. Revolutionary advancements have therefore been brought into the field of meteorology. These include :-

1) The launching of the earth's artificial satellites to gather data relating to earth's climate and

2) The introduction of super computers for the data analysis and for making mathematical models.

World wide data gathered from the satellites is now fed routinely into the super computers for analysis and forecasting. These computers are capable of assimilating the data and running such mathematical models of world wide weather systems which can help in making forecasts for several days ahead. The models are set out to describe the world's climate in precise calculable terms and to explore the factors that can cause changes in the climate. The world has been sometimes hotter than it is now and sometimes cooler than it is now. As mentioned earlier weather is the state of air at any particular time and place. These changes in climate are therefore attributed to the state of air. The changes in the state of air is traced to the human activities as well as to the natural fluctuations that take place usually. Therefore it is essential for you to understand what is climate? what changes can occur in the climate ? and what factors can influence these changes ?

To get answers to the above questions you must know briefly about :

The structure of the Earth's Atmosphere

The temperature inversions in the Atmosphere

Global warming factors

Green house effect

Air circulation patterns and Global energy balances.

Check your progress - 1

What is meteorology ?

Note : (a) Write your answer in the space provided below.
(b) Compare your answer with the one given at the end of this unit.

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2.4. MAJOR REGIONS OF EARTH'S ATMOSPHERE

The insulating blanket of air around the earth is known as the *Earth's Atmosphere.* The temperature of the earth at the equator would have risen to 82°C during the day and dropped to -140°C at night if the atmosphere of the earth was not present at all. Thus the earths' atmosphere is vital to make life possible on the earth. The atmosphere is a reservoir of oxygen needed for all forms of life for their survival and of carbondioxide needed for the preparation of food by plants. Without the atmosphere probably there would be no sound and no light on the earth. The surface of the earth would have been possibly as bleak and sterile as that of the moon.

The earth's atmosphere consists of a gaseous mixture that changes very little in its composition under normal conditions. The earth's atmosphere has a density of 1.225 kg/m^3 at the sea level under normal conditions of temperature and pressure. It has a mass of 5.3 X 10^8 kg and extends to an altitude of about 300 km. The temperature also varies with the altitude and does not follow any uniform pattern of rise or fall. The important regions of the atmosphere are troposphere, stratosphere, mesosphere and thermosphere.

Troposphere

Around 80% of the atmospheric mass resides in this region only. This region or zone is the nearest to the earth's surface and runs up to about 15 km into space. Most of the variations that occur in this region would generally lead to weather conditions and fluctuations. This region is therefor the most important region as far as air pollution is concerned. Air pollution in any specific area generally means the pollution of the troposphere of the region within which the pollutants reside before they are removed by the different natural phenomena. However pollutants if directly injected into the next zone namely the stratosphere, they remain there for longer periods and effect the entire globe. Major volcanic eruptions throw dust and sulphuricdioxide gas into stratosphere and cause serious global effects such as formation of fine hare. The temperature falls in this troposphere region from about 288°C with increasing altitude and attains a minimum of 217°C at the *tropopause.* The rate of temperature drop is about 6.4°C per km. This is called normal *lapse rate.*

Stratosphere

This zone begins on the top of the troposphere and extends upto 50 km. It contains substantial amounts of ozone (O_3) which absorbs ultra-violet radiation coming from the sun to the Earth. The temperature rises to about $271^{\circ}C$ with altitude from about $217^{\circ}C$ the minimum attained at the tropopause. This temperature increases with altitude (in contrast to the temperature decrease noticed in the troposphere) is called *inversion*. Since the cold air is denser than warm air, inversion is very stable against vertical mixing effects. The maximum temperature of $217^{\circ}C$ is reached at the tropopause. From then again the temperature registers a decrease beyond this and also through out the next region called *mesosphere*.

Mesosphere

This extends roughly to 85 km from 50 km the top of the stratosphere. The temperature drops from about $271^{\circ}C$ to about $179^{\circ}C$ with altitude in this region as expected of lapse rate and attains the minimum temperature at the mesopause.

Thermosphere

This zone is above mesosphere and extends from 85 km up to 500 km. The temperature in this zone registers an increase with the altitude from $179^{\circ}C$ to $1473^{\circ}C$ and reaches the maximum value of 1500-2000 K at a height of several thousand kilometers.

The air density in this region is so low that it can hold very little heat.

Homosphere and Chemosphere

The region present below about 90 km in the atmosphere where the bulk composition of the atmosphere is essentially the same as that at the sea level is called the *homosphere*. In this sphere the diffusion phenomenon takes place very slowly and the composition of the air controlled by mixing factors only. The lower part of the thermosphere and the whole of the meso and stratospheres included in the homosphere are collectively known as *chemosphere*. Major chemical changes such as photodissociation of O_2 occur in this region only. This region is therefore very vital for air pollution effects.

2.5. INVERSION

The temperature structure of the atmosphere is very important since it controls the vertical movements of the substances in the atmosphere. This movement is very important for air quality conditions.

If the actual change in the temperature in the eminent air is greater than the lapse rate (the rate of temperature drop, about $6.4^{\circ}C/km$) the rising air will be at higher temperature than the surrounding air. Such a condition is called *unstable*. If the environment cools less rapidly with the height than the *lapse rate* an *inversion* is said to have occurred. Thus inversion is an important control factor of the weather because it inhibits vertical transport of substances. If this inversion occurs at lower levels (30-100 meters above an industrial area) the products emitted by the industry are retained in the lower layer of the cold air. Thus the air gets polluted and its quality suffers. The concentration of the noxious gases and the dust then increases rapidly. This causes damage to the people the animals and the plants in that area. These inversion situations depend on the season of the year. The frequency and the duration of inversion situations are generally greater in winter compared to the summer. Large scale down ward movements of air can also give rise to inversions. These are called *subsidence inversion.* Inversions called *radiation inversions* are also known to form at nights when the ground cools more rapidly than the air. Cold air with an advancing front can slide into warm air and can produce an inversion. This inversion is known as the *frontal inversion.* Cold mountain air may go down into warmer valley at nights and thus produces *advective inversion.* Thus inversions can be seasonal inversions, subsidence inversions, radiation inversions, frontal inversions and advective inversions. Sea breezes are regularly formed during the day and the air warmed up by the rise in the temperature of the land surface during day time rises vertically. This therefore draws a sea breeze off the oceans. At nights the reverse happens and the land breeze runs out to sea. These breezes therefore remove pollution from a coastal city during the night and deposit it back the next day. Similar things occur in the valleys too. The air moves up and down in a valley. But the side wise movements of the air are prevented by the valley. The advective inversion prevents the escape of the air from the top. The net result therefore is that the polluted air rises up and down the valley during the day. All these types of inversion conditions may therefore lead to different weather conditions and consequential pollution effects.

Check Your Progress - 2 & 3

2. Name the major regions of the Earth's atmosphere.

3. What do you call the region where chemical reactions occur in the atmosphere ?

Note : (a) Write your answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

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2.6. GLOBAL WARMING

It is believed and to some extent substantiated by scientific studies that global warming is taking place. An assessment of this global warming trends is therefore very essential in the context of air pollution studies. This assessment can be made in more than one way. For example it can be done on the basis of the historical temperature records available in the different countries and with different agencies. But fortunately such records are not easily available and many a time they may not be highly reliable also. Present days, the global temperature measurements are complied through the world weather system, a global net work of national meteorological services. In earlier days these observations were largely made by the individual observers working without any co- ordination between them. Recently these assessments have been made through a project sponsored by the US Department of Energy by the scientists of the Climate Research Unit, England, in collaboration with the scientists of Environmental Resources Laboratories and National Oceanic and Atmospheric Administration, USA. Those assessments showed that the earth has experienced an overall warming trend of half a degree celsius since the late 19th century. This rise in temperature has been attributed to what is known as *green house effect* caused primarily by the increase in the content of carbondioxide in the atmosphere. The different groups of scientists working in this direction agreed that it would be around the middle of the next century that the carbondioxide content of the atmosphere would be doubled. However, the temperature rise expected to occur due to this doubling of CO_2 content varied from one model to the other model proposed by different groups. Some predicted as little as 1^oC rise in temperature while the others predicted as much as 5^oC.

The carbondioxide content of the atmosphere has increased by more than 20% over the past century. So we ought to be able to detect the climate warming in the global temperature record. But it is a very difficult task to confirm this because the climate is always in a state of fluctuation. Further it is difficult to separate out the temperature changes that are caused by the rise in CO_2 content in the atmosphere from the temperature changes occuring due to the natural fluctuations in the atmosphere. Further the climate temperature records are usually designed not specifically for the purposes of determining the climatic conditions. However, the analysis made by the US and UK scientists of the available temperature records are of the view that a net increase in the temperature ranging from 0.3^oC to 0.8^oC has occured during the past century. But accepting that an increase in global temperature had really taken place, it is still difficult to conclude whether this temperature change is due to the natural fluctuation or due to green house effect.

The temperature records as well as the mathematical models proposed provide support to both the courses. What ever may be the real fact, these evidences of rise in temperature warrant serious action now in order to avoid any future risk.

2.7. GREEN HOUSE EFFECT

This is a warming effect produced by the presence of gases like carbondioxide (CO_2), Chlorofluorocarbons (CFC), methane (CH_4), nitrous oxide (N_2O) and water vapour (H_2O) in the lower atmosphere.

The sun, the most important source of energy for the Earth, sends radiations covering all most all the regions of the electromagnetic spectrum. Carbondioxide in the atmosphere absorbs heat radiation (IR) or reflects it back to the earth. Carbondioxide in the atmosphere thus functions in the same way as glass functions in the green house. (Glass house: where plants are grown for experimental purposes). The glass allows solar radiation to pass through it but holds back IR radiation. The net result is a warmer temperature in the green house than outside. A similar thing occurs as an essential natural process in the atmosphere to maintain the earth's temperature for this carbondioxide is needed in the atmosphere at the specified levels. The earth's surface would have cooled much more rapidly at night than what it is now if carbondioxide is not present in the atmosphere. But increase or decrease in CO_2 content in the atmosphere would certainly alter the speed of the green house effect. The other gases as mentioned earlier that are contributing to the green house warming are chlorofluoro carbons (CFC). Ozone (O_3), nitrous oxide (N_2O), methane (CH_4) and water Vapour (H_2O).

Check Your Progress - 4, 5 & 6

4. What is meant by Global warming ?

5. What is green house effect ?

6. Name the gases that are expected to contribute to green house effect.

Note : (a) Write your answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

2.8. AIR CIRCULATIONS

Air in the troposphere is constantly in motion. The air never stops moving. Air as it moves carries with it the heat and the water around the globe giving us our weather. Horizontal movements of air called *Winds*. Vertical movements are called *Currents*. World winds blow because there is differences in pressure and temperature between one place and another. Winds blow from an area of high pressure to an area of low pressure. Where air is warm it is less dense than the cold air and therefore rises up causing an area of low pressure. Cold air therefore sinks down to the earth and moves in to fire, the gap left by the warm air. It is this vertical circulation of air that forms the air currents. Winds which blow all the time in the same area of the world are called *prevailing winds*. They determine the weather pattern around the globs. They move because the equator gets more heat from the sun than the poles get. Hot air moves north and south from the equator where it gets cooled. The winds that blows from north-east and south-east, either side of the equator are called *trade winds*.

Winds and currents thus determine the major circulation pattern of air. Cool surface air flows towards the equator and forces currents of warm air to rise. In the upper atmosphere warm air flows towards the poles. Cold air sinks to the earth's surface at the polar region. From the poles the air flows toward the equator. This circulation of air carries heat from the equatorial region to the rest of the earth. The circulation patterns of the air have very important implications. A polluted air mass at 30^{0} latitude may be transported over much of the hemisphere. But it would be difficult for it to cross the equator. If polluted air is transported to the stratosphere it is no longer restricted to the air circulation patterns of the troposphere. In the stratosphere inter hemispheric transport is much easier. Air can enter the stratosphere very easily at the points where the tropopause breaks down. For example when large nuclear explosions occur, radioactive debris makes way into the stratosphere and from there the fall out distributes itself over the entire globe.

Thus air circulation patterns or winds and currents patterns play a significant role in the transport and distribution of polluted air mass over the globe.

2.9. GLOBAL ENERGY BALANCE

The sun emits radiation at a temperature of about 6000^{0}K. These emissions range in the wave lengths from very short to very long wavelengths. Earth receives sun's energy and radiates a part of it back into the atmosphere. Emersions from the earth are of much longer wavelength and are of much lower intensity than those received from the sun. Much of the incoming radiations reach the surface of the earth because the outer atmosphere is transparent to them. But the atmosphere is not transparent to the out going thermal radiating from the earth's surface and is therefore absorbed by the atmosphere. Because of this absorption the lower atmosphere is warmer than the upper one. Long wave radiations (heat radiations) as mentioned earlier are absorbed by water vapour and carbondioxide in the atmosphere. It is for this reason that humanity is now warned to put a stop to all activities that contribute to the increase in carbondioxide content in the atmosphere. Other important process that transports heat vertically namely convection is also of vital importance because it lowers the temperature of the ground. Convection occurs because warm air is lighter than cold air. Thus warm air at the surface will move up and carry heat with it. As the warm air goes up it expands and if this expansions occurs under adiabatic conditions (no exchange of heat with outside air), the air gets cooled (adiabatic expansion produces cooling). Thermodynamic calculations show that the lapse rate (fall in temperature/km) should be 9.8^{0}C. But the measured value is only 6.4^{0}C. This is because the air is wet and as it rises it condenses with release of latent heat. Thus the vertical mixing process and the atmosphere of remitted long wave radiations explain the temperature changes of the lower part of the atmosphere. The atmosphere is however not transparent to ultra violet radiations (lower wave length). Therefore, they are absorbed by ozone at about 40 km altitude and thus results in the considerable warming of the stratosphere which contained the ozone.

The temperature of the stratosphere thus increases with altitude. In the thermosphere region the temperature is very high. In this layer, the atmosphere is very thin and therefore molecules are exposed to the higher energy radiations from the sun. The energies are large enough to dissociate these molecules such as oxygen and nitrogen releasing lot of energy. Here the cooling of the atmosphere by re-radiation is not efficient. The temperature of the thermosphere increases with altitude. It is also stable against convection. Heat can be lost only by inefficient diffusion process. As a result the temperatures of the thermosphere are extremely high.

Check Your Progress - 7

Why is lapse rate less than the theoretically expected ?

Note : (a) Write your answer in the space provided below.
(b) Compare your answer with the one given at the end of this unit.

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2.10. CLIMATE CHANGES AND FUTURE ACTION

The absolute maganitude of the misery and suffering experienced presently by the human beings due to unwarranted climate changes may be much larger than it ever was. This is because the human population in all parts of the world is much more than what it was earlier. It is not merely the question of survival of the human race as a species but it is a question of social disruption and human suffering. Some sort of awareness about the global climate changes and the concerned causes for it has therefore to be created in the minds of common people.

The climate changes may occur over the next few decades from three factors :

1. The input of energy from the sun does vary a little. But any scientific predictions in this regard basing on past climate records may be debatable.
2. The absorption of solar radiation by volcanic dust and sulfate aerosols in the atmosphere. This ofcourse depends on the random occurance of large volcanic eruptions. It is difficult to predict where the next large eruption occurs.
3. The continued increase of CO_2, CH_4, CFC's and other green house effect gasses in the atmosphere.

In sum these three effects may combine to produce air eratic variation of the mean temperature and consequential climate changes.

A large volcanic eruption may modify the stratosphere for about 2 years and the green house effect gases will increase insidinously.

Agriculture is the major area likely to be effected because, crop growth depends on the spacing and intensity of hot and cold periods as well as wet and dry periods. Pollution of stratosphere is likely to be severe and might get worse as more southern nations develop heavy industry and burn more coal.

Another speculation is that climate changes taking place due to air pollution may alter the geographical distribution of various disease producing organisms. Certain of these organisms may have access to human populations which have no prior evolutionary experience with them and hence have little or no resistance to them. Sometimes what was hither to considered a minor hazard may become a plague.

Climate warming is evident in a rising frequency of heat waves or of other weather anomalies.

Future Actions

1. Energy conservation and efficiency shall be the first priority. Increase in energy efficiency would reduce urban pollution and acid precipitation.
2. Use of natural gas and biogas should be encouraged in place of fossil fuel mix (coal and oil). This significantly reduces CO_2 emissions into the atmosphere.
3. Major investiments in non fossil energy sources are highly desirable.
4. Reforestation and forest preservation shall be encouraged and given top priority. These give ecological and climatic benefits.
5. People including agriculturists should be encouraged and educated to adapt to climate changes. Farmers can change crops and water use can be regulated. sea level rise and the consequential inflow of salt water into fresh water bodies shall be tackled by changing land. Use patterns rather than investing heavily in the construction of protection structures along the coasts.
6. last but not least every average man must be adequately educated about the pollution problems and their prevention and remedial measures.

Check Your Progress - 8

What hazards are anticipated from climate changes due to human activity ?

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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2.11. SUMMARY

Troposphere is most effected in air pollution instances. The temperature fall/km with the increase in altitude of the atmosphere is known as *lapse rate*. This is about 6.4^{0}C/km.

The increase in the temperature of the atmosphere with altitude (instead of decrease) is known as *inversion. Different types of inversions are known. These are substances inversion, radiation inversion. frontal inversion and advective inversion. The state of air at any time and place is called weather.* The presence of gases such as CO_2, CH_4, N_2O, H_2O and chlorofulorocarbons seems responsible for the rise in earth's temperature. The rise in temperature of the earth's surface due to presence of these gases in the atmosphere is called green house effect. Winds and currents determine the major circulation patterns of air. Climate changes occuring due to air pollution may have long range adverse effect. Every common man shall be educated about these hazards.

2.12. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The Science dealing with the predictions of the weather conditions is called meteorology. The weather can be defined as the state of air at any particular place and time.

2. The major regions of Earth's atmosphere are Trophosphere, Stratosphère, Mesosphere and Thermosphere.

3. Major chemical reactions occur in the region of Chemosphere. The lower part of the Thermosphere and the whole of the Mesosphere and Stratosphere are collectively called as chemosphere.

4. The rise in temperature of globe due to the increase of carbondioxide content in the atmosphere is called global warming.

5. This is a warming effect procedure by the presence of gases like carbondioxide (CO_2), Chlorofluorocarbons (CFCs) methane (CH_4), Nitrous oxide (N_2O) and water vapour (H_2O) in the lower atmosphere. Carbondioxide in the atmosphere absorbs some of the heat radiation (Infra Red range) and some of it is reflected back to the earth. CO_2 in the atmosphere functions similarly as glass functions in the green house (The glass allows solar radiation to pass through it but holds back IR radiation). The net result is a warmer atmosphere in the green house than outside. Similarly the increase in the level of concentration of CO_2 gas on the earth increases the atmospheric temperature of earth.

6. The gases which contribute to green house effect are CO_2, Chlorofluorocarbons, methane, N_2O and water vapour.

7. Thermodynamic calculations show that lapse rate should be 9.8°C. But the measured value is only 6.4°C. This is because the air is wet and as it rises it condenses with the release of latent heat.

8. The following major hazards are anticipated from climate changes due to human activity.

   i) Agriculture is likely to be effected as crop growth depends on spacing and intensity of hot and cold periods as well as wet and dry periods.

   ii) Air pollution may alter the geographical distribution of various disease producing organisms. This may lead to spreading of diseases among human populations.

   iii) Climate warming leads to rising frequency of heat waves, droughts, floods and other such weather anomalies.

2.13. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Explain the term 'meteorology' and explain its role in air pollution studies.

2. Explain the terms, lapse rate, inversion, weather, climate, winds, currents as far as the earth's atmosphere is concerned.

3. Discuss the role of human activities in altering earth's temperature. What are the ill effects caused by this global warming.

II. Answer the following questions in about 10 lines each.

1. What is the broad structure of the earth's atmosphere ?
2. What is weather and what is climate ?
3. What is lapse rate ?
4. Explain the term 'Inversion'.
5. How is weather data collected now for meteorological forecasts ?
6. What major hazards are expected due to global warming ?

Prof. S. Brahmaji Rao

UNIT - 3 : EFFECTS OF AIR POLLUTION

Contents

3.1. OBJECTIVES

After going through this unit, you will be able to:

- list out the chemical substances which can pollute air,
- describe the damage caused by a particular chemical,
- describe the method of entry of pollutants into the host bodies,
- explain the effects depending on the concentration of the pollution and the time of exposure.

3.2. INTRODUCTION

The undesirable components with detrimental effects present in the atmospheric air in forbidden concentrations can be broadly taken as air pollutants. These may be gases or vapour or particulate forms. The gaseous pollutants include SO_2, H_2S, CO_2, CO, O_3, oxides of nitrogen, organic vapours and some obnoxious fumes. The particulate form pollutants are very diverse in character and are comprised of organic as well as inorganic substances. Their particle size generally varies from 0.01mμ to 100mμ. Toxic trace metals, smog, suspended dust and other types of particles are considered as air pollutants belonging to the particulate form category. The pollutants are emitted into the atmosphere from industries, automobiles and fossil fuels. Therefore, these are named as *sources.* Some of the pollutants are removed to large extent from the atmosphere by the processes such as chemical reactions and wet and dry deposition processes. These are therefore referred to as *sinks*. The study of the effects of air pollutants on the human health as well as on the animal and plant life has been a subject of major concern since a long time. Even the enactment of various laws against the different human activities likely to effect human health or the animal and plant life has begun as early as the thirteenth century itself. These ill effects of pollutants on human health can be *acute* or *chronic*. *Accute* effects are immediately recognised and felt by the effected human beings. These are generally caused of people are exposed to high concentrations of air pollutants for a short time. *Chronic* effects will take place on continuous exposure of human beings for longer periods to low levels of pollutants. It is difficult to detect these chronic effects. So the air pollution health hazards being reported in the News papers, radio and television from time to time refer to *acute* pollution effects only rather than the chronic pollution effects. Therefore we are really unaware how many of us are really suffering from these chronic effects. Deaths, if any, occuring from air pollution disasters are referred to as "excess deaths". The number of deaths occured in any polluted area over and above the number of deaths normally occured in that area in the absence of pollution is taken as "excess deaths".

3.3. AIR POLLUTION AND RELATED TERMS

Pollutants exert their effect on individuals but recognition of an effect is only seen where large numbers and even whole communities are effected. The amount of pollutant reaching a receptor (organism, population or community) is referred to as *exposure*. The biological change caused by such an exposure is called *effect*. The amount that is taken into an organism or individual is called *dose*. The death causing dose is known as *lethal dose*. It is a function of concentration and period of exposure. Supply of pollutant in one large package of high concentration is named as *acute exposure*. Supply of an equivalent amount at lower concentration over an extended period is called *chronic* exposure. Following cessation of exposure, chronic damage is frequently reversible, although continued exposure may prove fatal. Lot of secondary effects too are caused in addition to the direct impact of pollutants on living species. Therefore there is a need for careful consideration of these secondary effects also. For example the secondary effects may relate to community and habital changes such as distribution of predator-prey relationships or a dramatic decline of one or more species in a food web or disturbances in biogeo-chemical cycles. Thus secondary effects may relate to ecosystem effects rather than individuals effects. It is rather a difficult task to make studies in real situations of air pollution effects. Very often the study on the effects of gaseous air pollutants on plants has been done in the controlled environment of growth chambers. Therefore, the design and size of this chamber, the density of plants and the air velocity play a significant role in these studies. It is for these reasons, some times varied responses had been reported for seemingly equipment studies. Hence careful planning of the experiment, efficient monitoring of the effects and the reliable analysis of the data are required to assess the impacts of air pollution on different forms and aspects of life.

Check Your Progress : 1, 2 & 3

1. What is meant by "exposure"? what is the "effect" related to Air Pollution?
2. What is meant by dose and lethal dose?
3. Explain the terms acute and chronic exposures.

Note : (a) Write your answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

3.4. ENTRY MECHANISM AND PATHWAYS OF POLLUTANTS IN HUMAN SYSTEM

Absorption is the process where by pollutant makes it way into the organism, which it comes into contact. The organism may be a human being or a plant or an animal. Therefore the interface between the organism and the environment plays a significant role in the environmental pollution effects. Atmospheric pollutants make their presence as gases or as particulate matter and hence their characteristics (physical and chemical) bends the characteristics of the interface between the pollutant and the organism determine the nature and the extent of pollution. For example in mammals the main routes of entry are through lungs, the skin and the gastro intestinal tract. In terrestrial mammals, including man, entry through skin is unimportant. Inhalation is the most important route of uptake for many gases and vapours. In human beings absorption of pollutants through gastro-intestinal tract is also an important route of entry. Since the circulation system is closely associated with the intestinal tract, entry into capillaries is rapidly effected. Various blood flow from the intestine introduces the pollutant into hepatic portal vein and this in turn transports it into liver. Phyto toxic gases generally exert their effect near the point of entry. For example sulphurdioxide disrupts chloroplasts and reduce the photosynthesis in plant leaves. The gas may also change the stomatal aperture. Tissues with the largest amount of fat accumulate the highest concentrations of liquid soluble compounds. The pollutants may also enter the human body through nose, mouth, eyes and skin. Pollutants can therefore cause eye and skin irritations or even eye and skin diseases. A number of elements of the respiratory system which encompass the parts of the body most susceptive to attack are affected by the pollutants. The sensitive areas may range from the mucus membrane to the lungs. Particulate pollutants are usually deposited at different points in the respiratory tract. Only the smallest particles penetrate into the lungs. Solid pollutants may also dissolve to some extent in body fluids and then can enter the blood stream.

A pollutant when once it is inside an organism it follows different pathways. Four main routes are identified in many cases. These are :

1. Some pollutant molecules are metabolised (converted) into less toxic compounds.

2. Some pollutant molecules get stored in some tissues. For example lead in bones, cadmium in kidneys.

3. Some pollutants and their metabolites are excreted from the organism. Metabolites are more easily excreted.

4. Pollutant residues, if any after the above three processes had taken place exerts an effect at the site of action. Primarly this action is biochemical in nature.

Chlorinated organic compounds such as DDT, PCB, HCB, CFC are stored in fat deposits of a wide range of fauna including birds and mammals. Studies showed that starved animals are more affected by DDT than healthy ones. Ofcourse many vertebrate and invertebrate animals are capable of bio-transforming a large variety of pollutants to less toxic compounds and these are also eliminated from the organism. In higher organisms bio- transformation takes place in two stages:

1) Oxidation of foreign compound and 2) formation of sulphate or glucoronide derivaties.

The net effect is conversion of hyophilic foreign substance into water-soluble metabolite. Numerous organic compounds (benzene and phenolic compounds) undergo such transformations.

Large number of studies have been done by different organisations on the effects of air pollutants on animals. But most of these studies have been done at very high concentrations. Therefore these have no direct significance for human beings since the human beings are exposed to lesser concentrations of pollutants. No extrapolation studies are possible since there is a fundamental difference in the tolerence limits between animals and human beings on one hand and animal and the other, on the other hand. Therefore direct impact assessment on human beings is needed and an useful exercise.

Check Your Progress - 4

What changes a foreign substance undergoes in the human system ?

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

3.5. EFFECTS OF AIR POLLUTANTS ON HUMAN HEALTH

Some of the commonly occuring air pollutants and their ill effects on human health are very briefly described in this section. The list of the pollutants or the list of the hazards caused by them on humans is no way exhaustive or complete. The account given in this section is only a typical illustrative one to high light or focus the health hazards of air pollutants.

Nitrogen dioxide (NO_2)

This is a gas associated with photochemical pollutants. It may vary in the atmosphere from 0.1 ppm to 15 ppm. Depending on the level of the pollutant, the ill effect varies as described below :

0.1 - 0.25 ppm	-	Epidemiological effects and impairment of dark adaptation
0.5 ppm	-	Some changes in lung morphology
1.5 - 2.5 ppm	-	Increased air way resistance to bronchial and normal patients
15 ppm	-	eye and nasal irritations

Sulphur dioxide (SO_2)

This gas seems to be relatively less harmful. The concentration limit for an 8 hour/day industrial worker is 5 ppm. But there were reports of death even at a concentration of 1 ppm. This is probably because, the other trace component presents in urban polluted area, amplify its toxic effects eventhough SO_2 in isolation is less harmful.

0.3 - 0.5 ppm	-	increased sensitivity of dark adapted eye
1 ppm	-	decreased human mucus flow rate
6-12 ppm	-	throat irritation
10 ppm	-	eye irritation
20 ppm	-	coughing

Carbon monoxide (CO)

It is mainly ejected into the atmosphere through fossil fuel burning and through automobile exhausts. The gas combines with haemoglobin and lowers the oxygen carrying capacity of blood.

upto 250 ppm - Headache and nausea

large concentration - May lead to death

Effects of Particulate Matter

Metal vapours and organic compounds may form aerosols in the atmosphere. Smog is one of the most harmful forms of air pollution. The word smog seems to have been derived from the combination of smoke and fog. Emissions from power stations and industries are mainly responsible for the aerosols (colloidal suspensions of particulate matter in air) in the urban atmosphere. Primary aerosols are dust, soot and other inorganic matter. Secondary aerosols are formed from photochemical reactions. High concentration of particulate matter in the city atmosphere may restrict visibility and may produce ill effects on human health.

Thus toxic trace metals such as lead, cadmium, mercury and nickel and classical smog and photochemical smog are the principal particulate pollutants of great concern. Some of the adverse effects caused by these pollutants on the human health are briefly listed below :

Lead

The one trace metal present in large concentrations in the atmosphere is lead. Most of it comes from antiknock additives in automobile fuels. Lead from automobiles is less than 2 mμ in diameter and does not settle rapidly. These fine particles are absorbed by the body and retained within the lungs. Lead is fortunately removed from the human body particularly through urine. But the process is slow and therefore lead tends to accumalate. Most of the lead goes into red blood cells and gets concentrated initially in the liver and kidneys. From there it may get distributed to the bones, teeth and even brain. In the bones, lead is unmobilised. Therefore, it may not immediately cause anxiety. But it is definitely a potential hazard. Symptoms of lead poisoning are seen in nausea, vomiting and abdominal pain. It may also lead to the degeneration of the central nervous system especially in children.

Cadmium

Cadmium levels in air are generally higher near zinc smelters. Cigarette smoke also constitutes a major source of cadmium. The common symptoms of cadmium poisoning are hypertension, anemia and kidney failure. The action of cadmium on human body is not as well understood as that of lead. Electroplating industries too contribute seriously to cadmium pollution. There is also evidence that cadmium can induce chromosome abnormalities and may act as a carcinogenic agent on the lungs.

Nickel

Nickel is used as a catalyst in many industrial processes including the "Vanaspati" industry. Nickel is widely used in different forms in electroplating industry. It is used as a mordant in dyes and a glazing agent in ceramics. Therefore all these industries are likely to contaminate the air with the metal. Nickel tetra carbonyl, a compound formed in the metallurgy of nickel, is particularly poisonous. This compound may deposit nickel in the lungs, which later leads to lungs cancer. Dermatitis (skin disease) and respiratory disorders are yet other hazards caused by nickel in the atmosphere.

Mercury

Mercury is used by man in different forms and in different industries and other activities. Mercury is also used in some forms as medicine. Nearly all the industries and other concerns where mercury is used, contribute to the air pollution. It is generally present as vapour in the atmosphere because of its high vapour pressure.

All forms of mercury are potentially toxic. The inorganic compounds of mercury are relatively less toxic. The poisonous effects are cumulative and their effect on neurological behaviour is notorinis. The toxicity depends very much on its physical and chemical state. Pure metallic mercury is not particularly poisonous. Metallic mercury passes through the body undergoing any chemical change. Mercury vapours on the other hand are very dangerous because they cause irritation and destruction of lung tissues. The liquid mercury is not very volatile but fine mercury spilt on the floor can saturate the entire room with mercury vapour. For example 3 ml of Hg can saturate a big room (12' X 12') with its vapour in a week's time. Another difficulty is that spilt mercury cannot be removed. The usual remedy is therefore to cover it with sulfur powder. This not only reduces its volatility but also forms less harmful forms of Hg like HgS. The other harmful forms of Hg are largely soluble mercuric salts or dimethyl mercury $(CH_3)_2Hg$ or methyl mercury $(CH_3)\ Hg^+$. The harmful effects are slow to develop. Some symptoms are sore gums and loose teeth. Mercury poisoning can cause brain damage to even unborn infants. In Japan two major epidemies of methyl mercury poisoning have occured. These are one in Minamata Bay area and the other in Niigata. Accumulation of methyl mercury in sea food (fish) and the consequential consumption of this food were found responsible for the epidemies. Similar epidemic due to methyl mercury poisoning occured in agricultural communities in Iraq in the winter of 1971-72. over 400 people died.

Check Your Progress - 5 & 6

5. Name the most hazardous gaseous pollutants.

6. What are the particulate pollutants present in the air in urban areas ?

Note : (a) Write your answers in the space provided below.
(b) Compare your answers with those given at the end of this unit.

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3.6. EFFECTS ON PLANTS

Air pollutants cause damage not only to human and animal life but also to plant life. Vegetation is rather sensitive to air pollutants. Lichens are most widely affected. They die in areas where excess sulphurdioxide is present in the atmosphere. The most serious effect of air pollution on plants is the disturbance of water balance in the plant. Other hazard effects of air pollutants on plants include loss of green pigment (chlorophyll) and prevention of photo synthesis. The particulate pollutants may block the stomata of leaves and thus interefere with transpiration. The most important of the pollutants causing damage to the plant life are sulphurdioxide, sulphuric acid, ozone fluoride and PAN (Peroxy acetyl nitrate). PAN is a product of photo chemical reactions in the air and is characteristic of photochemical smog. Depending on the nature of the pollutants and the magnitude of exposure, many forests were affected by air pollutants. The growth is reduced and the sensitivity to diseases increased. Vegetations around heavily industrialised areas and in the neighbour hood of metal smelting plants, SO_2 and metal vapours are reported to have caused extensive damage to vegetation. Severe damage seemed to have occured to forests at polluted sites in Gzechoslovakia, East Germany and Poland. It appears that ozone has caused wide spread damage to forests in California. Generally a polluted air mass contains a collection of phyto toxic agents. For example aerosol mixtures containing different proportions of SO_2, oxides of nitrogen, ammonia, Ozone and acids were noticed in the polluted air present in the industrial areas. Ozone is found to be the major phyto toxic agent in photo chemical smong which caused great injury to vegetation in Southern California and in Britain. Other effects of air pollution include damage to epicnticular wax layer of leaves and needles which can lead to the increased water loss. It was also observed that medium doses of SO_2 or NO_2 increases the population growth of aphids feeding on the plants. This naturally lead to the increased pest damage to the plants. Particulate material is shown to have severe effects on plant life. The soot in the atmosphere prevented the photosynthesis in plants and blocked the stomata of leaves.

Check Your Progress - 7 & 8

7. What chemical pollutants are harmful to plants ?

8. What are the effects caused by SO_2 to plants ?

Note : (a) Write your answers in the space provided below.
(b) Compare your answers with those given at the end of this unit.

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3.7. ACID RAIN AND ITS EFFECTS

Rain water is considered to be the purest form of water. In fact its quality is generally equated to that of distilled water for use in chemical laboratories. Rain water generally contains dissolved carbondioxide and ammonium, calcium, magnesium, potassium and sodium ions in traces. Chloride and sulphate are the anions present in the water. Most of these ions are generally present only in the first few showers of the rain. It is for this reason rain water, after few showers, is collected and stored for use as a subtitute for distilled water in laboratories. The pH of pure rain water is generally around 5.6. This shows that is weakly acid and this may be due to the disolved CO_2 This pH value of 5.6 is therefore considered normal for rain water. Any decrease in the pH value from 5.6 is considered due to pollution. Such rain water or snow whose pH is less than 5.6 is called acidic rain water (or acid rain). Rain water quality deterioration is traced to acid rain, acid precipitation and acid deposition. Acid here refers to excess of hydrogen ions in rain water solution *(Acid rain) Acid perception* includes the impacts of both the wet and dry atmosphere. *Acid deposition* relates to the acid precipitation at the ground level, once the atmospheric material has reached the surface environment.

Impact of Acid Rain

All forms of aquatic life especially fish are very badly effected by acid rain. Aluminium ion is often considered to be the direct cause of the toxicity of acid waters to fish. Thus both aluminium ions and H^+ (pH) effect the gills. Low pH values damage the fish eggs. It is observed that at pH 4.0 newly fertilised salmon eggs die within two days. So in places where there will be acid rain, fish population depletes significantly in lakes. North America and Scandinavia are the worst effected in this direction.

The acid rain and the acid precipitation may increase the acidity of the soil. This leads naturally to changes in soil biota and mobilisation of heavy metals. Acid mists cause damage to forests through attack on the leaves. Human beings may also suffer from skin irritation and other related disorders.

The acid rain is traced to the increased concentrations of SO_2, SO_3 and oxides of nitrogen in the atmosphere. It was observed that any region with a high density of industrial installations may have precipitation with a pH of 4 or less. Even buildings and statues are damaged by acid raid.

The term "stone leprosy" is used by some environmental chemists to describe the corrosion of stone caused by the acid rain.

Check Your Progress - 9 & 10

9. What is acid rain? what is acid deposition?

10. What chemicals in the atmosphere are responsible for acid rain ?

Note : (a) Write your answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

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3.8. SUMMARY

Various gaseous and particulate chemical substances present in the atmosphere at undesirable levels are called pollutants. The common air pollutants are oxides of sulphur, oxides of nitrogen, carbonmonoxide, hydrocarbons, ozone peroxy acetyl-nitrate (PAN), toxic traces metals such as lead, cadmium, mercury, nickel, dust chemical smog and photo chemical smog. Air pollutants cause immense damage to human health. The damage is mainly on the respiratory system. Deposition of metals in liver and kidneys, eye irritation, skin diseases, hypertension, blood cancer are some of the other damages caused by the air pollutants. Exposure time, exposure concentration are very important in pollution effects. The effect may be accute or chronic. Form of the chemical compound often plays a significant role in causing the damage or other wise. Air pollutants effect the plants and forest too. The ill effects include changes in photosynthetic and transpiration rates, removal of green pigments of leaves, making sensitive the plants and the forests to many diseases. Mercury poisoning effects very much sea foods especially the fish. Acid rain is caused by the presence of oxides of sulphur and nitrogen in the atmosphere. The pH of water in lakes and other water sources decreases from the normal value of 5.6 to about 4.0 due to acid rain effects. The increased acidity of water and the consequential changes in aluminium in concentration cause lot of damage to aquatic life especially fish. Acid rain causes damage to buildings and statues. This is normally referred to as "stone leprosy". Acid rain effects the human beings skin and may lead to many skin disorders.

3.9. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The amount of pollutant reaching a receptor viz. organism or population or community is referred to as 'exposure'. The biological change caused by such an exposure is called 'effect'.

2. The amount of pollutant that is taken into an organism or individual is called 'dose'. The death causing dose is known as 'lethal dose'. It is a function of concentration and period of exposure of a pollutant.

3. Supply of pollutant in one large package of high concentration is named as 'acute exposure'. Supply of equivalent amount of pollutant at a lower concentration over an extended period is known as 'chronic exposure'.

4. A foreign substance in an organism may undergo the changes in different ways. Four main pathways were identified in most cases.

   a) Some pollutant molecules are converted into less toxic compounds.

   b) Some pollutant molecules get stored in some tissues. e.g., Lead in bones, cadmium in kidneys.

   c) Some pollutants and their metabolites are excreted from organism.

   d) Pollutant residues, if any after the above three processes had taken place brings an effect at the site of action.

5. Nitrogen dioxide (NO_2). Sulphur dioxide (SO_2), Carbonmonoxide (CO)

6. Particulate pollutants present in the air in urban areas are dust, soot, smog, NO_2, SO_2, CO, vapours of trace metals such as lead, cadmium, mercury, nickel.

7. The main chemical pollutants harmful to plants are-Sulphur dioxide, sulphuric acid, ozone, flourides, oxides of nitrogen, ammonia, PAN (Peroxy Acetyl Nitrate) and vapours of some metals.

8. Increased levels of sulphur dioxide induces the growth of population of aphids feeding on the plants. This leads to the increased pests damage to the plants.

9. The rain water or snow whose pH is less than 5.6 is called acidic rain water or acid rain. 'Acid deposition relates to the acid precipitation at the ground level, once the atmospheric material has reached the surface environment.

10. Sulphur dioxide, sulphur trioxide (SO_3) and oxides of nitrogen are mainly responsible for acid rain.

3.10. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Give a concise account of air pollutants and their ill effects on human beings.
2. Describe the metallic air pollutants, their sources and hazards caused by them to human beings.
3. Describe with examples the ill effects caused by the air pollutants to plant and aquatic lives.

II. Answer the following questions in about 10 lines each.

1. What chemical substances contribute to air pollution ?
2. Name few metals and their sources that are causing air pollution.
3. What damage is done to humans by gaseous air pollutants ?
4. How is mercury poisonous to human beings ?
5. What is acid rain? How is it formed ?
6. Name the damages done by acid rain to aquatic life and stones.

Prof. S. Brahmaji Rao.

UNIT - 4 : AIR POLLUTION CONTROL METHODS

Contents

4.1. OBJECTIVES

After completing this unit you will be able to :

- describe the method of removal of particulates,
- list out and describe different types of scrubbers,
- describe the electrostatic precipitators and
- discuss about the automobile pollution control with specific examples.

4.2. INTRODUCTION

Air pollutants can be either natural or may be result of various activities of man like industrial operations. The industrial contaminants can be either by-products of external combustion like smoke, dust and sulphurdioxides or by-products of internal combustion like the reactions in petrol and diesel engines. Air born pollutants are significant because of the allergic responses produced in sensitive individuals. Many people suffer from asthma or hay fever, while most victims have an uncomplicated type of hay fever in which the symptoms disappear at the end of the pollen season.

Suspended particulate matter, sulphurdioxide, fluoride etc may be transported over great distances from large industrial complexes to residential areas. The agriculture is more affected by fluorides and sulphurdioxide because certain pollutants are more toxic and harmful to vegetation and animals than to humans. The affect of air pollution on human health is worst during the winter season, when pollution levels reach climax. An objectionable odour, visibility reduction, eye irritation or vegetation damage are useful guides to the livelihood or severity of health effects. Air born gases, vapours, fumes, mist and dust may cause irritation of the membranes of the eyes, nose, throat, larynx, tracheo- bronchial tree and lungs. There are three broad approaches to the control of particulates-dilution in the atmosphere, control at source and control by using pollution control equipments.

The traffic policeman, the automobile mechanic, and truck driver in a big city may all have substantial exposures to carbon monoxide and lead in association with their occupations. Therefore such individuals have an usually high risk from exposure to community air pollution. The diesel engine exhausts only about a tenth of the amount of carbon monoxide exhausted by gasoline engine, although its hydrocarbon emissions may approach those of gasoline engine. The major problems of the diesel engines are smoke and odour.

Various causes of the genesis and exodus of these pollutants have been identified and methods to control them have been outlined in this chapter. Certain modifications in the engine design and operating variable are suggested. The possibilities of some alternatives as suitable substitutes for modern automobiles are also explored and future strategy in the Indian context has been proposed. If air pollution problems are properly considered when an industry is designed and built, real economy can be effected. But in most cases air pollution control is an after thought and ways and means have to be devised to treat the polluted effluents.

For the control of principal gases in air the mechanisms are chemical engineering unit operations, which include combustion absorption, adsorption and condensation. These gases control devices are also explained in this chapter.

4.3. REMOVAL OF PARTICULATES

Particulates present in the air in the form of aerosol, dusts, mist, smoke, smog, smaze or cloud, pose a potential pollution hazard and the already worsened situation demands an immediate relief by means of a proper particulate Control Technology.

Four means are available for the control of effluent discharges into the atmosphere and thereby control of their deterimental effects. They are,

a) Reduction of pollutant discharge at the source by the application of control equipment.

b) Reduction at the source through raw material changes, operational changes or modification or replacement of process equipment,

c) Dilution of the source discharge by the use of tall stacks *d) Dispersion of source locations through allocation of land usage i.e., proper planning and zoning of industrial areas.*

But the most effective methods are reduction at the source by the application of control equipment and process control.

To remove the particulate matter from gas streams, various types of the control equipment are available. But to select the required equipment, certain basic configuration must be available,

1. *Quantity of the gas to be treated and its variation with time,*
2. *Nature and concentration of the particulate matter to be removed,*
3. *Temperature and pressure of the gas stream*
4. *Nature of the gas phase (for solubility and corrosive effects)*
5. *Desired quantity of the treated effluents i.e., efficiency of removal of particulates is required.*

The list of common types of collection equipment for aerosols (particulates) is as follows :

1. *Settling Chambers*
2. *Inertial Separators*
3. *Cyclones*
4. *Scrubbers or Wet Collectors*
5. *Filters*
6. *Electrastatic Precipitators (ESP's)*

Gravity Settlers, Cyclone Separators and Electrostatic Precipitators all function by driving the particles to a solid wall, Where they adhere to each other to form agglomerates that can be removed from the collection device and disposed off. Filters and Scrubbers do not drove the particles to a wall, but rather divide the flow into smaller parts where they can collect the particles.

4.4. SCRUBBERS OR WET COLLECTORS

Scrubbers or Wet Collectors are devices which utilise a liquid, usually water, to remove dusts and gasses from polluted air.

In air pollution control engineering, the term *Scrubber* originally meant a device for collecting fine particles on liquid drops. Every rain storm scrubs the air producing that fresh air sensation, that we all experience. In industrial applications, it is necessary to force the stack gases to be cleaned by contact with the liquid which is gong to do the scrubbing. This requires a lot of energy. As such, scrubbers are basically *'cheap'*, to install but *'expensive'*, to operate.

Four major steps are involved in collecting particles by Wet Scrubbing. The first of these is *transport*. The particles must be moved to the vicinity of the water droplets which are usually 10 to 10000 times larger. The second type is the *collision*. The particle must collide with the droplet. The third step is the *adhesion*. Adherence is promoted directly by the property of *Surface Tension*. The fourth step is *precipitation*, or removal of the droplet containing the dust particles from the gas phase.

Scrubbers are based upon the principle of collecting the dust either by liquid carriage or by particle conditioning. In the liquid carriage system, the particles are trapped by liquid and transported to a location outside the collector. When the polluted air is forced to strike against the liquid surface within the collector, the particles from the polluted air get separated from the liquid which also serves to prevent to re-entry of the particles.

In the particle-conditioning procedure, the particulate size is increased by condensation of water upon the particles when the water particles temperature through the dew point. Most often, the size of the small particles is increased through interception of fine dust particles by liquid droplets, leading to formation of a heavier dust-liquid agglomerates. Wet Collector are widely used for removing the particulate matter from the gaseous effluents in chemical industries, foundries, fertilisers, electroplating, paper mills, steel plants and mining operations.

Types of Scrubbers

Presently there are many Scrubber designs available, where the contact between the scrubbing liquid and the particles is achieved in a variety of ways. The common and important types of scrubbers are as follows :

a) Spray Towers

b) Venturi Scrubbers

c) Cyclone Scrubbers

d) Packed Scrubbers

e) Mechanical Scrubbers

a) Spray Towers

Spray Towers is the simplest type of Wet Scrubber into which water is introduced by means of spray nozzles (fig.4.1). It can be either round or rectangular, in which gas is passed, Counter-current to falling drops of liquid (usually water) from spray nozzles. The particle collection can be done by the mechanism of INERTIAL IMPACTION and INTERCEPTION on the droplets. Spray Towers cause very little pressure loss (Energy) and can handle large volumes of gases. The towers are very effective in removing particles in excess of 10 μm. The maximum efficiency occurs if droplets have a diameter of 800 μm (0.8mm). The efficiency of spray tower depends on the droplet size, flow velocity of the gas, velocity of liquid etc. Spray towers are used as coolers and as primary cleaners in treating blast furnace and for flyash and cinder removal.

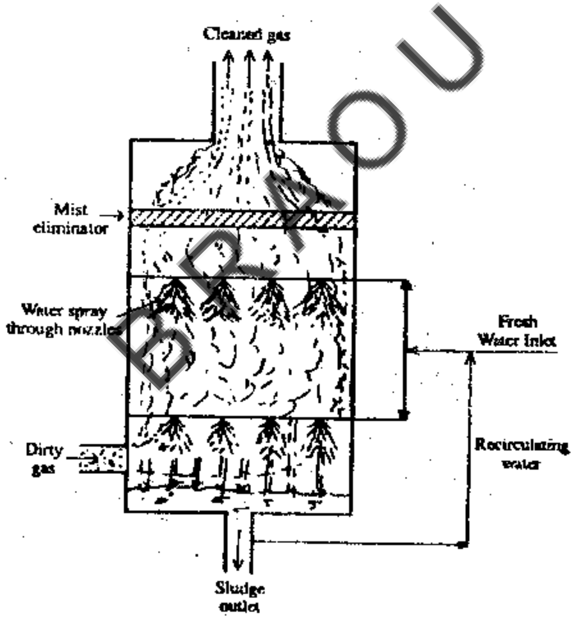

Fig. 4.1. Spray Tower.

b) Venturi Scrubbers

Venturi Scrubbers are high energy wet scrubbers with high performance collection of fine particles, usually smaller than 0.5 to 5 μm diameter. In this unit, the polluted air is forced through a duct that contains a narrow throated venturi section into which water is sprayed through circular jet etc., The atomised droplets produced by injecting the water through the jets collect the dust particles from the polluted air and the slurry collects at the bottom of the succeeding settling tank is disposed off.

Venturi scrubbers are used for removing mists and dusts from gases, from craft mill furnaces, various metallurgical furnaces and sulphuric acid concentrators.

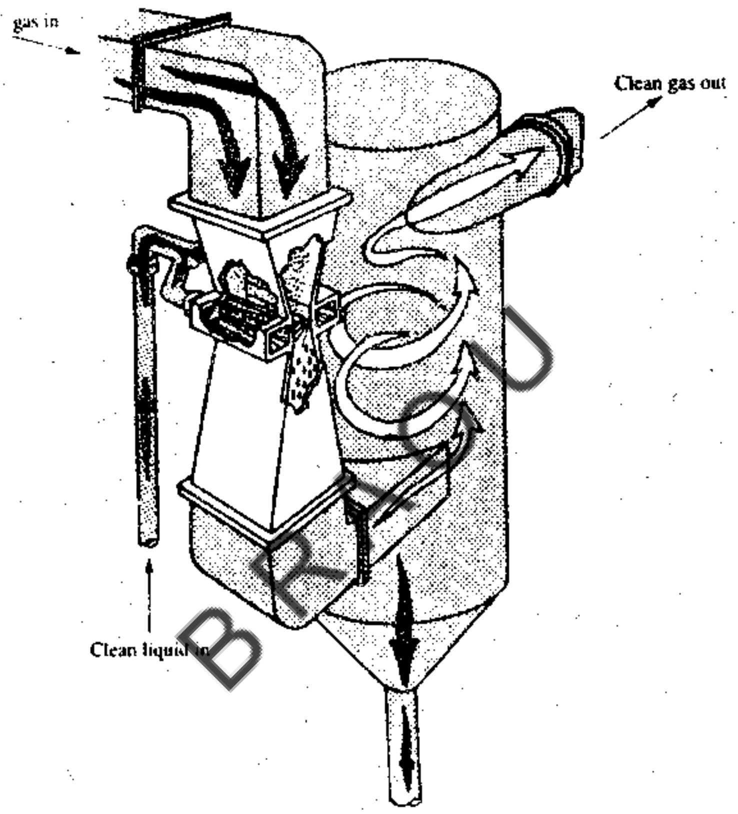

Fig.4.2. Schematic of a typical downflow venturi scrubber, with liquid injection at the throat and the discharge passing to a large cyclone separator.

c) Cyclone Scrubbers

Cyclone scrubbers is a modification of the dry cyclone by the addition of a liquid phase. Here also, the gas is tangentially swirled around just as in the dry cyclone. Water sprays from the top of the cyclone and outside the wall. These sprays assist in the collection of the dispersoid and prevent re-entrainment. In cyclone scrubbers inertial impaction and separation are the main collection mechanisms.

Generally, efficiencies slightly higher than those obtained with the spray towers or the dry cyclone can be expected.

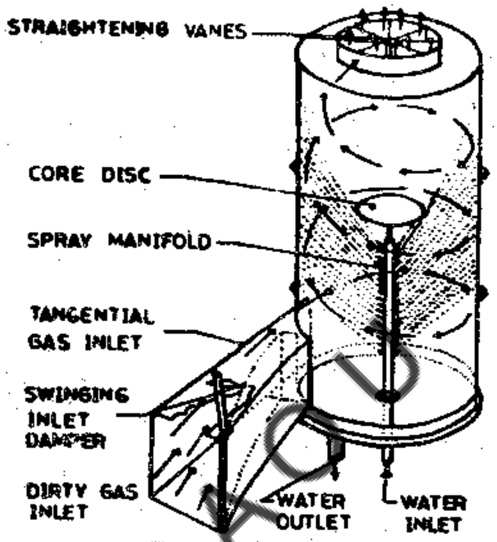

Fig.4.8. Cyclonic spray scrubber.

d) Packed Scrubber

In packed scrubber, fibre glass (fine glass filaments) or other packing, (coke or broken stone) are used as collection material. If the scrubbing liquid flows in the same direction as the polluted air, the scrubber is known as *co-current* ; if in the opposite direction to the air flow, *counter current* ; or if it is perpendicular to the air flow, *cross-flow*. While the incoming air contacts the most contaminated liquid, the out flow gets into contact with the cleanest liquid.

The gas stream passes through the packaging pore spaces and captures the particles by the inertial impaction. Small packing increases the efficiency of collection, but its shape does not appear to effect the collection efficiency.

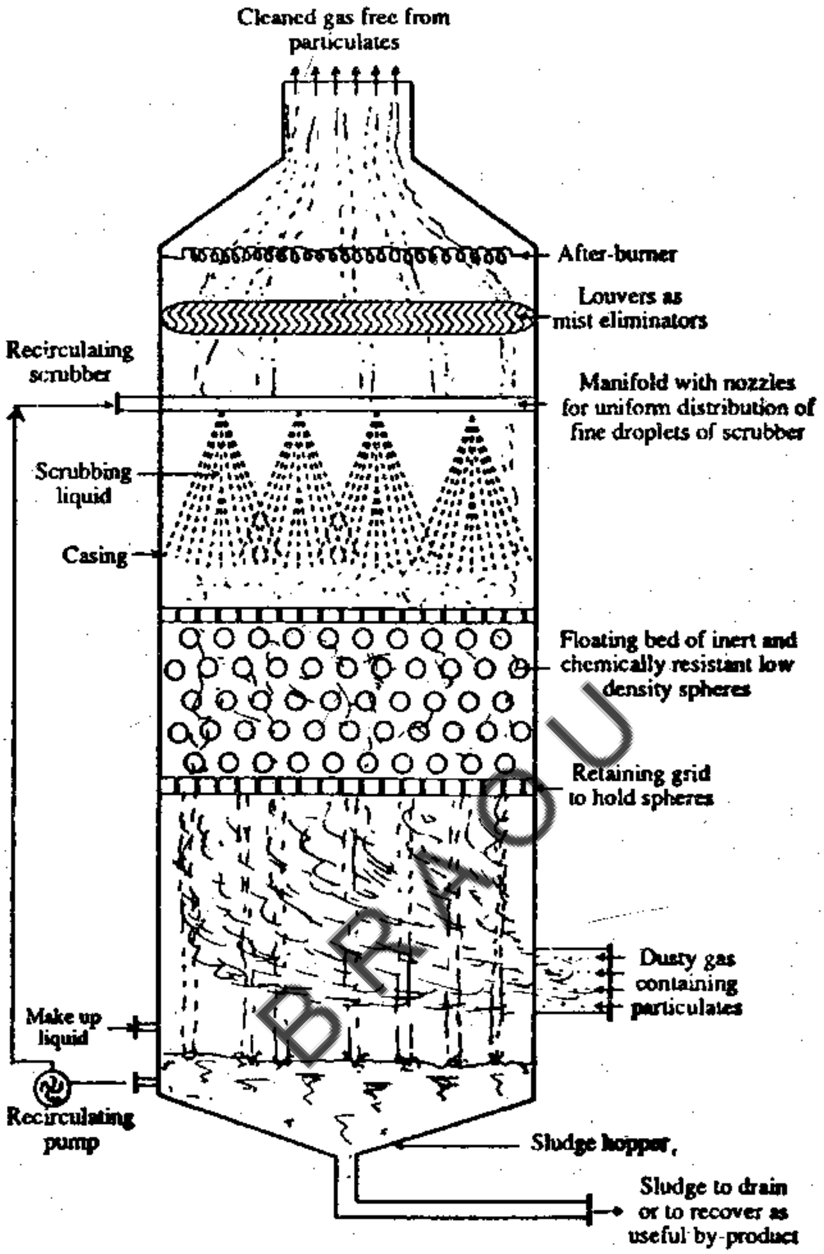

Fig.4.4. Packed Tower.

e) Mechanical Scrubbers

Mechanical Scrubbers is the high energy scrubber and has mechanical means of breaking up the scrubbing liquid into small droplets and simultaneously creating turbulence. It has internal rotating mechanical part, where the liquid dispersoid contact is achieved by the simultaneous introduction of the liquid medium and the gas stream. The scrubbing liquid dribbles down on the rotating part and is struck violently and disintegrated into time droplets that are thrown rapidly by the centrifugal force and are removed quite easily. These scrubbers have a high initial cost, high operating cost and required considerable maintenance. The quantities of water required and wasted also are very high.

S.No.	Advantages of Scrubbers	Disadvantages of Scrubbers
1.	Low initial cost	Relatively high energy cost
2.	Moderately high collection efficiency for small particles.	Problem of wet sludge disposal
3.	Applicable for high temperature installations	Corrosion problems
4.	They can simultaneously remove particulates and gases,	Visible wet plume, reduction in buoyancy
5.	There is no particle re-entrainment	Very small particles (sub micron sizes may not be captured)
6.	Hazardous of explosive dust air mixtures are reduced	
7.	Corrosive gases may be neutralised by proper choice of scrubbing liquid.	

Check Your Progress - 1

What is meant by Scrubbers ?

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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4.5. FILTERS

Filtration is one of the most reliable efficient and economic methods by which particulate matter can be removed from gases. A filter generally is a porous structure composed of granular or fibrous material which tends to retain the particulate and allows the gas to pass through the voids of the filter. Filters can be broadly divided into the following two types (i) Fabric or Cloth filters, (ii) Fibrous or deep bed filters

Fabric filters are made in the form of tubular bags or cloth envelops and are suitable for the dust loading of the order of 1 gm/Cu. mtr. In case of deep bed filters, a fibrous medium like mats of wool, cellulose etc., acts as a separator and the collection takes place in the interstices of the bed, and is suitable for light dust loads of the order of 1.0 mg/Cu. mtr.

Bag Filters

The filter bags consists of woven or felted fabric material through which the polluted is passed. The fabrics are woven into tubular bags or envelopes are placed in a *Bag House.* The structure in which the bags hang is known as bag house. Generally particle laden gas enters the bag at the bottom and passes through fabric while the particles are deposited on the inside of the bag. A bag house or bag filter consists of numerous vertical bags 120-400 mm diameter and 2-10 metre long.

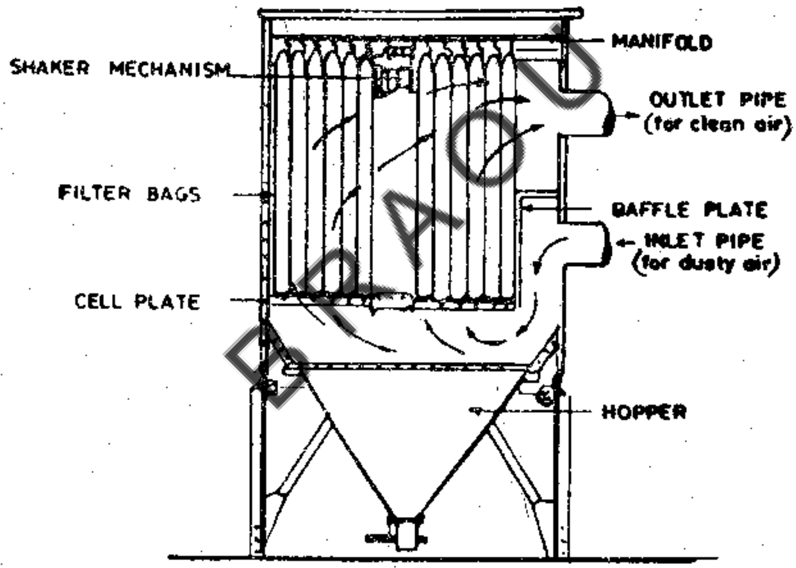

Fig.4.5. Bag house filter.

Large bag houses are constructed with several compartments so that one compartment may be isolated for cleaning as needed while other compartments are operating. The bags should be arranged in each compartment in such a manner that the available space is utilised effectively and proper access to each bag is provided for its replacement. Hopper's are provided for dust collection and the dust is removed usually by rotary or screw valves.

The bag filters are used to collect small particulates that are not captured by the settling chambers of cyclones and hence they are put at the end of the mechanical collector for removing particulates upto 0.5 μ in a large measure and upto 0.01 μ to some extent. Cement, carbon black, metal oxides, clay and pharmaceutical particulates can be removed. Chemicals and abrasives can also be removed. These are generally used for removal of dusts from steel furnaces, open hearth furnaces, cement kilns and fertiliser plants.

The cleaning may be accomplished by shaking the bags or by increasing the air pressure on the bag in a manner that causes the bag to collapse or other wise deform sufficiently to dislodge the accumulated dust. Cleaning generally takes less than I min. with the bulk of the dust being removed in a few seconds. A good cleaning schedule ensure longer bag life and efficient filtration.

S.No.	Advantages	Disadvantages
1.	High collection efficiencies for all particles sizes especially, for particles smaller than 10.0 μ in diameter.	Operation limits are imposed by high carrier gas temperatures. high humidity etc.
2.	Simple construction and operation.	High maintenance and fabric replacement costs.
3.	Nominal power consumption.	Large size of the equipment.
4.	Dry disposal of collected material.	Problems in handling dusts which are abrade, corrode or blind the cloths.

4.6. ELECTROSTATIC PRECIPITATORS (ESP)

The ESP is one of the most widely used devices for controlling particulate emissions at industrial installations ranging from power plants, cement and paper mills to oil refineries. They have been successfully used for removal of fine dust from all kinds of waste gases with very high efficiency. They can also be used for air cleaning in public buildings, theater, railway cars etc. The principle on which this equipment operates is that when a gas containing aerosols is passed between two electrodes that are electrically insulated from each other and between which there is a considerable difference in electric potential, aerosol particles precipitate on the low potential electrode. A typical wire and pipe is given in fig.

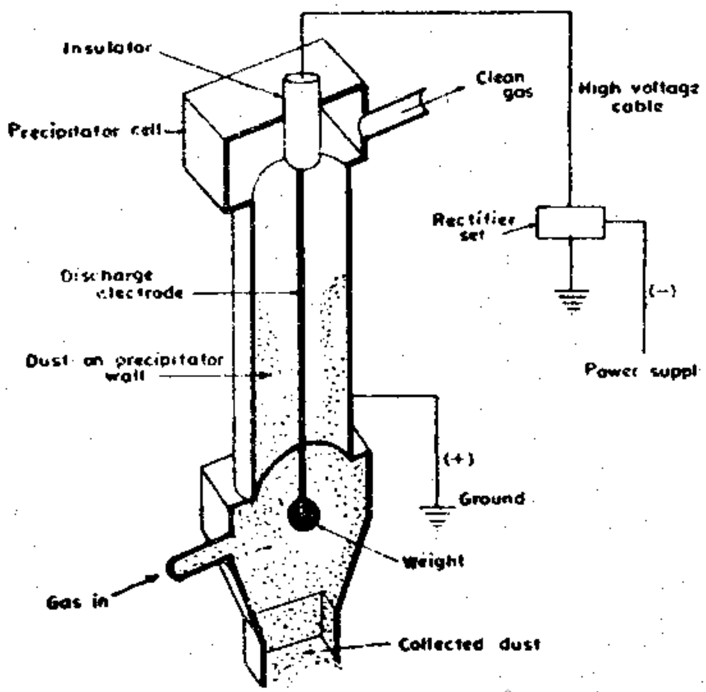

Fig.4.6. Schematic diagram of a wire and pipe precipitator.

The electrodes are *discharge electrode* at a high potential and an *electrically grounded collecting electrode* (voltage is zero). Due to the high potential difference a powerful ionising field is formed. under the action of electical field gas ions formed in the corona move rapidly towards the collecting electrodes and transfer their charge to the particles by collision with them.

The electrical field interacting with the charge on the particles then causes them to drift towards and be deposited on the collecting electrode. The particles deposited on the collecting electrode lose their charge and then are removed mechanically by rapping or vibration to hopper below the electrical treatment zone and are collected for ultimate disposal. When the particles are liquid droplets, the collected droplets coalese on the collecting electrode and drip off the bottom of that electrode into a collecting pump.

The precipitators collect 1 μ to 44 μ size particulates with high efficiency. They remove particulates upto sub micron range with high gas volumes of 50,000 to 2.0 million Cu. Ft./minute, over a broad range of temperatures and pressures. In case of excessive dust loads, a mechanical collector may be placed so as to precede the electrostatic precipitator. They are used in thermal power plants, steel plants, cement kilns and paper mills, sulphuric acid and non-ferrous metallurgical plants. Acids, high temperature wastes and corrosive materials which cause damage to bag filters can be collected by the precipitators.

S.No.	Advantages	Disadvantages
1.	High collection efficiency	High initial costs and large space requirement.
2.	Particles as small as 0.1 μ can be removed.	Sensitive to variable particulate loading or flow rates.
3.	low maintaining and operating costs.	possible explosion hazards during collection of combustible gases or particulates.
4.	Can handle both gases and mists for high volume flow.	The poisonous gas, ozone is produced by the negatively charged discharge electrodes during gas ionisation.
5.	Pressure drop and hence power requirement is small compared to that in other devices.	Safeguard of operating personnel from high voltage is necessary.
6.	Economical and simple to operate.	Gases cannot be removed by ESP's.
7.	Satisfactory handling of large quantities of high temperature gas.	
8.	There is no limit to solid, liquid or corrosive chemical usage.	
9.	Treatment time is negligible.	

Check Your Progress - 2 & 3

2. What are the uses of bag filters ?

3. What is the use of electrostatic precipitators ?

Note : (a) Write your answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

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4.7. AUTOMOBILE POLLUTION CONTROL

The most important pollutants from automobile exhaust include carbonmonoxide (CO), unburnt hydrocarbons (HC), oxides of nitrogen (NO_x) and particulate matter. Partial oxidation of Hydrocarbons like aldehydes, alcohols and high molecular weight hydrocarbons including the cancer causing traces of Benzo-pyrenes are also harmful. The quantities of CO and unburnt HC emitted into the atmosphere depending upon the air-fuel ratio and the stoichiometric completeness of combustion of fuel in the engine cylinders. As the air-fuel ratio increases complete burning occurs and there by reduces CO and unburnt fuel to zero levels. However, the consequential rise in temperature increases the formation of NO_x dramatically. In practice, factors such as cylinder misfiring that discharges the entire air fuel mixture into the exhaust systems, engine combustion characteristics, spark timings and other engine conditions influence the formation of pollutants.

The exhaust from petrol engines is almost colourless due to homogeneity of fuel-air mixture and high temperatures involved during combustion. On the other hand, the diesel exhaust usually dirty due to improper mixing of fuel & air and lower combustion temperature. The diesel engine smoke may be white, blue or black.

Smog (Smoke + Fog) conditions that occur due to interactions between olefenic hydrocarbons and oxides of nitrogen in the presence of sunlight leads to the partial oxidation products with irritating toxic and light scattering properties. Smog and oxidants cause damage to plant life also. The increased incidence of lung cancer in industrial and urban areas is attributed to the rising levels of Benzo-pyrene from automobile exhausts. The heavy concentration of CO emitted by the automobiles effect the oxyhaemoglobin levels in the blood. Since the pollutants including lead (Pb) particulates and unburnt HC cause damage to living beings, it is necessary to control the pollution from automobiles.

Automobile Emission Control

The control of pollutant emissions from automobiles is based on the following *four* approaches :

1. *Reduction of the amount of pollutants formed during combustion by suitable modification of the internal combustion engine.*

2. Development of exhaust system reactors that will complete the combustion process and change potential pollutants into more acceptable materials.

3. Development of suitable fuel for petrol that will produce low levels of pollutants upon combustion.

4. Replacement of internal combustion engine with low pollution producting engines.

Engine modifications include electronic fuel injection, quick heating intake manifolds, new ignition systems that do not use spark plugs and cylinder head modifications to reduce quenching zones and improve combustion. Another possible solution to the CO problem involves changing the fuel either by mixing petrol with other substances or by substituting another fuel for petrol. With modified internal combustion engines methane or natural gas (CH_4) Hydrogen (H_2) and methanol (CH_3 OH) as fuels can be tested as petrol substituents to decrease pollutant emissions.

HC and CO emissions can be reduced by two approaches, one approach is by adding fresh air to the hot exhaust to supply necessary oxygen needed for more complete burning as the mixture moves through the exhaust system. Another approach is controlled combustion system which utilises engine design parameters to achieve emission control through combustion.

The control of NO_x emissions from automobiles can be accomplished by two methods. Exhaust gas recirculation (EGR) is one of the methods. In this method a portion of the exhaust gas, which is inert, is continuously recirculated through the engine so that the burning air-fuel mixture is diluted. The exhaust gas recirculated is regulated by an EGR valve, and is generally 15 to 20% by the volume of air-fuel mixture. Another method for NO_x emission reduction is Catalytic Reduction. In this dual-catalyst system NO is reduced to N_2 (95% of NO_x is in the form of NO), while hydrocarbons and CO are oxidised to CO_2 and H_2O simultaneously. The exhaust gases are initially passed over a reductive catalyst where NO reacts with CO to form N_2 and CO_2. Air is then injected and the mixture is passed over an oxidative catalyst, where the remaining HC and CO are oxidised to CO_2 and H_2O. In the reduction catalyst chamber some ammonia may form which will subsequently be converted to NO or N_2O in the oxidising catalyst chamber.

Three types of automobiles are used in India

a) Petrol Engines (4 strokes)

Air pollution control from petrol engines require the estimates of emissions from (i) exhaust (ii) Crank-case and (iii) Evaporation. Among the exhaust emissions of carbon monoxide, hydrocarbons, oxides of nitrogen and particulates containing lead, the first three depend on air fuel ratio, spark timing and engine operating conditions.

Proper timing and reduction in faults of ignition system cut down carbon monoxide levels by 50%. Idle CO, an indicator of total CO emissions is generally limited to 4.5%. Exhaust hydrocarbons that account for 55% of total hydrocarbon emissions from a car are dependent of upon engine operating conditions. By simple tuning idle HC can be reduced by 40%. By using rich fuel mixture and suitable designed exhaust reactor NO_x level can be reduced.

The pollutants from crank-case consist of engine blowby that lead fast the piston and also the oil vapours generated into the crank- case. The emissions can be fully controlled by recycling the blowby gases into the engine by means of the positive crank-case ventilation system. The evaporation from fuel tank and carburettor of an automobile accounts for about 20% of the total HC and works out to 20 kg per year per passenger car. Esso charcoal system uses activated carbon to absorb the vapours that are recycled into the engine through the timely opening the purge wall.

b) Petrol Engine (2 strokes)

Except for crank-case emissions the source and types of emissions from 2 - stroke petrol vehicles like motorcycles and autos are similar to those from passenger cars. Modifications to carburettor and spot timing and exhaust reactors used for cars can be used for these vehicles.

c) Diesel Engines

While black smoke and bad smell characterised emissions from diesel engines, their HC levels are lower by 38% and NO_x levels are higher by 40% than these from a petrol engine. Additives with barium content of 1 gm/litre of a fuel have reduced smoke by 50% to 70% but caused a marginal increase in CO level. Catylatic mufflers, additives and good maintenance of engines helps in controlling the pollution from the diesel vehicles.

4.8. CONTROL OF GASEOUS POLLUTANTS

The principal gases of concern in air pollution control are the sulphur oxides (So_x), Nitrogen oxides (NO_x), Carbon oxides (CO, CO_2), organic and inorganic acidic gases and hydrocarbons (HC). Gaseous pollutants can be controlled by using combustion, absorption, adsorption and condensation.

Combustion : The organic compounds released from different manufacturing operations are converted to innocuous carbondioxide and water. To obtain complete combustion a proper proportion of oxygen, temperature, turbulence and time must be provided. The three methods of combustion commonly used in air pollution control are Direct combustion, Thermal combustion and catalytic combustion.

Direct combustion, is a method by which the waste gases are burned directly in a combuster with or without the aid of additional fuel such as natural gas. When the concentration of combustible pollutants is below the lower explosive limit, thermal incinerator or after burner is one of the choice for combustion. In this thermal combustion method, the combustibles in waste gas stream are brought above their ignition temperatures and burned with the oxygen present in the contaminated stream.

Catalytic combustion is used with success for the control of effluent gases, fumes and odours from refineries, burning wastes, cracking gases, phenolic-resin curing ovens, paint and enamel ovens, coffee roasting processes, foundry core baking ovens and chemical plants discharging maleic and pthalic anhydrides. When the concentration of the combustible portion of the gas stream is below flammable range and when lower operating temperatures are desired, catalytic combustion processes are used. In catalytic units, the waste gas stream need not be heated to high temperatures as in thermal incineration because, ignition temperature is lower in catalytic processes.

The catalysts used for effective pollution control are the precious metals, primarily platinum and palladium or their alloys. The catalyst is coated on to suitable elements such as metal ribbons, ceramic rods or alumina pellets. These elements are then packed into the catalyst bed. The catalytic combustion technique is recommended for gases that are free of particulate matter and certainly free of metallic substances which could poison the catalyst. The catalyst bed is cleaned periodically (quarterly or annually) by scrubbing with water or some times with acid and by heating to high temperatures.

Absorption : Absorption is a bulk phenomenon. The effluent gases are passed through absorbers (Scrubbers) which contain liquid absorbents that remove one or more of the pollutants in the gas stream. The efficiency of this depends upon :

(1.) amount of surface contact between gas and liquid,

(2.) contact time,

(3.) concentration of absorbing medium and

(4.) speed of reaction between the absorbent and gases.

Absorbents are being used to remove sulphur dioxide, hydrogen sulphide, sulphurtrioxide, fluoride and oxides of nitrogen. For effective absorption the pollutant gas must be highly soluble in the liquid and as far as possible, undergo an irreversible reaction with scrubbing liquid.

Among the different types of absorbers used to remove gaseous pollutants, the following substances are mostly used as scrubbing media for collection of different pollutants.

S.No.	Pollutant	Scrubbing liquids
1.	Chlorine	Water, NaOH, NH_3 etc
2.	Hydrogen Chloride	Water, NaOH, NH_3, $Ca(OH)_2$, $Mg(OH)_2$ etc
3.	Hydrogen Sulphide	NaOH, $Na_2\ (CO)_3$, KOH, $K_2\ CO_3$ etc
4.	Nitrogen oxides	$Ca(OH)_2$, $Mg(OH)_2$, Na_2SO_3, $NaHSO_3$, Urea etc
5.	Sulphur dioxide	$Ca(OH)_2$, $Mg(OH)_2$, CaO, MgO, NaOH, KOH, $Na_2\ CO_3$, NH_3, $CaCO_3$, etc.

Adsorption : Adsorption is a surface phenomenon, by which gas or liquid molecules are captured by and adhere to the surface of solid adsorbent. The attractive forces holding the molecules at the surface may be either physical (Physical Adsorption) or Chemical (Chemisorption) in nature. In Physical adsorption the gaseous material condenses upon the surface of the solid, accompanied by an evolution of heat. The adsorbed material can be removed or desorbed by reducing the pressure or by increasing the temperature. This process is reversible. Chemisorption, which is the result of a chemical interaction between the solid and the adsorbed material, is usually irreversible with the heat of adsorption being much higher than that for physical adsorption. The molecules are held to the solid surface by chemical bonds and original material undergoes a chemical change.

The rate of adsorption of a substance depends on the concentration of the material around the adsorbent, the surface area of the adsorbent, the pore volume of the adsorbent and some other properties such as temperature, molecular polarity and chemical nature of the adsorbent surface. The commonly used adsorbers include activated carbon, silica gel, activated alumina, molecular sieves, bone charcoal, magnesia, lithium chloride, activated bauxite and clays like wollostanite, china clay, montomorillonite etc. Activated carbon appears to be the adsorbent most suitable for recovering organic solvent vapours.

The steps necessary for effective removal of gaseous pollutants by adsorbents are :

1) contact of the gaseous or vapour pollutants with the solid adsorbents

2) separation (desorption) of the adsorbed gaseous pollutants from the solid adsorbent by regeneration or replacement of the adsorbent.

3) recovery of the gases for the final disposal.

The efficiency of removal of gases by adsrobents depends on

a) the physical and chemical characteristics of the adsorbent

b) the concentration and nature of gas to adsorbed

Desorption is accomplished by rising the temperature of the granular bed above the boiling temperature of pollutants by super heated stream, submerged heating elements or combustion gases. Desorption may also be performed by reducing the pressure. The typical data for adsorbent materials and their uses are given below.

S.No.	Adsorbent	Major uses
1.	Activated Carbon	Eliminating odours, purifying gases, recovering solvents
2.	Alumina	Drying air, gases and liquids
3.	Bauxite	Treating petroleum fractions, drying gases and liquids
4.	Bone Charcoal	Decolourising sugar solutions
5.	Fuller's earth	Refining animal oils, lube oils, vegetable oils, fats and waxes.
6.	magnesia	Treating gasoline and solvents, removing metallic impurities from caustic solutions
7.	Molecular sieves	Controlling and recovering Hg, SO_2 and NO_x emissions
8.	Silica gel	Drying and purifying gases
9.	Strontium Sulphate	Removing iron from Caustic solutions.

Check Your Progress - 4

What is the most suitable adsorbent for recovering organic solvent vapours ?

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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Condensation : Condensation of vapour from the effluent gases as method of recovery is applicable only if the vapour gas mixture is rich in vapour or saturated with it. Condensation of organic material using water at room temperature serves as an effective preliminary removal method prior to treatment such as adsorption or combustion. However, the efficiency of condensation can be increased by employing a refrigerated fluid such as chilled water.

Surface and contact condenser are the two basic types of condensation equipment. In surface condensers, the coolant such as water, refrigerant., chilled water or brine passes through the tubes whereas the vapour is on the shell side. In this condensation, physical adsorption plays a key role, since contaminants are adsorbed onto a surface as gaseous component condenses.

In a contact condenser, the vapour and cooling medium are brought into direct contact. The cooled vapour condenses and the water and condensate mixtures are removed, treated and disposed off. The chief advantages of contact condensers are that they are less expensive and more flexible than surface condenser and they are more efficient in removing organic vapour.

The method of condensation is widely used as an air pollution control device in petroleum refining, petrochemical manufacturing, manufacturing of ammonia and chlorine solutions and miscellaneous processes involving dry cleaning, degreasing and tar dipping.

4.9. SUMMARY

Air pollutants can be either natural or may be result of various activities of man like industrial operations. There are four means available for the control of effluent discharges into the atmosphere and there by control of their detrimental effects. They are : (a) Reduction of pollutant discharge at the source by the applicant of control equipment, (b) Reduction at the source through raw material charges, operational charges or modification or replacement of process equipment, (c) Dilution of the source discharging by the use of tall stacks, and (d) Dispersion of source locations through allocation of land usage i.e. proper planning and zoning of industrial areas.

The term scrubber means a device for collecting fine particles on liquid drops. Four major steps are involved in collecting particles by wet scrubbing. They are (i) Transport (ii) Collision (iii) Adhesion (iv) precipitation. Filtration is one of the most reliable efficient and economic methods by which particulate matter, can be removed from gases. Filters are divided into two types (i) Fabric or cloth filters (ii) Fibres or deep bed filters. The principle involved in operating the device electrostatic precipitators (ESP) is that when a gas containing aerosols is passed between two electrodes that are electrically insulated from each other and between which there is a considerable difference in electric potential, aerosol particles precipitate on the low potential electrode. The most important pollutants from automobiles exhaust include carbonmonoxide, unburnt hydrocarbons, oxides of nitrogen (NO_X) and particulate matter.

4.10. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Scrubbers or wet collectors are devices which utilise a liquid, usually water, to remove dusts and gases from polluted air.
2. The bag filters are used to collect small particulates that are not captured by the settling chambers of cyclones and hence they are put at the end of the mechanical collector for removing particulates upto 0.5 μ in a large measure and upto 0.01 μ to some extent.
3. The ESP is one of the most widely used devices for controlling particulate emissions at industrial installations ranging from power plants, cement and paper mills to oil refineries.
4. Activated carbon appears to be the absorbent most suitable for recovering organic solvent vapours.

4.11. MODEL EXAMINATION QUESTIONS

I. Answers the following questions in about 30 lines each.

1. Write the important types of scrubbers and explain them with figures.
2. Discuss the Automobile pollution control with specific examples

II. Answer the following questions in about 10 lines each.

1. What are the means that are available for the control of effluent discharges.
2. Write a short note on electrostatic precipitators.

Dr. K. Mukkanti

UNIT - 5 : AIR POLLUTION MANAGEMENT

Contents

5.1. OBJECTIVES

After completing this unit you will be able to :

- know clearly the requirement to practice air pollution management in a region,
- explain the guidelines for setting up of industries,
- enumerate the basic techniques for planning of town ship,
- discuss how the process change can be achieved.

5.2. INTRODUCTION

The basic use of air resource is to sustain life. All other uses of air must yield to the maintenance of air quality that will not degrade, either acutely or chronically, the health or well being of man. There are two major areas of possible compromise. These are the aesthetics and the economic impact of air pollution and its control. The cost borne by a society to achieve a desired quality of air should be in balance with benefits to make plans and decisions as to how air is to be used and protected. The approach in doing so is called Air Pollution Management/Air Resource Management.

5.3. AIR POLLUTION MANAGEMENT

Air pollution management is the regulation of the amount, location and time of pollutant emissions to achieve some clearly defined objectives or goals. It includes the evaluation of various sets of emission control schedules to determine the consequences to air quality and also formulation of alternative emission contro techniques to meet air quality standards. From the definition, it follows that to practice air pollution management in a region, the following are required:

1. *A set of air quality standards or goals to be achieved:* These can be locally, nationally or universally determined and must be directly measurable, if one is to manage air quality. Thus a standard for total suspended matter of " not more than 75 μ g/m3 annual average, as determined by high volume sampling is a perfectly clear and manageable standard. A standard like " the incidents of asthma shall not exceed 20 per 100 population is also an air quality standard, but very difficult to manage as it requires a subjective evaluation.

2. *An inventory of the emissions from various sources in the region, including man made emissions and emissions from natural sources:* Ideally, an emission inventory should not only the location of the source, but also the emission schedule (emission rate and plume rise parameters versus hour of the day and day of the year) for each source.

3. *Predictive methodology to relate air quality of emissions:* Normally this will be some type of diffusion model. These models usually include local meteorology. The ideal model is one which would accurately depicts the air quality at any location and at any time for any set of emissions and meteorological conditions. It would provide both short term and long term average predictions and shows the impact of each emission source on air quality at each location. Air quality management, therefore is inherently dependent upon air quality models.

4. *Monitoring data to determine the status of ambient air quality:* Adequate storage, retrieval and analytical procedures for these data are necessary to be sure that they are correct, accurate and properly interpreted, since the ultimate goal of air quality management is to regulate emissions to meet a clearly diffident a air quality standard.

5. *Data on cost effectiveness of various control devices and options:* The estimated cost should include both capital cost and operating cost.

6. *An enforcement procedure* which allows the air quality manager to implement his planned emission control program.

A diagrammatic representation of Air quality management requirements is given in the Figure 5.1.

Thus, the elements of air pollution management may be listed as follows :

- Development of a public policy on air conservation
- An organizational framework and staff capable of operating along the functional lines (e.g. engineering, technical services, field services) and its funding support
- Continual assessment of existing air quality and preparation of estimates for the future situation

- Assessment of the emissions from all existing pollution sources and those expected to exist in the future
- Development of the necessary information about factors that influence the transport of air pollutants
- Assessment of the effects of air pollution on man and his environment
- Establishment of ambient air quality standards
- Development of an effective information and educational program to inform the public of the need to solve air pollution problems promptly and effectively

Hence, air pollution management concept provides a base for the organization of tasks so that the air quality managers can perform them systematically, purposefully, will understanding and with a reasonable probability of accomplishment.

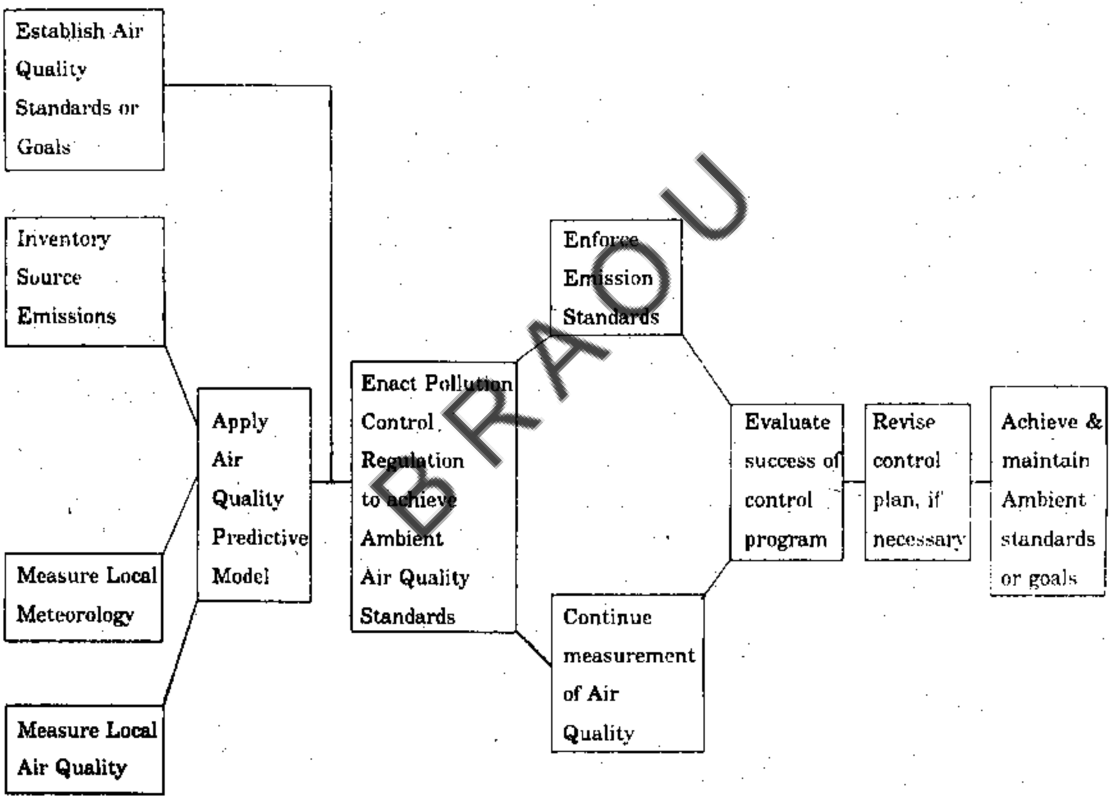

Fig.5.1. Air Quality Management Requirements.

5.4. LOCATION OF INDUSTRIES

At present, industries are being located on the basis of raw material availability, access to the market, transport facilities without adequate attention to the environmental consideration. Improper/judicious siting of an industry can seriously effect the environmental feature such as air, water, land, flora, fauna, human settlements and health of the people. In order to help the concerned authorities and also for ensuring optimum utilisation of natural and man made resources. it is necessary to frame guidelines for siting an industry. It is also necessary to identify the parameters that should be taken into account whole setting up an industry. With this in view, the following guidelines are recommended (by the working group of the ministry of Environment and Forest, Govt. of India) for siting of industries to ensure sustainable development with minimal depletion, degradation and/or destruction of the environment :

I. Areas to be avoided

In siting industries, care should be taken to minimise the adverse impact of the industries on the immediate neighbourhood as well as distant places. Some of the natural life sustaining systems and some specific land uses are sensitive to industrial impacts because of the nature and extent of fragilioty. With a view to protect such systems, industrial sites shall maintain the following distances from the areas listed below :

a. Ecologically and/or otherwise sensitive areas* : At least 25 Km; depending on the geo-climatic conditions, the requisite distance shall have to be increased by the appropriate agency.

b. Coastal Areas : At least 1/2 Km from high tide line.

c. Flood plain of the rivirine systems : At least 1/2 Km from flood plain or modified flood plain affected by dam in the upstream or by flood control systems.

d. Transport/Communication system : At least 1/2 Km. from highway and railway

e. Major Settlements (3,00,000 population) : distance from settlements is difficult to maintain because of urban sprawl. Hence, at the time of siting industry if any major settlements notified limit is within 50 km, the spatial direction of the growth of the settlement for atleast a decade must be assessed and the industry shall be sited atleast 25 km from the projected boundary of the settlement.

* Ecological and /or otherwise sensitive areas include (i) Religious and Historic places (ii) Archeological monuments (iii) Scenic areas (iv) Hill resorts (v) Beach resorts (vi) health resorts (vii) Biosphere reserves (viii) Coastal areas rich in Corals, Mangroves, Special species (ix) National parks and Sanctuaries (x) Lakes, swamps (xi) Seismic zones (xii) Areas of Scientific and geological interest (xiii) Defence Installations, specially those of security importance and sensitive to pollution (xiv) Border areas (xv) Air ports

I. Siting Criteria

Economic and social factors are recognised and assessed while siting an industry. Environmental factors must be taken into consideration in industrial siting. Proximity of water resources, highway, major settlements, markets for products and raw material resources is desired for economy of production, but all the above listed systems must be away for environmental protection. Industries are, therefore, required to be sited, striking a balance between economic and environmental considerations. In such a selected site, the following factors must be recognised.

◇ Associated township of the industry must be created at a space having a physiographic barrier between the industry and the township.

◇ No prime agricultural land shall be converted into industrial site.

◇ No forest land shall be converted into non-forest activity for the sustenance of the industry.

◇ Within the acquired site the industry must located itself at the lowest location to remain obscured from general sight.

◇ Each industry is required to maintain three ambient air quality measuring stations with in 120 degree angle between station

Check Your Progress - 1

What are the factors to be recognised for selecting site ?

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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5.5. PLANNING OF TOWNSHIP

A direct solution generally recommended to tackle air pollution problem is to enforce legal sanctions against the polluting sources with a view to control pollutants to the specified standards. However the sources of air pollution in cities are so numerous and so widely distributed that effective control of pollution by this method is not so easy. An indirect solution hence lies in controlling these parameters through environmental planning measures which involves the control of location, size, orientation and structure of cities with a view of ensuring ample ventilation within cities. The basic techniques are enumerated as follows :

- *Location with respect to climate :* Since the wind speed is the basic parameter in the ventilation of cities and the formation of heat island, the regional wind pattern is to be considered while locating or expanding cities. Cities in areas of low wind speed, particularly in winter months are susceptible to pollution hazards much more than cities in areas of high wind speed.

- *Location with respect to terrain :* Since the wind speeds are modified by the barrier effects terrain, the sites for the location of new towns, especially industrial townships shall not be in the bowls and valleys of mountains. A plain site is preferable to such pollution prone areas.

- *Orientation of township :* The prevailing wind direction should decide the orientation of town ship. In passing through a built up area, the speed of the wind is reduced by frictional drag of building surfaces. Hence the city is to be oriented. The minimum width of the city can be in the direction of low winds. The growth of the town should not be allowed to take place in this width-wise direction.

- *Layout of Streets :* The major channels of air flow at ground level are the network of streets. The pattern of the street network should follow the direction of low wind in winter and high wind in summer.

5.6. PROCESS CHANGE

Before dealing with the air pollution control techniques, it is necessary to ponder over the question of prevention of air pollution since prevention is better than cure. One of the techniques of preventing the formation and /or release of air pollutants is process change. Process change can be either a change in operating procedure for an existing process or the substitution of a completely different process. This process change can be achieved either by

1. Changing raw materials used in the process
2. Using alternate fuels
3. Changing processing methods

Changing Raw Materials

Some of the raw materials used in industries contain non-essential ingredients and serve as pollution sources. If such ingredients are removed prior to processing, the pollution potential can be reduced. Sulfur is one of the principal toxic but non-essential component which may be present in organic fuels and pollutes the environment around the thermal power stations. The fuel can be at thermal power station before combustion for removing sulphur

In the Iron and Steel industry, the use of sintered ores can reduce particulate emissions. Similarly, weted stone in stone crushing machines reduces dust emissions. If automobilies discharge high lead levels into the urban environment, it is necessary to eliminate lead from petrol.

Using Alternate Fuels

Less polluting fuels can be used in place of fuels which cause considerable air pollution. It is recommended that if a thermal power station cannot get an alternate source of coal with low sulfur content, it is better to convert the plant to work on natural gas than looking for a necessary control equipment. Anthracite coal is better than bituminous coal in avoiding smoke. The most convenient way to reduce emissions from fuel impurities is to clean the fuel. Coal washing is a common technique to reduce sulphur and ash.

Changing Processing Methods

Changing of processing method is as effective as product substitution in elimination of air pollution emissions. Control of production process like closing down or reducing the time of operation of production units or reducing output during unfavorable meteorological conditions are in general, some important measures for preventing or minimizing air pollution problems.

The following are the examples of process and operational modifications for prevention of air pollution in Industries, Agricultural fields and Transportation.

◇ *Industry*

* In chemical and Petroleum industries, changes in processing method which provide for continuous automatic operations and completely enclosed systems that minimize the release of materials to the atmosphere. Some of them are:
* Control of loss of volatile materials by condensation (by providing condensation units on volatile products storage tanks) and reuse of vapours
* Recycling non-condensable gases for using in additional reactions of the process.
* In Kraft pulp mills, the old high emission furnaces can be replaced by new furnaces of latest design.
* In Metallurgical industries, substitution of bauxite flux for fluorine containing fluorspar in open-hearth furnaces and use of borate salts as a substitute for elemental sulfur (used as an antioxidant and flux) in casting of molten magnesium metal will result in decreased emission of air pollutants.

◇ *Agriculture*

* Use of liquid and gaseous fertilizer chemicals, e.g., anhydrous ammonia, applied by injection into the earth instead of being spread across the field as finely divided powders subjected to wind entrainment will reduce fugitive dust pollution

* Spraying for insect and weed control should be conducted during windless weather to confine the spread of insecticides to the intended areas.

◇ *Transportation :* Changes in automotive use patterns by the entire urban community plays an important role in controlling air pollution. These include

* enlarging and improving urban mass transportation systems to reduce the need for bringing private vehicles to the city

* speeding traffic flow to decrease average trip time and to take advantage of decreased per kilometer contaminate emission rates at higher speeds

* encouraging the use of small, low-horse power vehicles that emit less contaminants per kilometer of travel.

Check Your Progress - 2

What is meant by process change ?

Note : (a) Write you answer in the space provided below.
(b) Compare your answer with the one given at the end of this unit.

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5.7. SUMMARY

Air pollution management is the regulation of the amount, location and time of pollutant emissions to achieve some clearly defined objectives or goals.

(1) A set of air quality standards or goals to be achieved

(2) An inventory of the emissions from various sources in the region, including man made emissions and emissions from natural sources.

(3) Predictive methodology to relate air quality to emissions,

(4) Monitoring data to determine the status of ambient air quality

(5) Data on cost effectiveness of various control devices and options are required to practice air pollution management.

The guidelines for siting of industries include (a) Areas to be avoided (b) siting criteria. There are some basic techniques for planning of township also.

Process change one of the technique of preventing the formation/release of air pollutants be either a change in operating procedure for an existing process or the substitution of a completely different process.

5.8. CHECK YOUR PROGRESS : MODEL ANSWERS

1. – Associated township of the industry must be created at a space having physiographic barrier between the industry and the township.
   – No prime agricultural land shall be converted into industrial site.
   – No forest land shall be converted into non-forest activity for the sustenance of the industry.
2. One of the techniques of preventing the formation and/or release of air pollutants is known as process change.

5.9. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. What is Air pollution management ? What are the requirements of air pollution management ?
2. Describe the following techniques for prevention of air pollution :
   a) Changing raw materials
   b) Fuel change
   c) Changing processing methods

II. Answer the following question in about 10 lines each.

1. "Process change helps to control Air pollution". Explain.
2. **Explain the Guidelines for locating industries with reference to air pollution control.**
3. Enumerate the techniques of planning of township with respect to air pollution control.

Dr. N.V. Lakshmi

BLOCK - 2
WATER POLLUTION

UNIT - 6 : NATURAL WATER CYCLE AND WATER POLLUTION

Contents

6.1. OBJECTIVES

After going through this unit, you will be able to :

- explain water cycle and how it operates on the earth,
- discuss about water use and audit details of water on earth's crust, and
- explain water pollution, sources of pollution and their implications.

6.2. INTRODUCTION

The relationship of man with the environment is necessarily symbiotic. Through out man's existence on the earth, he depends upon a neat balance among various elements of the earth. Among all these, water is the most crucial and covers more than 90% of the human activity directly or indirectly.

Rapid population growth, acquisition of knowledge about science and technology, unplanned towns and random growth of industry accelerated the exploitation of natural resources, and of all the resources water is the most hampered one. The rate at which the worlds water resources are being disturbed is exceeding the natural assimilation capacity and reproducibility (water cycle). This is resulting in the various environmental problems which we will be dicussing further.

6.3. WATER CYCLE AND WATER USE

6.3.1. Water Cycle

"Water-water every where nor a drop to drink." Yes it is very much true in the current world scenario. If real audit of the worlds water resource is done, it is found that oceans and seas contain 97% of the earths circulating water and most of the remaining water is held in the polar ice-caps. Less than 1% is distributed as fresh water in streams, lakes, ground water and water vapour in atmosphere. Still this 1% is not a small amout and as per the scientific calculations, solar energy is evaporating annually 80,000m^3 of water from ocean, 15,000m^3 from land surface and lakes and 24,000m^3 of water returns to the land as rain and snow.

6.3.2. Water Use

When the actual figures are worked out it is found that roughly 47% of the total fresh water available on the earth's crust is used for agriculture, power generation, 44% for industry and only 9% for house-hold purpose.

6.4. WATER POLLUTION

6.4.1. Natural Water Pollution

Natural water bodies like rivers, lakes and seas are composed of not only water but also a wide variety of living organisms existing in dynamic equilibrium. It has been estimated that 90% of water in India comes from polluted rivers. There are reports on the problems of contamination of ground water by industrial waste application on ground and excessive use of fertilisers and herbicides.

Any water is classified as polluted if it is not fit for human/animal consumption, disturbing the eco-bio-diversity, not useful to industrial or agricultural use, navigation and recreation purposes.

6.4.2. Sewage Pollution

When the water resource is polluted by domestic/municipal sewage it is called sewage pollution. The sewage contains naturally occuring macro, micro organisms, pathogens, organic matter, dissolved inorganic mater, oils, fats, trace metals etc. If sewage pollution is minor, the stream which is receiving the sewage, by virtue of its self purification capacity (2.42 for Ganga Water) may attain natural characterstics. But if the degree of pollution is more, then it poses health and usage problems.

Generally sewage polluted waters when taken as source of water supply, spread diseases, affect the taste, odour and filtration problem (due to algal growth). They also affect the aquatic life and may result in various industrial process.

6.4.3. Industrial Pollution

The discharge of untreated industrial effluents into surface waters and land application causes pollution of water resources. The degree of toxicity of industrial pollution is much more as they cause corosion and erosion of earth, besides leading to dangerous health hazards which are lethal in some instances.

It is difficult to generalise industrial pollution. There are atleast 18 categories of industries which have been identified as pollution causing industries. For example pesticides, fertilizers, paper, oil refineries, paints, dyes, leather, chemicals, bulk drugs, pharmaceutical and others.

Check Your Progress - 1

What is sewage pollution ?

Note : (a) Write your answer in the space provided below.
(b) Compare your answer with the one given at the end of this unit.

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6.5. SUMMARY

Water plays a crucial role in the Ecological balance. Evaporation due to solar energy and precipitation (rain) keeps water cycle balanced in the enviroment. Due to increased population, and rapid growth of industrialisation, natural water resources on the earth are getting polluted. Urbanisation, improper town planning and sewage systems are causing sewage pollution. Untreated industrial effluents discharge into the environment is causing pollution of water resources like rivers, ponds and ground water. Health hazards are many due to sewage and industrial pollution of water supplies.

6.6. CHECK YOUR PROGRESS : MODEL ANSWERS

1. If the water resources are polluted by domestic municipal sewage it is called sewage pollution.

6.7. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Discuss the sources of sewage and industrial pollution and its implication on the environment.

II. Answer the following in about 10 lines each.

1. Explain water cycle.
2. Define water pollution.

Dr. N.V. Lakshmi

UNIT - 7 : INDUSTRIAL EFFLUENT TREATMENT

Contents

7.1. OBJECTIVES

After going through this unit, you will be able to :

- list out major pollution industries and describe their effluent characteristics,
- describe the general principles of treatment methods,
- list out and describe the special treatment for some specific industrial effluents.

7.2. INTRODUCTION

Man's natural environment is being degraded by the use of (i) industrial products like detergents, chemicals, plastics etc. (ii) emission of pollutants during the production like noxious air emissions, waste in the form of effluents and solids.

It is realised that deterioration of the natural environment caused by these industrial production process is an instance of "Social Cost" i.e. the impact of Pollution Control Measures taken will affect the production costs and in international competetive market which in turn result on the product value, there by affecting the economic status of the society.

Even though by definition developing countries have lesser number of major industrial projects, than the advanced countries, the damage due to the pollution would be much more than the developed countries. The reason being the lack of strong pollution control strategies and lower market value for the product. Hence the long term consequences of environmental pollution may be much more severe in developing countries with tropical ecological conditions than that of the temporate zone of developed countries.

It is emphathitically pointed out that there has been a chemical revolution in the last decade. The number of new products are increasing day by day and much is done by them due to increase in health and living standards. But they also bring new dangers, as they find their way in to the environment by many different paths through industrial discharges.

7.3. GENERAL CHARACTERISTICS OF INDUSTRIAL EFFLUENTS

The industrial effluents includes acids, alkalies, floatings and suspended solids, oil and grease, odours & colours due to dissolved solids like chloride, trace metals phenoles and other toxic organics. Thus it is difficult to generalise industrial effluent character.

But broadly can be classified into two types :

i) **Biodegradable :** This type of wastes are those which can be ultimately converted to non toxic end products by different kinds of bacterial activities and ultimately gets assimilated in the nature course.

ii) **Refractories :** Phenols, metals and cyanide type of wastes fall into this category. These wastes are not easily bio-degradable and requires some pre-treatment.

The treatment process opted for the different industrial wastes will be different.

Environmental legislation of Government of India has brought some regulation on water pollution activities under the water act of 1974. This water pollution control act has provision to regulate industrial discharges by fixing uniform standards depending on the point of discharge.

Table 7.1. gives the different discharge stands prescribed under water act.

Table - 7.1. Discharge standards prescribed under water act.

Characteristics	Tolerance limits for Sewage effluents discharged into inland surface water	Tolerance limits for industrial effluents discharged into	
		Inland surface water	Public sewers
	IS : 4764-1973	IS : 2490-1974	IS : 3306-1974
1	2	3	4
BOD (5 day 20°C) mg/l	20	30	500
COD, mg/l	--	250	--
pH	--	5.5-9.0	5.5-9.0
Total suspended solids, mg/l	30	100	600
Temperature, °C	--	40	45
Oil and Grease, mg/l	--	10	100
Phenolic compounds, mg/l	--	1.0	1.5
Cyanides (as CN), mg/l	--	0.2	2.0
Sulphides (as S), mg/l	--	2.0	--
Fluorides (as F), mg/l	--	2.0	--
Total residual chlorine, mg/l	--	1.0	--
Insecticides, mg/l	--	zero	--
Arsenic (as AS), mg/l	--	0.2	--
Cadmium (as Cd), mg/l	--	2.0	--
Chromium, hexavalent (as Cr), mg/l	--	0.1	2.0
Copper, mg/l	--	3.0	3.0
Lead, mg/l	--	0.1	1.0
Mercury, mg/l	--	0.01	--
Nickel, mg/l	--	3.0	2
Selenium, mg/l	--	0.05	--
Zinc, mg/l	--	5.0	15.0
Chloride (as Cl), mg/l	--	--	600
Sulphates, mg/l	--	--	--
% Sodium	--	--	60
Ammoniacal Nitrogen, mg/l	--	50	50
Nitrates (as NOs), mg/l	--	--	--
Radioactive materials :			
γ-emitters, μc/ml	--	10^7	--
β-emitters, μc/ml	--	10^7	--
Dissolved Oxygen, mg/l	--	--	--
Coliform organism (monthly average) MPN per 100 ml	--	--	--

Check Your Progress - 1

Write the general characteristics of Industrial effluents.

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

7.4. EFFLUENT TREATMENT

The treatment technology to be adopted for the wastes depends on "the ultimate goal which we want to achieve from this treatment process".

This is usually decided by the (i) disposal site like surface water and land and sea disposal (ii) the second option will be the cost effectiveness of the treatment process.

Due to the varying nature of the industrial wastes many of the industries plan their treatment plants designing to meet the discharge standards established by the Indian Standard Institute (ISI) and Pollution Control Boards.

The following table gives the standards laid by ISI, for the Sewage & Industrial effluents :

Due to the varying nature of the industrial wastes, before going for the treatment, clear idea of the characteristics of the raw effluents is very essential. After establishing the raw water characteristics, waste treatment should be divided into two steps (i) Preventive (ii) Curative

(i) Preventive step includes (a) reduction of volume of wastes (b) Reduction of the strength or concentration of the wastes by looking in to the possibilities of recycle, reuse of wastes, conservation of wastes by locating the source points in the process, good house keeping, maintenance of process equipment, by product recovery etc.

(ii) The curative measures deal with the actual treatment of liquid effluents by Physical, Chemical and biological methods or in combination of these three depending on the nature of the pollutants.

(a) Primary treatment : which handles mostly non-toxic wastes in effluents and works on the princple of physical methods like solid/liquid separation.

(b) Secondary treatment : handles toxic and non-toxic wastes and involves some special chemical/biological treatment depending on the toxic nature of the wastes.

(c) Tertiary treatment : This part of the treatment is not practiced in general because of cost of the treatment. But depending on the sensitivity of disposal site, they will be practised. Reverse osmosis, membrane filteration, activated carbond treatment etc., are some of the techniques used in this type of treatment.

Screens/Bars : This is the first unit process in the treatment plant, this is accomplished by a set of inclined parallel bars fixed at certain distance. This is intended to remove large size floating materials.

Grit Chamber : This is designed to remove grit consisting of heavy inorganic solid, works on the principle of gravity separation and governed by the flow of effluents.

Oil & Grease Crap : Removes floating oil and grease on the effluent surface.

Equalisation and or neutralisation tank : This is required mainly to equalise the flow variations and variations in the effluent characteristic during batch process in the industry. It consists of holding the waste for some pre-determined time in a continuosly mixed basin which produces an effluent of fairly uniform characteristics. Some times this tank is also used as a neutralisation tank by combining wastes containing excessive acid/alkali or by adding required chemicals lime/acid. By fixing flash mixture (lime/alum) coagulant aids also can be added here.

Primary clarifier/Settling tank : After the equalisation and chemical dosing, light weight organic matter in the colloidal form is removed hear by settling. The entire process is governed by particle size, concentration of particles and particle velocity gradient (stokes law) and many other known and unknown parameters.

Chemical/Biological unit process (Secondary treatment): This unit process is selected depending on the nature of the effluents. This includes chemical or biological treatment process. For eg. Hexavalent chromium can be reduced to trivalent chromium which is less toxic, by giving SO_2 dosing, cynides are oxidised to cynate by st ong oxidants like Cl, sodium hypochlorate, Ozone dosings for the oxidation of refractory organic wastes are practiced. If the COD/BOD ratio of the wastes indicates that the wastes are ammenable for biological treatment, the (aerobic) activated sludge process or anaerobic treatments are opted.

Secondary clarifier: This removes the disested organic sludge by seperation and settling principle. This sludge is disposed and some part of it is recycled in the secondary (biological) unit process as a seed to the tank and to balance mixed liquor suspended solids (MLSS) in the biological treatment plant.

Tertiary treatment : Usually in sensitive disposal sites or with high toxic wastes only this treatment is practiced. Because of the high costs involved and due to maintenance problem the application is limited. Generally PAC (powdered activated carbon paved columns), reserve osmosis are practiced. If having metal industrial wastes then electrodialysing is used.

7.5. PULP AND PAPER INDUSTRY

Pulp and Paper Industry is one of the oldest major industries in India. It is one of the major industries that contributes a lot towards the water pollution problem. In the plup & paper mills plup mill section contributes more pollution problems than paper section.

In the above process, mainly, in the digester section (Kraft process) digesting chemicals like sodium sulphate, sodium hydroxide are used. This produces black liquor which is strong in chemical concentration. In big industries, chemical recovery and reuse is practiced for the black liquor. This produces green liquor and lime treatment of this gives white liquor. If good house keeping and chemical recovery are not practiced, paper mill wastes will be rich with these chemicals and shows high COD and colour. The colour of wastes are attributed to dissolved lignins (refacctory) present in the effluents.

For this kind of effluents a general primary and secondary (biological) treatment options are practiced. This treatment will solve the problems of COD, BOD, SS and DS but not the colour problem. Treatment of lime or ozone treatment is necessary for colour removal. Segregation of strong black liquor and bleaching plant effluents is very essential and gives good results out of biological treatment.

7.6. PHARMACEUTICAL INDUSTRY

Like many other industries pharmaceutical industry produces a wide variety of products. This industry uses both inorganic or organic materials as raw material. The effluent discharges may be of small volume unlike in bulk drug process, but still be very concentrated. Therefore, it is very difficult to make any generalisation regarding the effluent characteristics and treatment technologies. If the waste is from and antibiotic process unit, it adversely affects biological population of the stream in to which it is discharged. If the wastes are from synthetic bulk drug unit the wastes contain high COD, BOD and dissolved solids in addition to toxic elements like cynides and heavy metals. These wastes will be in general, highly acidic/alkaline. To meet this kind of highly diversified pollution, selection of the treatment technology should be well planned and needs careful study from characterisation to lab scale treatability studies.

The general treatment option will be seggegration, equalisation/nutralisation followed by biological treatment with already tested acclaimalised bacteria. Depending on this disposal site tertiary treatment is planned. The segregated strong wastes with high dissolved solids like chlorides and sulphates are subjected 'Solar concentrators'. Seggregrated toxic wastes with refractory organics, cyanides and heavy metals are given a suitable pre-chemical treatment and further subjected to biological treatment.

7.7. SUGAR INDUSTRY

In India, more than 200 sugar factories normally work on a seasonal basis from October end to May. Most of these factories are located in small towns. Wastes produced in these industries are normally discharged on to land or into nearby water courses. Inspite of their easy biodegradable nature, they get purified and result in obnoxious odours in the surroundings due to lack of enough dilution effects.

Suspended solids (SS) high BOD and alkalinity are the general characteristics of sugar mill wastes. These wastes, because of their high biodegradable nature can be treated by biological treatment process. However, only aerobic treatment with activated sludge process is found to be not satisfactory, hence a two stage biological treatment with anaerobic lagoons followed by aerobic waste stabilisation ponds are found to be practically suitable in Indian conditions.

7.8. PLASTIC INDUSTRY

Synthetic plastic are synthetic organic material which are rigid in their final useful form. Synthetic resins are the materials from which synthetic plastics are made. Plastics are classified as (i) Synthetic resins (ii) Cellulose resins (iii) Natural resins (iv) Protein resins

In general during the manufacture of plastics, binders, filters, plastics, dyes, pigments and thermosetting catalysts are used. Effluents from the plastic industry may be less in volume but contain potential pollutants. Hence these wastes may require a pretreatment with oxidants and destablisers for breaking the polymer chain into small molecules to make the wastes amenable for biological treatment. Burning the waste at high temperature (incineration) is also practiced. To remove the residual organics after secondary (biological) treatment, PACT (Powered Activated Charcoal Treatment) process is also practised.

7.9. DYE INDUSTRY

Serious problems are involved in the use of chemicals, especially those encountered in the production of dye stuffs and their intermediates. Mainly the aniline, an intermediate used in the dye production is the reason attributed for bladder cancer of the workers of the dye industries.

Since these effluents are rich with organic chemicals and coloured pigments a suitable chemical treatment like ozone dosing followed by biological treatment is suggested for these effluents.

7.10. SUMMARY

Industrial effluents vary in the nature. Treatment options depend on the disposal site and costs requirement. Before selecting the treatment technology, effluent characterisation, industrial process studies and treatability studies are required to be carried out. Industrial effluents are generally characterised as biodegradable and refractory.

Unit operations/process involved in the treatment plant are generally classified as primary, secondary and tertiary treatment processes.

7.11. CHECK YOUR PROGRESS : MODEL ANSWERS

1. General characteristics of Industrial Effluents are broadly classified into two types.

   i) **Biodegradable :** The wastes which can be ultimately converted to non-toxic end products by various bacterial activities and ultimately gets assimilated in the nature course.

   ii) **Refractories :** This type of wastes are not easily bio- degradable and requires some pre-treatment. Phenols, metals and cynide type of wastes come under this category.

7.12. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Discuss the general principles of treatment methods.
2. Explain the sources of Industrial effluents.

II. Answer the following questions in about 10 lines each.

1. Explain about waste water treatment.
2. Describe the process involved in sugar industry.

Dr. N.V. Lakshmi

UNIT - 8 : DEFLUORIDATION OF WATER

Contents

8.1. OBJECTIVES

After going through this unit, you will be able to :

- explain the importance of analysing drinking water in your area for fluoride content,
- list out the precautions which are to be taken to prevent the ill effects of large fluorides in water,
- describe the principles underlying the defluoridation techniques.

8.2. INTRODUCTION

The ground water supplies in many areas contain natural fluorides dissolved in them. The content varies from area to area. The fluoride (F^-) content ranges from 0.2 to 4.0 ppm and in some waters it goes upto 8.0 ppm. Fluoride in waters upto a level of 1.0 ppm is essential to prevent teeth decay due to dental caries. However presence of fluoride in drinking water in greater than 1 ppm is injurious to health. There is a need to enrich waters with fluoride, if its amount is very much less than 1.0 ppm.

8.3. DISTRIBUTION OF FLUORIDES IN BODY

Fluoride is present in almost all the tissues of the human body- Soft tissues, hard tissues and fluid tissues. The average fluoride content of blood is 0.1 ppm. A good proportion of fluoride from the water is retained in the hard tissues. The fluoride content of different parts of the skeleton is variable and is dependent on the metabolic activity of the tissues concerned besides the duration and the amount of fluoride ingested. About 50% of the fluoride taken in, is retained in the skeleton and the rest is excreted through the urine. Younger persons excrete lower percentage of fluoride and retain large percentages. A 24 hour urine sample is needed for the estimation of fluoride excretion. Fluoride balance in humans is given in the table 8.1.

Table - 8.1. Fluoride Balance in Humans (Largent - 1961)

Fluoride (ppm)	Age (years)	Length of residence (years)	Fluoride ingested/day			Fluoride excreted/day		
			food	water	Total (mg)	Feaces	Urine	Total (mg)
2.0	35	10	1.2	2.4	3.6	0.4	2.9	3.3
5.5	55	29	1.3	3.8	5.1	0.6	4.5	5.1
6.1	57	34	1.0	6.7	7.7	0.4	8.1	8.5
8.0	57	19	2.5	11.3	13.8	1.4	10.4	11.8
20.0	30	8	1.5	20.8	22.3	1.4	12.3	13.7

No active transport mechanism is involved in the process of absorption of fluorides from the Gastro-intestinal Tract. Site of absorption was found to be stomach. In vitro experiments have demonstrated that the fluoride ions cross the gastro-mucus membrane. The presence of calcium, magnesium and aluminium in large amounts reduce the absorption of fluoride owing to the formation of less soluble complex fluorides. Fluorides present naturally in normal human diets are absorbed to an extent of 80%.

Fluoride is chiefly excreted from the body through urine and feaces. Traces of fluoride are also found in sweat, milk, skil, hair and tears. Most of the foods are found to be poor sources of fluoride except tea and sea foods like fish. Therefore, the amount of fluoride ingested with food is very minimal. Ingestion with drugs is negligible since fluorine is present in the drugs in the bound form as C-F bond. This is not cleaved by the biological processes. Inhalation of fluoride containing dust (mining operations) also does not contribute much to the fluoride content in the body.

8.4. MECHANISM OF ENTRY OF FLUORIDE INTO DRINKING WATER SOURCES

Earth's crust contains large quantities of the element (Fluorine) and by solvent action of water on the rocks and soils of earth's crust, fluorine gets into water. Rock forming minerals contain high quantities of fluorine. Mica shows fluoride value as high as 68000 ppm. Probably this may be the reason for high fluoride content in drinking water sources of Nellore district (Andhra Pradesh). Granite rocks also show high fluoride content ranging from 1,100 to 4,700 ppm. This may be the reason for high fluoride content in drinking water sources of Rayalaseema (Kadiri and Penukonda) in Andhra Pradesh. Gypsum, limestone and phosphate rocks also contain high amounts of fluoride. Alkalinity, high temperatures and presence of calcium ions increase the solubility of fluorides in water. Underground water, and sub-soil water will have greater contact with fluoriferous material. Hence the fluoride content in well water will be generally high.

8.5. FLUORIDE CONTENT OF CERTAIN FOOD STUFFS

Different types of food stuffs which humans consume contain fluoride ion at different levels. Some of the important food stuffs and the fluoride content in them is presented in table - 8.2.

Table - 8.2. Fluoride content in some food stuffs.

Food stuff	Fluoride content (ppm)
Dried fish	84.47
Fresh fish	26.89
Egg	1.2
Milk	0.07 to 0.22
Tea	97
Corn yellow	0.1
Rice (dry)	0.76
Apples	0.22 to 1.32
Banana	0.23
Orange	0.18
Mango	0.11
Water Melon	0.11
Cabbage (dry)	15.38
Carrot (dry)	6.92
Garlic	17.72
Onion	10.11
Potatoes	22.00
Tomatoes	2.40
Baking	222.00
Coffee	0.2 to 1.6

Check Your Progress - 1

Why is fluoride in very small amounts needed for human beings ?

Note : (a) Write answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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8.6. FACTORS AFFECTING FLUORIDE INTAKE

The amount of fluoride ingested through water into the body depends on - (1) the quantity of water consumed (2) the amount of fluoride present in water.

The quantity of water taken depends on (a) the size of the body (height & weight) (b) types of food eaten (c) habits (d) physcial activity and (e) climatic conditions.

For example in Rayalaseema the climatic factors demand higher intake of water and the estimate of water intake is 3.5 to 4.0 litres/day. Fluoride absorption is enhanced generally by poor diet, higher fat intake, calcium and vitamin deficiencies, higher day temperatures, greater physical strain and younger age.

Sedentary habits, intake of less quantity of water, large consumption of Vitamin c and calcium reduce the absorption of fluoride.

Hence in some cases where it is not possible to reduce the fluoride content in drinking water, its adsorption in the body can be reduced by suitably regulating our food and other daily habits and also by taking lot of calcium and Vitamin C.

8.7. DETERMINATION OF FLUORIDE IN HUMANS (EXCRETA)

Fluoride is chiefly excreted from the body through urine and feaces. A 24 hour urine sample is essential for the estimation of fluoride excretion. The blood plasma or serum is the most reliable fluid for estimating the fluoride content of body fluids. Blood fluoride in normal being is 0.02 ppm and in chronic endemic fluorosis patients with and without neurological manifestation is 2.0 and 4.0 ppm respectively. None remains for a long time in the blood or in the soft tissues. The great portion of the fluoride is absorbed by the hard tissues in the body (bones) and the rest is excreted through urine. For this reason the fluoride uptake by bones is higher during the growth period. Bones of the active parts of the body take up fluoride more than the other parts.

Check Your Progress - 2

Which part of the body absorbs fluoride ion most and how it is excreted ?

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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8.8. DEFLUORIDATION TECHNIQUES

Methods of removal of fluoride from drinking water and the principles underlying these methods are collectively known as *defluoridation techniques*. The general methods usually applicable for the removal of dissolved cations and anions from water are not very effective in the removal of fluoride ion. For example ion- exchange methods are not very useful in the removal of fluoride. This may perhaps be due to the fact that fluoride ion is very small in size. From time to time different methods have been suggested for reducing or removing completely the fluoride ions in drinking water. No one method seems equally applicable in all situations. Defluoridation has been one of the serious problems faced by India for the last so many decades. Even in Andhra Pradesh in many places, the drinking water is contaminated with fluoride at most impermissible levels.

Defluoridation techniques make use of several substances such as magnesium hydroxide, activated alumina, aluminium sulphate, activated bone char and even minerals such as serpentine. Magnesium hydroxide seems to be of much help in removing fluoride from water by precipitation techniques. It is for this reason removal of fluoride is relatively convenient and easy in the case of hard waters containing magnesium salts. Some defluoridation techniques in use are briefly described below .

1. Activated Bone Carbon Process

This method has been in use to reduce the fluoride contents from 4.5 - 12 ppm level to the level of 1 ppm. The water contaminated with fluoride is passed through bone carbon filters and at the end of the run the water is free from fluoride to large extent. The filters after the use are regenerated by washing first with 4% caustic soda solution and then with 1% phosphoric acid solution. This technique involves large expenditure. Hence the cartridge type of filters were designed for house hold purposes. The commercial activated carbon filters are of vertical pressure type. To avoid any possible reaction between carbon and the metal, the steel shells were lined with plastic materials. The filters contain a bed of crushed and screened activated carbon ranging in depth from 24 to 36 inches supported by layers of graded gravel and course sand. The amount of carbon required is about 30 lb/cu.ft. The sterilization of the bed is carried by heating it with steam. A bed is good for one year.

Different types of vegetable carbons including the blood char prepared from the waste blood from slaughter houses can substitute the activated carbon.

Different agencies working in the field of defluoridation methods found that ion-exchange resins, saw dust carbon, coconut shell carbon, defluoron-1 carbon, magnesia, serpentine (mineral of asbestos) and defluoron-2 can be successfully used as adsorption agents.

2. Domestic Defluoridation Technique

A defluoridation unit was fabricated for domestic purposes long time back using defluoron-1. Pilot plant studies were made at Gangapur (Rajasthan), using carbon. To overcome the problems faced within the use of saw dust carbon, defluoron-1 and carbon, defluoron-2 was developed in 1968 for removal of fluoride in drinking water. Two units using defluoron-2 with a capacity to treat 91 cubic meters were installed at Nalgonda. Even though the process was found successful, the process of regeneration and maintenance of the plants met with some difficulties in the rural areas. Therefore, a new method was developed in 1973 by NEERI, Nagpur. This method was named as 'Nalgonda Technique'. This is a simple and less expensive method.

The method involves *in situ* precipitation of fluoride on the addition of bleaching powder, lime and filter alum in sequence. The contents are stirred for ten minutes and set aside for an hour. The amount of alum required to be added depends on the amount of flouride and the alkalinity of water. Lime hastens the settlement of the precipitate. Bleaching powder ensures disinfection. The dose of lime is 1/20 of filter alum. On the basis of field work and revised costs of chemicals cost per capita/annum was calculated in 1970s as Rs.2.00

Check Your Progress - 3

Name the techniques in use for defluoridation.

Note : (a) Write your answer in the space provided below.
(b) Compare your answer with the one given at the end of this unit.

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8.9. SUMMARY

Ground waters contain usually fluoride but in different amounts. The amount may vary from 0.2 ppm to 8.00 ppm or even more depending on the locality. An amount of 1 ppm of flouride is essential in drinking water to prevent dental caries (decay). But fluoride content exceeding 1 ppm in drinking water is injurious to health. It causes dental fluorosis or even skeletal fluorosis. Site of absorption of fluoride into human system is stomach. Fluoride is chiefly excreted from the body through urine and feaces. Fluoride enters into drinking water sources naturally on account of the solvent effect of water flowing through mineral deposits and rocks, such as mica, granite rocks and phosphate rocks. Food stuffs also contain fluoride in varied amounts. Dried fish contain amounts as high as 84 ppm and tea contains 97 ppm. The amount of fluoride entering human body is dependent on the quantity of water consumed and the amount of fluoride in water besides the size of the body, the type of food taken, the physcial activity of person concerned and the climatic conditions. Sedentary habits, intake of less quantity of water, large consumption of Vitamin C and calcium reduce the absorption of fluoride. Fluoride absorption is enhanced by poor diet, high fat intake, calcium and vitamin deficiency, higher day temperature, greater physcial exercise and younger age. Defluoridation techniques are not simple and always effective. These techniques make use of several substances such as magnesium hydroxide aluminium sulphate, activated bone char and even minerals. Adsorption, ion exchange and precipitation are the three main chemical processes that are made use of in the defluoridation techniques. Different types of activated carbon are used in the adsorption techniques. Nalgonda technique is the most popular precipitation technique used in the removal of fluoride from drinking water. This involves addition of bleaching powder, lime and alum to the water. The contents are stirred and set aside for precipitation.

8.10. CHECK YOUR PROGRESS : MODEL ANSWERS

1) Fluoride (F^-) upto a level of 1 ppm is essential for human beings to prevent teeth decay due to dental caries.
2) Hard tissues of the human body (i.e. bones) absorb the fluoride ions. Fluorine is chiefly excreted from the body through urine and feaces.
3) There are three deflouridation techniques in use. They are a) Activated bone carbon process b) Domestic deflouridation technique c) Nalgonda technique.

8.11. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Name the different sources of fluoride which make the drinking water rich in fluoride content. Explain the absorption and elimination methods of fluoride in human body.
2. Describe with the underlying principles the different defluoridation techniques available.
3. What type of diseases are caused by excess fluoride in water and what are the remedies useful to prevent these diseases?

II. Answer the following questions in about 10 lines each.

1. How does fluoride enter drinking water sources?
2. Name the food stuffs which contain large quantities of fluoride.
3. What are the diseases caused by the presence of fluoride in large quantities in drinking water ?
4. Describe Nalgonda technique.

Prof. S. Brahmaji Rao

UNIT - 9 : TOXIC SUBSTANCES FROM AGRICULTURE AND INDUSTRY

Contents

9.1. OBJECTIVES

After going through this unit you will be able to

- list out the toxic substances which are likely to be released in an industry,
- list out and describe the possible diseases caused by these toxicants.

9.2. INTRODUCTION

About 75,000 chemicals are being traded through out the world. But as many as 35,000 are definitely or potentially harmful to human health. The chemicals which in small doses can cause adverse health effects are really of primary concern in environmental health. Such chemical substances which are harmful to living organisms are called toxic chemicals. Those chemicals that reach the tissues in the human body can cause discomfort and diseases. Some chemicals are harmful to animals and plants but not to human beings. Some are poisonous to humans but not to other species. The substances that are concentrated in the living systems through food chains are really harmful.

9.3. CLASSIFICATION OF TOXIC SUBSTANCES

Toxic chemicals can be broadly categorised into three groups. These are corrosives, irritants and systemic poisons.

Corrosives react indiscriminately with organic materials in human tissues. e.g., strong acids, alkalies and oxidants. *Irritants* are mainly heavy metals and their compounds. These can damage all kinds of tissues. *Systemic Poisons* are organic compounds that interfere with enzymatic reactions, oxygen metabolism or neutral functions. These chemicals resemble those present in human cells, mainly proteins.

9.4. NATURAL SOURCES

Plants, animals, microorganisms and minerals are the main natural sources of toxic compounds. Aflatoxin found in corn, rice, sorghum, peanuts and many other foods is highly toxic and may cause even cancer. This is produced by a fungus *Aspergillus flavus*. The toxicity of some forms of mushrooms is well known. Ergot, a toxic product of fungus *Claviseps purpuria* which grows in rye and other grains is a very toxic substance and it causes abortion and gangrenous limbs.

Plants containing alkaloids, glycosides are equally potent sources for the release of toxic substances. *Salmonella* organisms which are natural inhabitants of some animals cause salmonellosis due to eating infected poultry, egg and meat products.

Check Your Progress - 1 & 2

1. What are toxic substances ?
2. How are toxic substances classified ?

Note : (a) Write your answers in the space provided below.
(b) Compare your answers with those given at the end of this unit.

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9.5. TOXIC SUBSTANCES ARISING FROM AGRICULTURAL PRACTICES

The increased agricultural output in recent times is due to the multiple cropping of high yielding hybrid varieties of cereals especially wheat and rice. This practice has increased the vulnerability of the crops to pests. To control the pests, the farmer resorts to extensive and intensive use of a variety of pesticides. The term pesticides encompasses all materials used for the control of animal and plant pests. These include insecticides, fungicides, herbicides and rodenticides.

The earliest chemical pesticides in use were nicotine, rotenone and pyrethrins from plant sources. The first synthetic pesticide was Paris Green (Copper aceto arsenate). The first synthetic organic pesticide used was DDT (dichlorodiphenyl trichlo ethane). This was followed by other organo chloro insecticides namely Aldrin, BHC, Dieldrin and Haptachloro organo phosphates were introduced in 1930. These include Parathion, Malathion, Methoate and others. But these compounds break down quickly when exposed to weather, unlike organochloro pesticides such as DDT, BHC etc. But organo phosphates are more dangerous to mammals than organo chloro compounds. The third class of insecticides, the carbonates are not that dangerous except few. The other new class of insecticides includes pyrethroids. These resemble pyrethrin and hence the name.

The pesticides are generally degraded in the environment and detoxified through biochemical process. However, we cannot be negligent about the pesticidal residues because it was reported that these caused discomfort, irritation, diseases and many other ailments in human beings. The solubility of chlorinated compound pesticides in lipid (fat) tissue leads to tumours, convulsions and even death. Methyl isocyanate (CH_3 NCO) usually known as MIC is a raw material used in the synthesis or manufacture of carbomate pesticide. Symptoms of MIC exposure are chest tightness and breathing troubles due to irritation of the respiratory tract. This compound is usually associated with phorgene ($COCl_2$). The combined effect of MIC and $COCl_2$ is fatal and Human beings may die within 24 hours. The Bhopal gas leak accident that occurred in the early hours of 3rd December, 1984 killed many people and caused permanent disability in many more. Thousands of people woke up from their sleep due to breathlessness, coughing, splutting and vomiting. About 50,000 patients passed away through the seven hospitals located in Bhopal. There are no reports of chronic toxicity of chlorinated insecticides in humans but there are some indications that it may exist.

The toxic effects of organo phosphorus insecticides is attributed to their interference in the transfer of nerve impulses from one nerve cell to the next. The serious problem associated with the organo phosphorus insecticides is their environmental conversion to more toxic substances. Parathion is oxidised easily by atmospheric oxygen or enzymatically to a product which is four times as toxic as parathion itself.

Pesticides are thus very toxic not only to human beings but also to all kinds of living organisms. These detrimental effects of pesticides can be broadly listed as :

1. Many domestic animals are poisoned since meat and milk are contaminated with these pesticides.

2. Large numbers of honey bees and wild bees are poisoned.

3. Significant loss of fisheries and wild life are reported.

4. Pesticides cause destruction of microflora and microfauna.

5. Pesticides cause allergies and even cancer.

Check Your Progress - 3

Name the important classes of toxic substances released from Agricultural activities.

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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9.6. TOXIC CHEMICALS ARISING FROM INDUSTRIAL PRACTICES

Most of the toxic chemical contaminations arise from human activities. Some of these related to the industry can be listed as :

(a) Mining and extraction of metals

(b) Production and manufacture of goods and products

(c) Transportation of raw materials and finished products

(d) Waste disposals from industrial processes.

9.6.1. Metal Extractions

Metals are extracted from their ores and these ores are dug from the mines. Both these major activities release into the atmosphere many toxic substances including the metals. These toxic metals get circulated through water, soil and air and get built up in human food chains. They cause known and unknown health effects on human systems. Some of the toxic metals and their effects are presented in Table 9.1 in a brief manner.

Table - 9.1. Toxic Effects of Some Metals

Metal	Toxic effect
Arsenic	Inflammation of stomach and intestines, cirrhosis of liver, bone marrow degeneration and severe dermatitis.
Beryllium	Diseases of heart, liver and spleen
Cadmium	Cancer, testicular tumor, high blood pressure and kidney disorders.
Chromium	Lung tumours
Copper	Irritation of stomach and intestines

Lead	Impotence and sterility, damage to bones, kidneys, heart and circulatory system.
Mercury	Impairment of speech and hearing
Molybdenum	Causes gout and disorders of bone
Nickel	Effects central nervous system causes blood sugar
Selenium	Causes liver and kidney problems and dental caries.
Zinc	Causes stiffness and pain in muscles. Loss of apetite and nausea.

Among non-metals fluoride and boron are considered toxic. Boron causes lung disorders and fluoride causes fluorosis.

9.6.2. Production and Manufacture Process

Toxic chemicals may be released at different stages in the production processes. For example the mercury poisoning episode of Japan and methyl isocyanate (MIC) leakage from Bhopal plant in India are specific instances of catastrophies caused by leakage of the toxic chemicals. It is unwise to list all the possible toxic chemicals because the list is quite long and never complete. But some toxic chemicals identified in US Environmental Protection Agency include :

Carbon Compounds

1. Benzene
2. Carbon Tetrachloride
3. Chloroform
4. Dichloromethane
5. Methyl Ethylketone
6. Methyl Isobutyl Ketone
7. Trichloroethane
8. Trichloroethylene
9. Xylene

Metals

1. Cadmium
2. Chromium
3. Lead
4. Mercury
5. Nickel

The nature of the chemical form of an element influences its toxic effect. For example Sn^{2+} and NL^{2+} are particularly toxic but $Sn(CH_3)^{+}{}_3$ is dangerously toxic. Similarly Cr (VI) is more toxic than Cr (III). The concentration of toxic material to give 50% mortality is used as a measure of toxicity.

Check Your Progress - 4

Name some important toxic chemicals arising from industrial practices.

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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9.7. TOXIC EFFECT PATTERNS

A major mode of toxicity is the inhibition of enzymes. Elements such Pb^{++}, Cd^{2+}, Hg^{2+}, As^{3+}, As^{5+} can block the active sites of enzymes or replace an essential element such as Zn^{2+}. Some toxic materials are mutagenic i.e. they produce changes in the base sequence in DNA. This makes transmission of incorrect genetic information. The outcome is the production of wrong proteins and enzymes. This leads to a change in the organism. This is called mutation. It is established that over 80% of the carcinogens are also mutagenic. Some of the chemicals identified to be mutagenic are - Methane, Triazine, diepoxy-entame formaldehyde, usethane and mustard gas, caffeine, hydrogen peroxide etc.

The other type of toxic effect is known as *teratogenic* effect. A teratogen is a compound that directly changes the foetus at doses that do not affect the mother. Some organophosphates and carbomate pesticides are teratogenic. The teratogenic effects are not felt uniformly in animals and humans.

More than 50% of cancer cases are attributed to the substances known as *carcinogens* present in the industrial products and pesticides. A carcinogen is a cancer causing chemical. The chemicals extensively used in industry and agricultural practices such as Vinylchloride, poly chlorinated bi phenyls (PCB), insecticides, pesticides are identified to be carcinogenic in nature. Some of the carcinogens and the type of cancer caused by each one of them are presented in Table 9.2.

Table - 9.2. Environmental Carcinogenic Chemicals.

Chemical	**Type of Cancer**
Arsenic	Skin, Lung
Chromium	Lung
Nickel	Lung and Nasal Tissue
Benzene	Leukemia
Vinylchloride	Liver

Many food additives in the form of preservations, emulsifiers, stabilizers, anti caking agents, colours, artificial sweeteners, antioxidants flavouring agents and nutrients are all found highly toxic to humans. Detergents and detergent chemicals such as surfactants, chemicals used in building material are all found to be highly toxic.

Check Your Progress - 5

Name few teratogenic substances.

Note : (a) Write your answer in the space provided below.
(b) Compare your answer with the one given at the end of this unit.

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9.8. TOXICITY OF SELECT CHEMICALS

Poly chlorinated biphenyls (PCB) : These do not exhibit significant immediate toxicity and therefore have been considered to be non-toxic. But many persons in Japan who ate oil contaminated with PCB developed darkened skin, eye damage and severe ache. Some children were born with the same symptoms. This suggested that PCBs can readily cross the placental barrier.

DDT : The toxic effects of DDT are not attributed to the chemical reactivity of the compound but to its size and geometry that allows for the blockage of the pores of nerve membranes.

Organo phosphorus insecticides : The toxic effect is due to their interference in the transfer of nerve impluses from one nerve centre to the next. Generally these are converted in the environment to more toxic substances.

Metals : The toxicity of metals tend to increase down a periodic group in Zn, Cd, Hg, Cu, Ag, Au, Al, In, and Mg, Ca, Si, Ba. Many biochemical molecules offer potential dilating sites for metal ions and these alter the reactivity of these molecules.

According to the surveys conducted by the World Health Organization, nearly 750,000 people are known to get poisoned every year causing some 14,000 deaths. Developing countries account for only 30% of the victims of pesticide consumption.

9.9. SUMMARY

Out of 75000 chemicals traded, about 3500 are identified to be toxic to humans. The substances that are bioconcentrated in the living systems through food chains are more harmful than others. Toxic chemicals are broadly classified as corrosives, irritants and systemic poisons. Many natural sources, plants, animals and micro organisms contribute the toxic substances to the environment. Aflatoxin, mushrooms (poisonous), ergot, alkaloids, glycosides are some examples of such natural toxicants. Many pesticides or biochemical products of these pesticides act as toxic substances for human beings. These include polychlorinated benzenes, organo phosphorus compounds and some metal ions. Industrial products, intermediates and wastes of industrial process too act as toxicants. The list is quite large. But metals and fluorine compounds are worst of them.

9.10. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The chemical substances which in small doses cause effects in living organisms are called toxic substances. Toxic substances can be broadly classified into 3 groups - corrosives, irritants and systemic poisons. Corrosives react indiscriminately with human tissues e.g. strong acids and alkalies. Irritants - They are mainly heavy metals and damage all kinds of tissues. Systemic poisons - They interfere with enzymatic reactions and chemically resemble those present in cells mainly proteins.

3. There are four classes of insecticides in practice in the field of Agriculture. They are - (a) Organo chloro insecticides e.g. DDT, BHC. Dieldrin (b) Organo phosphates - eg. Parathion, Malathion (c) Carbonates e.g. Aldicarb (d) Pyrethrinoids e.g. Pyrethrin

4. The toxic chemicals arising from industrial practices are metallic, non-metallic, organic in nature.

   Metallic toxic substances : Arsenic, Beryllium, Cadmium, Chromium, Lead, Copper, Mercury, Molybdenum Nickel, Seinium, Zinc.

   Non-metallic substances : Flourine and Boron

   Organic substances : Benzene, carbon tetrachloride, chloroform, dichloromethane, mythyl ethyl ketone, methyl isobutyl ketone, toluene, trichloro ethane, trichloroethylene, xylene etc.

5. Some pesticides belonging to organophosphates and carbonates are teratogenic substances.

9.11. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Give a detailed account of the toxic substances likely to be thrown out from the agricultural practices and their ill effects.

2. Name the toxic substance expected from the different industrial processes.

3. Explain the terms mutagerns, teratogeus and carcinogens. Give examples.
4. What are the toxic metals and what are their ill effects.

II. Answer the following questions in about 10 lines each.

1. Name three toxic substances released into the atmosphere from agricultural practices.
2. What toxic substances are obtained in industrial practices ?
3. What type of ailments are expected from pesticides ?
4. Name few carcinogens .
5. What are the precautions to be taken to reduce the toxic nature of the effluents ?

Prof. S. Brahmaji Rao.

BLOCK - 3
SOIL POLLUTION

UNIT - 10 : SOIL CONTAMINATION

Contents

10.1. OBJECTIVES

After going through this unit, you will be able to :

- explain how the soil is generally contaminated,
- describe the method of deposition of these contaminants in the soil, and
- explain the adverse effects caused by the soil contaminants.

10.2. INTRODUCTION

The surface of the earth consists of land, sea and air. Land surface has been further classified into 'Lithosphere' and 'Pedosphere'. The former consists of rock formations and the latter is composed of disintegrating compounds of rock and stone forming soil. All the components of the environment namely Atmosphere, Hydrosphere, Lithosphere, Pedosphere and Biosphere are interdependent and interact with each other.

The pedosphere is a meeting ground for air from the atmosphere, water from the hydrosphere, minerals from the lithosphere and the organisms of the biosphere. The ground covering the surface of the earth consists of loose and solid stone, rock and of humus. The ground components constitute a three phase system consisting of a solid (mineral), a fluid (water) and a gas (air). These are in a state of flux. Rocks of different grain sizes, clay minerals and salts belong to the inorganic component of the land, while living organisms (bacteria, fungi, mites etc), dead organic matter (plants, microorganisms etc) belong to the organic component.

10.3. LAND POLLUTION

What is normally referred to as land pollution, is in reality the soil pollution. The nature and quality of vegetation that can be grown on a given piece of land depend strongly on the characteristics of the soil only. As mentioned earlier, soil is the weathered top surface of earth's crust constituted by mineral matter (sand, silt and clay), organic matter (humus) and micro organisms (bacteria, fungi etc) mixed together. Soil is very important for the sustenance of life on this earth. All living beings are ultimately the products of soil and after death, the body materials are returned to the soil. The contamination of soil with harmful chemicals and other materials can be broadly named as soil pollution. The contaminants are generally referred to as pollutants. The effect of pollutants on soil are difficult to evaluate. Air borne pollutants coming from the factories may travel long distances and slowly deposited on the soil. Agrochemicals which are very widely used in agriculture constitute the other major pollutants.

10.4. SOURCES OF SOIL CONTAMINANTS

Soils receive contaminants or pollutants from a wide variety of sources. These include (1) Atmospheric fallouts (2) Agrochemicals (3) Waste disposals (4) Incidental accumulations and (5) Industrial effluents.

(1) Atmospheric fall outs : The gaseous products that are released into the atmosphere reach the soil through rain. For example fossil fuel combustions release into the atmosphere oxides and oxyacids of N and S and similarly Pb and PAHs from automobile exhausts. From metal smelting operations, the metallic vapours of Cd, Cu, As, Ni and Zn reach the atmosphere and then return to the soil. Radio isotopes from reactor accidents and atmospheric testing of nuclear weapons and soot and other chemicals from oil well blow outs also reach the soil from the atmosphere.

(2) Agrochemicals : Herbicides, insecticides, fungicides and fertilizers contaminate the soil. Some of the chemical substances such as chlorinated hydrocarbons, DDT, BHC, Cu, Zn, Hg and organic molecules reach the soils from the agrochemicals.

(3) Waste disposals : These may be intentional or unintentional additions to the soil from the waste disposals. These include farm manures, sewage sludges, composts from domestic wastes, mine wastes, seepages from land fills, ashes from fossil fuel combustions, incinerators, and accidental fires. Burials of diseased livestock on farmland also add to the soil pollution. These waste disposals majorly contain metals such as Cd, Cu, Pb, Zn, Ba etc.

(4) **Incidental accumulations :** Wood preservatives from fencing, leakages from underground storage tanks, corrosion of metals in contact with soil, warfare chemicals, accumulations from sports activities, all these add to the soil contamination.

(5) **Industrial effluents :** Building demolitions, production wastes contaminate heavily the soil. For example phenols, tars, cyanides, arsenic and cadmium reach the soil from gas works. Electrical industries release into the soil, Cu, Pb, Zn, solvents etc. Tanneries release some organic chemicals and chromium metal.

10.5. ADSORPTION OF CONTAMINANTS IN SOILS

The contaminants bind to the surfaces of the colloidal constituents of the soils. The phenomenon of this binding is called adsorption. This adsorption therefore prevents leaching of the contaminants down the soil to the water table. The contaminants deposited on the surface of the soil either react with the colloidal material or are washed into the soil profile in rain, irrigation water or snow melts. The soluble contaminants enter the system of pores. The insoluble ones will bind to the soil surface. Different reactions occur between the contaminants and the soil components. Ionic contaminants are adsorbed on soil colloids and non-ionic organic molecules such as pesticides are adsorbed on humic polymers by physical and chemical mechanisms.

Thus soils act as sink for contaminants due to several adsorption processes. There is thus a tendency for most organic contaminants to be concentrated on the top soil. But in soils with low organic matter and high sandy or gravel materials, the organic contaminants go down the soils to great extent. Pesticide contaminants are relatively insoluble and therefore they do not move down the soil. Organic wastes such as sewage sludges and composts added to soils act as a sink for contaminants. The degradation of organic matter by micro organisms is affected by factors such as soil pH, temperature, supply of oxygen and the nutrients. Most important other factors are the chemical structure of the contaminant, the toxicity, the water solubility and adsorption capacity.

Therefore the persistence of organic contaminants in soils is determined by the balance between adsorption onto soil colloids, uptake by plants and degradation processes. The pesticides (organo chlorine molecules) are regarded as highly persistent molecules. They stay in the soil for 2-5 years.

Check Your Progress - 1 & 2

1. What is soil ?

2. What are the sources of land pollution ?

Note : (a) Write your answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

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10.6. EFFECTS OF SOIL CONTAMINATION

As, Cd, Pb, coal, tars, phenols etc harm directly the children and animals. The organic hydrocarbon solvents, mercury rich pesticides cause inhalation hazards and sulphate, methane, some metal vapours cause phototoxicity. Coal dusts, oils, petroleum, tar, rubber, high calorific organic wastes lead to fires and explosions. Contact of people with contaminants during demolition activities may cause severe diseases. Thus contaminants in soil can effect human beings by adsorption into the body through oral or inhalation or cutaneous pathways. The effects are related to the amount absorbed into the body. Dust particles can penetrate into lungs directly. Oral intakes cause problems to children playing on contaminated soils. Oral intake occurs in adults through the consumption of soil adhered to vegetables.

10.7. SUMMARY

Pedosphere is a meeting ground for air, water, minerals and the living organisms. The soil consisting of disintegrating compounds of rock and stone is considered as pedosphere. The soil pollution is referred to as land pollution. The contaminants reaching the soil from different sources are known as soil pollutants. Contaminants reach the soil from atmospheric fall outs, agrochemicals, waste disposals, incidental accumulations and industrial effluents. The contaminants bind to the soils by adsorption. The contaminants either react with the colloidal matter or are washed into soil profile through rain. Soil contaminants effect children, animals and even adults.

10.8. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Disintegrating compounds of rock and stone is called soil. In a broader sense it may also be defined as the weathered top surface of earth's crust constituted by mineral matter (sand, silt and clay), organic matter (humus) and micro organisms (bacteria, fungi etc.)

2. Important sources of land pollution are (a) Atmospheric fall outs (b) Agro-chemicals (c) Waste disposals (d) Incidental accumulations and (e) Industrial effluents.

10.9. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Give an account of different contaminants of the soil and their sources.
2. How are soils contaminated ? what are the adverse effects of these contaminants ?

II. Answer the following questions in about 10 lines each.

1. What is land pollution ?
2. Name the land pollutants ?
3. Mention few adverse effects of soil contaminants.

Prof. S. Brahmaji Rao

UNIT - 11 : WASTE OR REFUSE DISPOSAL

Contents

11.1. OBJECTIVES

After completing this unit, you will be able to :

- describe various types of wastes which are anticipated from different industries,
- assess the magnitude of wastes and the probable harmful effects caused by such wastes,
- list out the relative advantages and disadvantages of different disposal methods in use, and
- realise the importance of disposal methods in existence for hazardous and nuclear wastes

11.2. INTRODUCTION

Since beginning of human civilization different human activities resulted in generation of liquid, solid and gaseous wastes. However there was no problem of their safe disposal so long as the density of population was low and land was available in plenty. But with the increased population, industrialization and urbanisation the management as well as the disposal of wastes created problems. This excessive production of wastes is overtaxing earth's waste absorptive capacity. Indeed in the complex web of plant and animal life, one organisms waste is anothers sustenance. Even then if the waste accumulation exceeds certain limits, waste becomes pollution. This pollution is not merely a nuisance, but it is hazardous to life. It is therefore, very necessary to manage waste generation, transport, treatment, utilization and disposal without causing environmental degradation.

11.3. SOURCES AND NATURE OF WASTES

Wastes include garbage (decomposable waste), paper, wood, glass, plastics, ashes, agricultural wastes, sewage sludge, demolition rubbles, junked appliances, pathogenic refuse from hospitals, mining wastes, industrial wastes and many others which are thrown away after use.

The sources of the wastes can be listed as Domestic, Municipal, Industrial, Mining, Commercial, Agricultural and others (miscellaneous).

These sources broadly release the wastes as specified below :

Domestic	:	Garbage, hospital wastes, sewage
Municipal	:	Street sweepings, wast of sewage treatment plants.
Industrial	:	Refuge from manufacturing units
Commercial	:	Thrown outs from stores and offices.
Agriculture	:	Residues of Fertilizers, Pesticides, Biomass.
Others	:	Nuclear wastes, Natural calamity wastes etc.

The wastes thus include decomposable as well as non-decomposable materials, both synthetic and natural. Chemically these wastes contain both inorganic and organic materials. The organic materials contain in them bio - degradable and bio - nondegradable components. As far as the inorganic wastes are concerned, metals constitute a major fraction of the wastes. Urban refuse represents important source of copper, mercury, lead and zinc. It is estimated that hazardous waste is about 1000 million tons per year.

11.4. MAGNITUDE OF WASTES

Throw away has become a way of life in the developed countries. According to an estimate, the Americans alone were generating 1.5 billion tons of mineral wastes, 0.55 billion tons of agricultural wastes even as early as 70s. The scientists calculated that an average of 0.5 bottle for sq.km and total of 35.4 million plastic bottles and 5.9 million red rubber sandals would be floating about in North Pacific Ocean. The global discharge of solid wastes of various categories into the soils alone during one year in 80's has been estimated as shown in Table 11.1. In 90s, this must be atleast doubled.

Table - 11.1. Solid wastes (global) thrown into soils

Solid wastes	(x 10^9 tonnes)
Agricultural and Food Wastes	151
Animal Wastes, Manure	21
Logging and other wood wastes	11
Urban refuse	440
Municipal sewage sludge	20
Miscellaneous organic wastes	210
Solid wastes in metal manufacturing	380
Fertilizers	166
Peat	375
Coal ash and bottom flyash	3,720

(Source : Introduction to Environment By M.N. Sastry, Himalaya Publishing House)

Soils receive large amounts of trace metals from the wastes. These metal inputs on the average vary from 20 tonnes to 2000 tonnes per year. Manganese seems to be the most abundant and cadmium the least abundant. These metals going into the soils through solid wastes include arsenic, cadmium, chromium, copper, mercury, manganese molybdenum, nickel, lead, antimony, selenium, vanadium and Zinc.

Check Your Progress - 1

What is a waste ?

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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11.5. SOLID WASTE DISPOSAL METHODS

The most common methods in use for waste disposal are : (a) Open dumping. (b) Sanitary Refills, (c) Composting, (d) Ocean dumping and (e) Incineration

A) Open dumping method : This is the most common method. The wastes or refuse is dumped on open lands usually situated at places far off from the town or city for the purpose. However, these open dumps produce health and pollution problems. These dumps act as breeding places for population of flies, rats, cockroaches, mosquitoes and other pests. Flies may cause or transmit diseases such as typhoid, cholera, dysentry, tuberculosis etc. Rats may cause plague, rabbis, while cockroaches, mosquitoes may transmit malaria, yellow fever, encephalitis and filariasis. These dumps cause serious air pollutions and water and land pollutions.

B) **Sanitary land fills :** The waste is spread in thin layers and these layers are compacted with the help of bulldozers. After this process further layers are spread. The layer is then covered with a thin layer of clean earth and this is also compacted in the same manner. The method offers some advantages over open dumping method. Public health problems are minimised since the breeding of flies, rats and other pests is prevented. But the land fill site is to be chosen correctly other wise this may lead to ground water or surface water pollution. The aerobic reactions may take place and produce toxic substances. Even after the oxygen content is exhausted, anaerobic reactions occur to form methane hydrogen sulphide, carbondioxide and water. Methane being a highly imflammable gas, it may cause fire hazards. But if properly dealt with it may be a profitable source of energy. These land fills are generally useful to convert marshes and pits into parks and play grounds. Structures may also be built on these land fills.

C) **Composting :** This is a process of converting the refuse or waste (not all types) into a valuable source of humus essential to the soil. This conversion is effected by fermentation process and is carried out by heaping the refuse and moistening it and letting it undergo fermentation. This process is not very attractive and useful for urban wastes because these contain many non - compostable materials such as glass, pottery, plastics, metals, rubber and leather. Unless these materials are separated first, from the compostable waste, this process is not useful and attractive.

D) **Ocean dumping :** This is a very common method in the coastal zones. But this is a dangerous and unhealthy practice especially when the refuse contains toxic materials. US was dumping millions of tons of the waste into the seas till 1988 when a law banning such dumping was enacted. This ocean dumping is most dangerous to marine life and in turn this is also lethal to those who live on marine foods.

E) **Incineration :** The process of incineration is adopted as a preliminary treatment in many developed countries to reduce the weight of the solid wastes, But this method of incineration may add air pollution to the existing one. This appears as a popular saying the "add pollution to prevent pollution". New incinerations are therefore, designed to reduce this unwarranted situation as well as to recover the heat for useful purposes. Attempts are also made in some instances to recover the useful compounds.

By and large, all the methods mentioned above are use in the solid waste disposals. But it is always advantageous to minimise the quantities of wastes by proper management techniques and by new types of industrial processes. There is an increasing concern over the improper disposal of medical wastes especially those contaminated with communicable diseases of viruses (AIDS and Hepatitis)

11.6. WASTE WATER MANAGEMENT AND DISPOSAL

Waste waters containing harmful substances from industries like pulp and paper distillaries, cane sugar, textiles, tanneries, fertilizers, petroleum refineries etc, is on the increase in many parts of the world. The waste water menace and discharges containing acids, alkalies, toxic chemicals, colouring bodies in big cities and industrial places in India is at present as bad as in developed countries. As per one estimate 4900 medium and large scale industries in India are discharging large quantities of waste waters into rivers and seas. These industries include sugar industries 300, distillaries 128, caustic soda factories 38, fertilizer industries 65, petroleum refineries 38, man made fibre industries 29, integrated steel mills 7, textile mills 300, pulp and paper mills 150. Pharmaceutical industries 120, pesticide factories 50, petrochemicals 10, inorganic chemical industries 150, daires 50,, thermal power plants 150, iron ferrous 9, metallurgical industries 12, dye industries and electroplating units 128 etc.

Therefore, there is an urgent need to develop a water quality management programme. Waste water disposal is essential but it will affect another body of water. Therefore, some form of control is essential. The most common way to control the discharge of polluted water is to treat the waste waters at the source itself. The other way is to make changes in the manufacturing processes to reduce the contaminations or to recover by products from the waste waters. Waste water treatment should be made cheap in developing countries to avoid large expenditure.

Surface or sewage from a village or town can be treated in an oxidation pond followed by a fish pond. The effluent from fish pond can be used for developing a green belt around. This is an ecologically balanced waste water management system. Cost effective management schemes best suited to local conditions would afford the possibility of productive proposition. If ample land is available, simple biological treatment would produce an acceptable effluent. The sunshine and the temperature will reduce considerably the use of equipment, energy and skilled man power. The regional waste water treatment plants treating jointly municipal and industrial effluents will prove less expensive solution for waste water management and disposal.

Check Your Progress - 2 & 3

2. Name the different methods in use for waste disposal.

3. What is composting ?

Note : (a) Write your answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

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11.7. HAZARDOUS WASTE DISPOSAL

This has become an important environment problem in many countries in the world. The main issues include clean-up of the existing repositories of such wastes and the development of future programmes for safe disposal. A waste which when improperly handled, treated, stored, transported or disposed causes significant hazards to human health is called Hazardous waste. Therefore, such wastes must be minimised in quantity and treated prior to disposal. There are basically six approaches for safe disposal. These are :

1. Secure sanitary land fills
2. Co-disposal of hazardous and municipal wastes
3. Land spreading
4. Deep well disposal
5. Underground mine storage
6. Dumping at sea

11.8. NUCLEAR WASTE DISPOSAL

Nuclear wastes are classified as per their activity level into mildly active, moderately active and highly active wastes. The mildly active wastes consists of residues from filter and purification plants from contaminated laboratory equipment and of sewage sludge from waste water separation. Such wastes are disposed off by dumping in the sea by burial in the ground and by depositing in salt mines. Moderately active nuclear waste consists of radio active residues from purification processes and nuclear research projects. These wastes were formerly dumped at sea. In 1972, European Atomic Energy Authority dumped 3800 tons of such wastes packed in 7600 containers in the Atlantic Sea. Since these containers can not hold the wastes permanently it is feared that these wastes may be enriched in the food chain in the ocean. Highly radio active, wastes are those which are left behind as liquid upon separation of Uranium and Plutonium from burned fuel in reprocessing plants. Nuclear waste can not be destroyed in contrast to chemical waste. The principal problem concerning the disposal of fission products is their long half life values. For example strontium-90 has a half life of 26 years, caesium-137 has a half life of 30 years, plutonium-239 and iodine-12 have half lives of 24,400 and 17,200,000 years respectively. So the nuclear wastes produced now must be stored very securely for long periods hardly conceivable to man. Some countries are exploring the possibility of sinking radio active wastes through the ice in the Antarctic, NASA (National Aeronautics and Space Administration) had carried out studies for exploring the possibilities of extra planetary disposal of nuclear wastes.

Many countries are considering the storage of highly active nuclear wastes in tanks constructed on the earth's surface. America was using this method for the last 20 years. Over 3 million tons of highly radio active liquid were already stored in more than 200 steel and concrete tanks. These are to be cooled all the time to suppress the heat generated in the tanks. But there are many dangers associated with such storage methods. The wastes can corrode the tanks and the waste may seep into the ground. If the heat generated is not properly suppressed, the tanks may get heated up to or over 1000°C. This makes volatile products escape into atmosphere. Water molecules may get split into hydrogen and oxygen and an oxy-hydrogen explosion may occur if cooling system fails. Thus the storage of nuclear wastes in tanks and places above the ground is potentially very dangerous.

Check Your Progress - 4

How is hazardous waste disposed ?

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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11.9. WASTE UTILIZATION

Wastes can be better managed and their disposal problems can be much reduced if the wastes are put to reuse and recycling of wastes offer several advantages.

i) **Utilization :** Some solid wastes can be directly used. For example the fly ash and the bottom ash from thermal power plants and other industrial units can be used to prepare bricks. Biomass can be fermented to produce methane gas (Biogas).

ii) **Reuse :** Glass bottles and metal cans can be returned back to the manufacturing units for reuse. This reduces the non- biodegradable component of the wastes.

iii) **Recycling :** Recycling of paper and plastics is becoming a way of waste management in the Western countries. It appears that the recycling of Sunday New York Times Paper would itself be equal to saving 75000 trees. Scientists are at work to find the methods for recycling of various types of waste products and using them as different products.

11.10. SUMMARY

With increase of population, human activities are also increasing enormously in the field of production of food, shelter, clothing and other amenities. The increased human activity is also increasing the magnitudes of waste formation. Wastes include garbage, paper, wood, glass, plastics, ashes, agricultural wastes, sewage sludge, pathogenic refuses from hospitals, mining wastes, industrial wastes and what not Thus the waste generating sources are classified as domestic, municipal, industrial, commercial, agricultural and others. Wastes consist of disposable and non-disposable materials. The wastes run into millions of tons. For example agricultural wastes amount to 150×10^9 tonnes and coal ash wastes go upto $3{,}720 \times 10^9$ tonnes. Solid waste disposal methods include open dumping, sanitary refills, composting, ocean dumping and incineration. It is more useful if waste water management and disposal agencies shall resort to treatment of the wastes at the source itself before it is disposed off. Sewage can better be treated in an oxidation pond followed by a fish pond. If ample land is available, biological treatment offers advantages. Hazardous waste disposal may be effected through - (a) secure sanitary land fills, (b) co-disposal of hazardous and municipal wastes, (c) land spreading, (d) deep well disposal, (e) underground mine storage and (f) dumping at sea. Nuclear waste disposal is of utmost importance and different methods are employed depending on the level of activity. Storage in tanks constructed on the earth's surface, sinking the waste through ice into antarctic, extra planetary disposals of the wastes are some modern methods. Waste utilization through reuse and recycling may prove more useful than the existing disposal techniques,

11.11. CHECK YOUR PROGRESS : MODEL ANSWERS

1. 'Waste' may be defined as any matter, which is thrown away after use by man.
2. The most common methods in use of waste disposal are i) open dumping ii) sanitary refills iii) composting iv) ocean dumping and v) Incineration

3. Composting is a process for converting the refuse into valuable source of humus essential to the soil. This is effected by fermentation process and is carried out by heaping refuse, moisturing it and letting it undergo fermentation.

4. There are basically six methods for safe disposal of hazardous waste. They are : i) secure sanitary land fills ii) co-disposal of hazardous and municipal wastes iii) land spreading iv) deep well disposal v) underground mine storage vi) dumping at sea.

11.12. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Give a detailed account of waste water management and disposal.
2. Describe the methods in use for the disposal of nuclear wastes.
3. What should be the future plans for India in respect of disposal of wastes of different types ?

II. Answer the following questions in about 10 lines each.

1. How are wastes broadly classified ?
2. Name the waste disposal methods in use.
3. What is meant by incineration ?
4. How is sewage treated ?

Prof. S. Brahmaji Rao

BLOCK - 4
PHYSICAL POLLUTION

UNIT - 12 : NOISE POLLUTION

Contents

12.1. OBJECTIVES

After going through this unit you will be able to :

- explain the concept of noise pollution,
- describe the nature of sound and noise,
- describe the effects of noise pollution on human beings, wild life and non-living things,
- discuss about different methods for control of noise pollution.

12.2. INTRODUCTION

Noise is one of the major factors which pollutes the environment. Due to the industrialization and technological advancement the noise pollution becomes more and more in the environment. Population growth is also one of the root causes of our environmental problem. Thus we can say that the environmental pollution is due to a severe imbalance in the ecosystem. In olden days noise pollution was confined to certain areas where factories, machines and mills are existing. But now-a-days it spreads to every nook and corner due to the urbanization. As water, soil or air pollution, noise pollution is also very harmful. Noise is also one of the pollutants and it has harmful effects not only on human beings but also on animals, birds, plants and other non- living things. Noise creates more and more problems especially in the urban industrial areas.

12.3. CONCEPT OF NOISE POLLUTION

The word noise is derived from the latin word 'nausea'. Many industrial psychologists and environmentalists have defined the term noise. According to Blum "Noise acts as distractor and therefore, it interferes with the efficiency of the people. Tiffin states that "Noise is a sound which is disagreeable for the individual and which disturbs the normal way of life".

The noise from vehicles i.e. motor cars, aeroplanes, jet planes, buses, cars etc, and electric gadgets we use at houses like Grinder, Radio, T.V., Typewriter and Telephone are not only interfering with activities but also lowers the quality of life.

Noise is defined as unwanted or unpleasent or undesirable sound. Noise pollution is therefore referred to the unwanted sound dumped into the environment or atmosphere leading to health hazards.

12.4. NATURE OF SOUND

Noise is most often and most simply defined as unwanted sound. Sound is produced when an object vibrates alternately compressing and expanding the air. These compressions and expansions travel like waves from the source. They are called sound waves. When the effects of a sound are undesirable or unpleasent, it may be termed as noise. The basic characteristics of sound are pitch and amplitude and these two are related to loudness.

When an object serves as a source of sound, the *Pitch* is determined by how rapidly the object vibrates. The rate of vibration is called *frequency*. The frequency is measured in Hertz (Hz). The frequency of an object is defined as the number of vibrations per second. If the frequency is high the pitch is also high and the frequency is low, pitch is also low. Human beings can hear the sounds with frequencies from about 20 to 20,000 vibrations per second. But it varies from person to person. There are also differences between humans and animals to detect different frequencies. Bats produce and hear sounds having frequencies far above the range of human ear.

The distance that a vibrating object (such as a tuning fork) moves as it vibrates is called the *amplitude* of vibration. Sounds having the same frequency and pitch differ in the amount of energy involved. The greater the energy the greater the amplitude of the sound that is produced.

Loudness is the strength of the sensation of sound percieved by the individual. It does not depend entirely on the energy or amplitude of the sound wave but depends on the frequency or pitch. In acoustics noise is defined as any undersired sound.

Encylopaedia Americana defines it as "Noise by definition is unwanted sound, what is pleasant to some ears may be extremely unpleasant to others depending on a number of physiological factors. The sweetest music if it disturbs a person who is trying to concentrate or to sleep is a noise to him, just as the sound of hammer is noise to nearly every one. In other words any sound may be noise if it disturbs.

12.5. SOURCES OF NOISE POLLUTION

Sources of noise are many but they are broadly classified into two types.

i) Industrial and

ii) Non-Industrial

Noises from various industries operating in cities, like machinery, cotton mills, paper mills, flour mills, cement factory, transportation etc come under *Industrial Sources.*

Noise is a bi-product of energy conversion and many industries where big machines working are more responsible for noise pollution. These industries expose their workers to high noise for a long time in every day.

Non-industrial sources include loud speakers, auto-mobiles, trains, air crafts, construction work and radio, microphones etc. Now we will see how the non-industrial sources are responsible for noise pollution.

(a) **Loud Speakers :** Now-a-days loud speakers are used on many occasions continously for hours together. For every occasion whether it is a religious or non-religious, public or private, the use of loud speakers has become compulsory. These loud speakers make the worst kind of noise pollution around the residential areas and also create more disturbance to the students during examinations. Frequent use of loud speakers may have deafing effects on listners.

(b) **Traffic or Automobiles :** This is one of the most common sources of noise pollution. Particularly in the urban areas due to a large number of vehicles and their high speed, noise pollution becomes severe. Now-a-days it became a fashion to travel on motor cycles, scooters and autos without silencer pipes which produce undesirable noise. In most of the places no regulation is observed in blowing horns and use of defective silencer pipes.

The noise pollution generated by the continuous flow of vehicles affects the persons who are living adjacent to the roads. Though this traffic noise does not damage any physical part of the human being, it has other insidious effects as age-induced deafness. It also disturbs the sleep.

(c) **Trains :** In trains steam engines are used by railways in India. They produce lot of noise. This noise pollution is more where railway tracks are situated near residential areas.

(d) **Air crafts :** The noise pollution from air crafts is much serious, especially the areas which are close to the Airports. During take off and landing the noise is maximum and even unbearable some times.

(e) **Crowded markets :** The crowded markets have become a great source of noise pollution in metropolitan cities like Bombay, Calcutta, Delhi and Madras. The bargaining, chatting, use of loud speakers, sound from vehicle engines contribute a lot in increasing the noise levels in the market.

(f) **Domestic noise :** In India, especially in the urban areas no house is found without a single electronic device. Entertainment devices like TV, Radio, VCR, Telephone, musical instruments and fans, washing machines, mixer-cum-grinder, pressure cooker etc are the common sources of domestic noise. These entertainment devices cause deafness and other bodily changes in those who hear them with a very high volume.

(g) **Construction work :** Construction of roads, bridges, residential plots and commercial complexes are producing a lot of noise at the construction site when they are in operation.

(h) **Projection of Satellites into space :** This is a new source of noise pollution. Satellites are projected into space with the aid of high explosive rockets. Atomic and other explosions are used in these operations which increase noise pollution.

Some of the sound pressure levels for various sources of noise pollution are given in Table 12.1.

Table 12.1. Sound pressure levels for different sources of noise pollutions.

Sl. No.	Source	Sound Pressure level (dB)
*1.	Sirens and Loud speakers	150
*2.	Normal traffic	50-90
3.	Automobile	60-90
4.	Motor cycle	80-110
5.	Heavy truck	75-89
6.	Silencerless scooter	92
7.	Train	72-92
8.	Propeller driven air craft (at 30 mts)	110-120
9.	Jet take off	150
10.	Refrigerators	46-68
11.	Washing Machine	48-78
12.	Window A/C unit	60-73
13.	Vacuum cleaner	60-85
14.	Musical band party	84-93
15.	Broadcast studio	20
16.	Construction noise	110
17.	Large rocket engine	160-180
*18.	Space rocket at launching	170-180

(* Source : Pant, 1973 and Chauhan, 1977)

Check Your Progress - 1 & 2

1. Define Noise.

2. How are the sources of noise pollution classified ?

Note : (a) Write your answers in the space provided below.
(b) Compare your answers with those given at the end of this unit.

12.6. MEASUREMENT OF NOISE

As we know that sound consists of repeated alternative compressions and expansions of air, the apparent noise which is perceived by human ear depends on both frequency and intensity of the sound. The intensity of noise is measured in 'decibels' (dB) ('deci' means 10 and 'bel' is derived from the name of Scientist Alfred Graham Bell). Since loudness is measured in logorithmic scale, the formula for dB of sound is written as

$$\text{dB} = 10 \times \log_{10} \frac{I}{I_0}$$

Thus 'Decibel' is the ratio of sound intensity (I) and softest audible sound intensity (I_0). The softest audible sound that can be heard by human ear is called 'Zero decibel' and for testing purposes zero dB is considered to be the thereshold of hearing. In logorithmic scale dB increases by an additional 10dB. Hence 10,20,100 dB represents 10 times 20 times, 100 times that of the threshold intensity.

There is another scale dB (A) which is most commonly used scale for measurement of general noise levels. Here "A' denotes the weightage by giving more weight to high frequency. The sound intensity is measured by instrument known as Larn Barometer or Sonometer.

Besides dB, loudness or sound can also be expressed in terms of 'Sone' and 'Phone' which is a psycho-acoustic term. These two, always take into consideration both intensity and frequency.

Check Your Progress - 3 & 4

3. What is the measurement of noise ?

4. What is meant by zero decibel ?

Note : (a) Write your answers in the space provided below.
(b) Compare your answers with those given at the end of this unit.

12.7. EFFECTS OF NOISE POLLUTION

Noise is one of the main pollutants causing most hazardous consequences. Before going to discuss the effects of noise pollution on living and non-living, it is necessary to know clearly the extent of sound intensity that causes health hazards. We have already learned that the sound at 0 dB is the threshold of audibility. Noise, its intensity and effects are given in Table 12.2

Table 12.2. Various noises, their intensities and effects.

Sl. No.	Source	Decibel dB (A)	Effects observed
1.	--	0	Threshold of audibility
2.	Leaves breathing	10	Very quiet
3.	Whisper rustling	20	Very quiet
4.	Rural areas at night time	30	Quiet
5.	Library	40	Quiet
6.	Day time in living room	53	Quiet
7.	Restaurent	60	Intrusive
8.	Free way traffic vacuum cleaner	70	Annoying
9.	Crowded Bazar, garbage disposal, train (50 ft.)	80	Hearing damage
10.	Jet at 10000 ft News paper press Train whistle	100-110	Serious hearing damage (8 hours)
11.	Air Craft (at 100 ft)	120	Human pain thereshold
12.	Jet take off (200 ft), steel mills, Live rock muck, Air craft carrier deck	120-140	Ear drum rupture
13.	Jet take off (close range) sirens and loud horns	150-180	Ear drum rupture

(Source : Pollution and the Environmental Law, Satish Shastri)

The optimum levels prescribed by World Health Organisation are 45 dB in day time and 35 dB during the night time. The noise of about 80 dB is hazardous as it harms hearing facility.

Table - 12.3. Acceptable noise levels at different localities.

Area	Place	Acceptable noise level (dB)
Residential	- Bed room	25
	- Living room	40
Commercial	- Office	30-45
	- Conference Hall	40-45
	- Restaurents	40-60
Industrial	- Workshop	40-60
	- Laboratory	40-50
Educational	- Class room	30-40
	- Library	35-45
Hospital	- Wards	20-35

* Source : The times of India, August 24, 1986

12.7.1. Effects on Human beings

Noise pollution is responsible for various ill effects. The ill effects are given below.

Noise effects on Human beings

Noise hazards
- Permanent hearing loss
- Neural humoral stress response
- Destruction of articrafts

Noise Nuisance

Efficiency	Comfort	Enjoyment
Mental stress	Sleep interference	Concentration Interference
Frustration	Communication	Meditation Interference
Task interference	Invasion of Privacy	Recreational Interference
Irritability	Habit of talking loudly	Temporary hearing loss

Table - 12.4. Effects of high intensity noise on human beings

Noise (dB)	Effects observed
0	Thereshold of audibility
50	Significant change in pulse rate
110	Stimulation of Reception in skin
120	Pain Threshold
130-135	Nausea, vomiting, dizziness, interference with touch and muscle sense
140	Pain in ear, prolonged exposure causing insanity
140	Extreme limit of human noise tolerance
150	Prolonged exposure causing burning of the skin
160	Minor permanent damage if prolonged
190	Major permanent damage in a short time

(* Source : Encyclopaedia of Environmental Sciences; Vol.22)

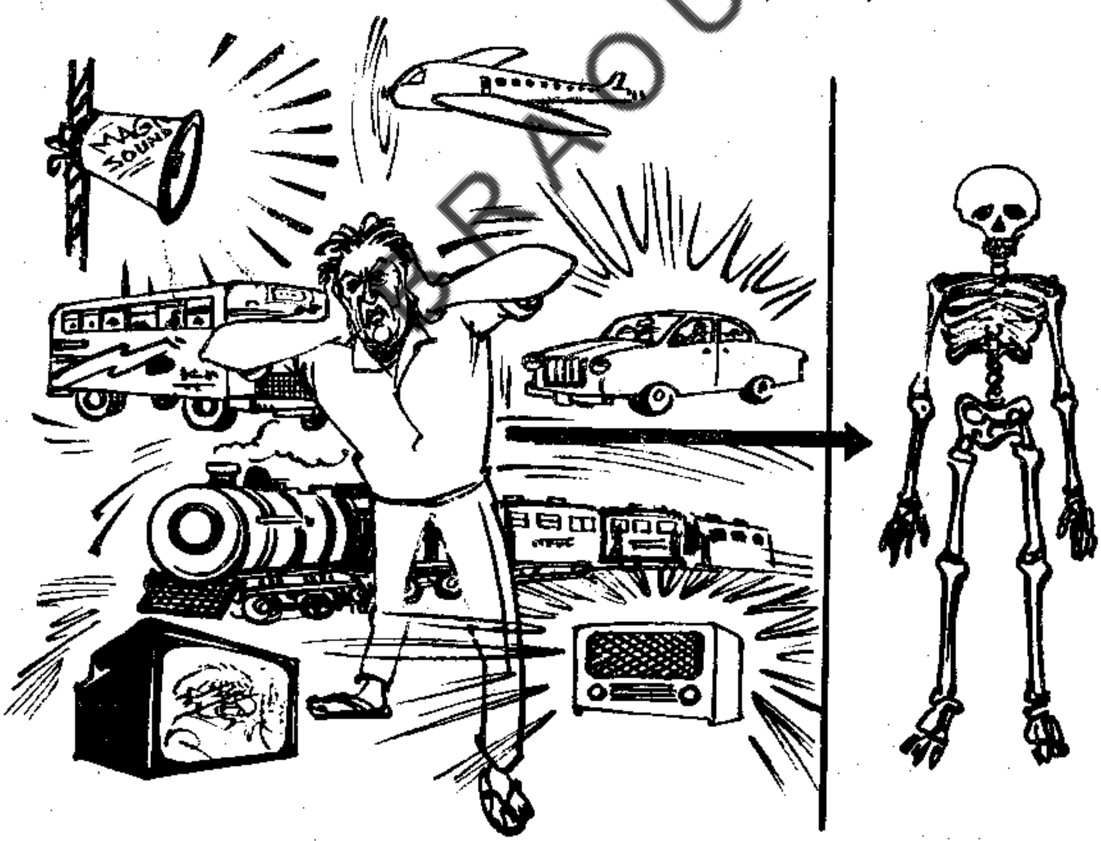

Fig.12.1. Effect of noise on Human beings.

Now we will discuss the effects of noise pollution on human beings, wild life and non-living things in detail separately.

Effect of noise pollution on human beings are of two types. They are :

(i) Auditory Effect and (ii) Non-Auditory Effect.

Auditory effects include (a) Auditory fatigue (b) Deafness.

(a) **Auditory fatigue :** Auditory or hearing fatigue appears in the range of 90 dB. It also associates with some other side effects like whisling and buzzing in the ears. It is greatest at 400 Hz.

(b) **Deafness :** This is a major hazard caused due to in exposure to noise that is too prolonged or too intense. Continuous or repeated noise may lead to gradual decline in hearing ability and the noise around 100 dB may result in permanent hearing loss. Exposure to noise above 160 dB may rupture the tympanic membrane and cause permanant loss of hearing.

Non-auditory effects are as follows :

(a) **Interference with Speech Communication :** The frequencies of Sound produced by road and air traffic in the range of 300-500 Hz cause disturbance to speech communication.

(b) **Sleep interference :** We know that noise reduces the quality of sleep. This affects the overall mental and physical health. Young people are not much affected by noise, but aged people often face this problem. Low frequency range of noise 50 to 60 dB (A) may affect certain parts of brain.

Therefore, the World Health Organisation Task Group on Environment Health Criteria for Noise has recommended sound level at 35 dB for sound sleep.

(c) **Deterioration of working efficiency :** A low level noise is always desired for mental efficiency and in some cases the work output is deteriorated due to high noise. Tiredness is also one of the consequences of noise pollution. If the noise level is below about 90 dB it affects the performance of either physical or mental tasks.

(d) **Physiological disorders :** Due to over-exposure to noise, a number of physiological disorders take place in a human body. Generally, they are anxiety in sweating, giddiness, nausea and fatigue. Direct exposure to noise also causes visual perception and reduces night vision. Prolonged exposure to noise is also responsible for changes in respiration, blood circulation in the skin and gastro-intestinal activity.

12.7.2. Effects on Wild Life

Due to noise there are adverse effects on wild life also. If there exist noise there is a decline in migratory birds to a habital. Because of traffic noise, the animals in the zoo particularly the deers, lions, rhinos were affected badly. They will not be active and alert. Their health also deteriorates.

12.7.3. Effects on Non-living Things

The high intensity of noise effects non-living things like buildings, walls etc. Due to this, plaster of building wall will be loosened giving cracks in walls. Some times the foundation of the building itself be shattered. The noise may also cause the depreciation of the value of residential property near airports and other noise prone areas. Also people who live in a noisy area may have the habit of shouting loudly.

Check Your Progress - 5

What are the optimum levels of noise prescribed by WHO ?

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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12.8. CONTROL OF NOISE POLLUTION

We have seen that Noise Pollution is responsible for serious and disastrous effects on living and non-living. As it is not possible to control noise pollution completely, it is therefore essential to take prevention and protective measures. However there are some ways to reduce noise pollution. The measures may be divided into two types. They are :

1. General Measures and 2. Legislative Measures.

General Measures to Control Noise Pollution

1. Loud speakers and amplifiers should be manufactured with in the limits of 80 dB of noise.
2. There should be a complete ban on the use of loud speakers from 10.00 p.m. to 5.00 a.m.
3. Industries, Rail tracks and high ways should be far away from the residential areas.
4. There should be a strict check on industries and mining operation while issuing and renewing of licence in order to control noise pollution.
5. Due to the machinery, much of the noise is produced. Therefore regular repairs of the machinery is necessary.
6. Reasonable distance should be maintained between the source and listner to reduce noise.

7. If noise is inevitable, then the workers should be provided ear defenders and ear plugs to protect from noise hazards when they are working in industry and factories.

8. Since plants are efficient absorbers of noise it is necessary to plant trees like banian, tamarind and neem along high ways in cities and towns.

9. Vehicles should use silencers, otherwise they should not be allowed to ply on the roads.

10. There should have some standard measures for all industries and factories to control noise.

Legislative Measures

In India laws are enacted to control water and air pollution.

(a) Water (Prevention and Control of Pollution) Act, 1974

(b) Air (Prevention and Control of Pollution) Act, 1981.

But there is no law which specifically deals with the problems of noise and its control. However there are some statues dealing with the control of noise pollution.

Indian Parliament has enacted the Environmental (Protection) Act, 1986 to control environmental pollution. But it does not have special reference to noise. Only section 6(2) (b) mentions the word noise and provides that the Government may make rules for allowable limits of environmental pollutants including noise.

Now we will discuss some of the Acts and their sections which relate noise pollution.

1. **Indian Penal Code :** Section 268 : "a person in guilty of Public nuisance who does any act or is guilty of an illegal omission which causes any common injury, danger or annoyance to the public or to the people in general who dwell or occupy property, cause injury, obstruction, danger or annoyance to persons who may have occasion to use any Public right".

   Section 290 : "Whoever commits a public nuisance in any case not otherwise punishable by this code shall be punished with fine which may extend to two hundred rupees".

2. **Section 133 Criminal Procedure Code :** "Under Section 133 Cr. P.C. the magistrates have been empowered to make conditional order requiring the person causing nuisance to remove such nuisance.

3. **The Motor Vehicle Act, 1939 :** The motor vehicles act, 1939 under sections 20, 21(J), 41, 68(i), 70, 90, 111-A empowers the State Government to frame rules for the upkeep of motor vehicles. But the rules made by the state government did not mention any control measure to control noise.

Bihar and Orissa Motor Vehicle Rules, the Delhi Motor Vehicles Act, 1940 and Rajasthan Motor Vehicles rules, 1951 provide certain protection from noise pollution.

4. **Noise Control Under Railway Act, 1890 :** We studied that trains in India use steam engines and therefore a huge amount of noise pollution is emitted by railway engines. But there is no provision of checking in the Railway Act, 1890, to curb this kind of noise pollution. Moreover the Indian Railways Act, 1890 has given statutory right for the use of locomotives to railway administration.

5. **The Air Crafts Act, 1934 :** Under this act, section 5 says that the central government has power to make rules for manufacture, possession, use, operation, sale, import or export of any air craft and this may cover the regulation of air transport services and the prohibition of the use of air craft. But in this Act also there is no provision to control noise pollution. But this Act suggests that the aerodromes should be constructed far away from the residential areas of a city in order to protect residents from noise created by frequent take off and landing.

6. **Noise Control Under Factories Act, 1948 :** Under this Act, section 11 has a direct provision for the control of noise pollution. Thus there is a statutory duty on the factories to provide adequate measures to control noise pollution.

Though there are some provisions of law in India, they are inadequate and vague. But many countries like USA and UK have specific legislations and evolved Scientific methods to control noise pollution. In England "Noise Abatement Act, 1960" and now "Control of Pollution Act, 1974 (Part III of the Act deals with noise Pollution and the Act replaces the Noise Abatement Act, 1960) takes care of noise pollution there. Therefore, there is an urgent need that the central government should pass legislations for the control of noise pollution in India also without any delay.

12.9. SUMMARY

The excess of anything that is solids, liquids, gases and noise, present in the atmosphere which are injurious to the living and non-living things are known as environmental pollutants. Noise pollution refers to the unwanted sound dumped into the environment or atmosphere leading to health hazards.

There are mainly two types of sources of noise pollution. They are (i) Industrial and (ii) Non-industrial. The optimum levels prescribed by World Health Organisation are 45 dB in daytime and 35 dB during the night time.

There are many ill effects on living and non-living by noise pollution. The effects of noise pollution on human beings are of two types (i) Auditory Effect (ii)

Non-Auditory Effect. Since noise pollution is responsible for various disastrous effects on living and non-living there is an urgent need to take prevention and protective measures.

12.10. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Noise is defined as unwanted sound.
2. Sources of noise pollution are broadly classified into two types. They are Industrial and Non-industrial. Industrial sources include machinery, cotton mills, paper mills, flour mills, cement factories, transportation etc where as Non-industrial sources include loud speakers, traffic, trains, aircrafts, crowded markets, domestic noise, construction work, projection of satellites into space etc.
3. The intensity of noise is measured in 'decibels'.
4. The softest audible sound that can be heard by human ear is called zero decibel' and it is considered to be the threshold of hearing for testing purpose.
5. The optimum levels prescribed by World Health Organisation are 45 dB in day time and 35 dB during the night time.

12.11. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Define noise pollution. Explain the sources of noise pollution.
2. Discuss the effects of noise pollution on living and non-living things.

II. Answer the following questions in about 10 lines each.

1. How do you measure the noise ?
2. Write notes on the effect of noise pollution on human beings.
3. What are the general measures to control noise pollution ?

Ms. Pushpavathy

UNIT - 13 : RADIOACTIVE POLLUTION IN ENVIRONMENT

Contents

13.1. OBJECTIVES

After going through this unit you will be able to :

- explain the sourcess of Radioactive pollution and their impact on environment
- discuss the health & safety management and control,
- describe the instruments used for monitoring of Radio active pollutants.

13.2. INTRODUCTION

Some naturally occurring minerals are found to be radioactive. The nuclei of these elements emit ionizing radiations identified as Alpha, Beta and Gamma radiations through decay processes. Another important source of production of radioactivity is through the interaction of cosmic rays with matter produce tritium and radiocarbon. The disintegration rate is taken as the unit of radiation. It is first named after Curie. The X-rays also cause radiation hazards even though they are extensively employed for diagnosis and therapy of several diseases.

The discovery of nuclear fission brought radioactivity into man's environment in abundant quantities. Reactors are built where atom is split, and the radiation and energy released are used for peaceful purposes. Excess radiation emitted is also used for the production of radioisotopes, which are very essential for diagnostic and radiotherapeutic purposes.

Large reactors are built for atomic research and power generation. The radioactive wastes from these reactors are highly hazardous to be released into the environment without properly treating them. The liquid wastes are classified as "Low, Moderate and Highly Hazardous," depending upon the concentration and type of radionuclides present. The processing also showed the production of highly toxic alpha emitting transuranic radionuclides of Plutonium, Americium and Curium in solutions.

The low level wastes discharged into water sources are traced from the movement of radionuclides. They are found in : Algae, Phytoplankton, sea-food, Shellfish, Oysters etc. The wastes also increase the Biological Oxygen Demand (BOD). The amount of food eaten by an individual and the amount of trace element, present can be used to determine the permissible levels of discharge.

13.3. SOURCES OF RADIOACTIVE POLLUTION AND IMPACT ON ENVIRONMENT

Becquerel found that some minerals, containing Uranium emitted radiation. Madame Curie examined several minerals and found radiation emitting substances which are later identified as Radium, Polonium and other products of the now famous radioactive decay series. The phenomenon of radioactive emission was identified to be connected with the instability of nuclei of heavy elements. The presence of radioactive substances in any media can be detected from the emission of ionizing radiation using monitoring devices like Geiger-Muller Counters, Ionization Chambers, Scintillation Counters etc.

Decay of radioactive elements yields a chain of radioactive daughter products chemically dissimilar from the parent. Radon a gaseous emission of radium gets into waters or is released during mining of uranium which on decay yields long lived Polonium and radio lead. These are just a few examples. Natural potassium has in it a radioactive isotope ^{40}K. As cosmic rays enter into the upper atmosphere, they produce by interaction with air radionuclides like ^{14}C, ^{3}H etc.

Man made radioelements are essentially produced through three processes.

(i) Radioisotopes production through reactor irradiation, and in particle accelerators.

(ii) Irradiated fuel reprocessing and

(iii) Nuclear weapons tests.

These processes produce ^{22}Na, ^{35}S, ^{58}Co, ^{7}Be, ^{55}Fe, ^{32}P, ^{45}Ca etc. Generation of fission products and activation of structural material, release a host of different radioelements. Some important examples are : ^{90}Sr, ^{137}Cs, ^{106}Ru, ^{144}Ce-Pr, ^{95}Zr, ^{54}Mn, ^{65}Zn, ^{55}Fe, etc. These radioactive pollutants come into the environment through waste streams and stack gases from Reactors.

These radioactive pollutants come into the environment through waste streams and stack gases from reactors, power generating and processing plants. Irradiation neutron bombardment of atomic fuel produces elements like Pu, Np, Am, Em which are highly radio toxic.

The hazards caused by them are classified into two categories

(i) Internal Exposure Hazards : The Alpha & Beta emitters are important in this category. The radioactive pollutants once they find access into the environment, enter the ecocyclic process into the food chains and interfere with the metabolic systems. For example the ^{65}Zn produced in reactors can be metabolized in oysters and on eating the meat man accumulates it in the liver, Gastro-Intestinal-Tract and Genital Organs.

(ii) External Exposure Hazards : The Beta & Gamma emitters are important in this category. This can be air-borne, carried in drinking water and aquatic products (sea water, sea foods).

For example the external exposure is likely when sediments take-up radionuclides of Cesium, Zirconium, Iodine, Cobalt etc. and deposit them on the beach sands. People walking and sitting on the beaches totally un-aware of the radioactive contamination are exposed to this external exposure.

The need for understanding radioactive pollution and monitoring of exposure levels arises because of the associated hazards. Some of the aspects of environmental control through management are specific to Indian conditions and they are highlighted in the latter sections of this chapter.

13.4. RADIATION UNITS, SOURCES AND CLASSIFICATION OF POLLUTANTS

(i) Units

The unit of measurement of radioactivity is a curie which is equivalent to 3.7×10^{10} disintegrations per second (dps), which is equal to the decay of 1 g of radium. Smaller units like milli, micro, nano, pico, curie are used for practical purposes.

(ii) Sources and Classification of wastes based on their strength

Liquid wastes produced in the nuclear industry are classified according to their activity levels as :

a. **Low level active :** These are large volume low active liquid wastes with activities less than "microcurie per litre" in solution. These are produced in laboratory operations.

b. **Intermediate level active :** The activity of these wastes is of the order of "few Millicurie/litre". These are generally evaporated. The condensates are directed to the low level waste tank for treatment. The concentrated residue is taken up for ultimate storage.

c. **High level active :** The activity of these wastes is "few Curie/litre". The primary fission product raffinates obtained from reprocessing of irradiated fuel are carefully stored.

(iii) Based on their Chemical Nature

a. **Ore Processing Operations :** Mining of radioactive ores of uranium like pitchblend and uranites release large volumes of mine waters. During milling for recovery of Uranium, several process effluents are released. They are slurried with other residues and taken to a tailing pond from which the effluents drain away to join the public sewage waters. Besides radioactive contaminants, chemical contaminants like Mn, Cr, SO_4 and NO_3 are also present in the effluents. Treatment of monazite also produces chemically toxic effluents.

b. **Wastes from Power Reactors, Processing Plants and Laboratories**

Information on liquid wastes from Pressurised Water Reactors (PWR), Boiling Water Reactors (BWR) and Heavy Water Reactors is presented in Table - 13.1.

Table - 13.1. Tritium released from Operating Power Reactors

Type of Reactor	Power Generation MW	Estimated Annual Discharge (Curies)	Rate of Discharge Curie/uW-Year
BWR[1]-Zirac alloy clad	200	5-10	0.037-0.074
PWR[2]-SS[3] clad	480	1755	5.1
D_2 O-Zirac alloy	200	15000	

1. Boiling Water Reactor, 2. Pressurised Water Reactor, 3. Stainless Steel

13.5. DISCHARGE OF RADIONUCLIDES

The engineering safeguards for designing systems for discharge of radio active wastes are based on the objective of realisation of maximum dilution and dispersion in a medium. When large dilution factors are required, pipe-lines are laid to reach the off-shore waters, terminating at a depth with efficient diffusers. Permissible discharge depends on dilution and dispersion capability of the receiving medium.

As the process effluents meet sea water, various chemical and biological interactions take place. Deep sea water is a stable matrix with pH 8.2 and has a steady distribution of its chemical constituents. The composition of coastal waters are influenced by dissolved inorganic species containing the multivalent elements. They hydrolyse in the stream and form suspension of radiocolloids.

They may be absorbed on filamentous algae, deposit on Sediments and are reconverted into organic complexes and enter the ecosystem. Filter feeders, intertidal organisms, bacteria, phytoplankton and their predators concentrate them in the food chain and reach man in a concentrated form in sea foods. Specific Concentrating organisms can be chosen as indicators of a particular type of radioactive pollution. The study of concentration factor in indicator flora and fauna and routine monitoring in the area of discharge helps to control radiation exposure to man from ingestion of contaminated sea foods.

If radioactivity reaches man in sea food at a Specific Activity less than the permissible specific activity, over-exposure is unlikely from ingesting such food. The acceptable specific activity (uCi/g) is defined as

$$\text{uCi/g} = \frac{\text{Maximum Permissible Body Burden (MPBB) uCi (MPBB)}}{\text{Mass of Stable element in the body (W) g}} \qquad \ldots (1)$$

The concentration factor in an organism living in the aquatic medium is defined as a ratio equal to

$$\text{CF} = \frac{\text{ug or uCi in 1 g of tissue}}{\text{ug or uCi in 1 g of water}} \qquad \ldots (2)$$

If the concentration of an element is expressed in relation to another like ^{90} Sr/Ca, or ^{137} Cs/K in the tissue and water, the ratio of the two is called 'Discrimination Factor or the observed Ratio (DF or OR).

$$\text{DF or OR} = \frac{^{90}\text{Sr pCi/Ca g tissue}}{^{90}\text{Sr pCi/Ca g water}} \qquad \ldots (3)$$

13.6. HEALTH AND SAFETY MANAGEMENT AND CONTROL

The hazards associated with discharge of wastes into coastal waters arise because of consumption of sea food and walking on the beaches along the coastline. It is important to ensure that no hazards arise out of these operations to the general public or to populations of neighbouring countries and far off fishing activities.

(i) Standards for maximum permissible exposure for occupational personnel and general public are laid down by the International Commission on Radiological Protection (ICRP).

(ii) ICRP also has given in the Report of Committee II the maximum permissible concentration values for different radionuclides in air and water.

Salt borne sprays have been observed along the shore over long distances. If sea surf and water contain radionuclides they get air borne and contaminate homes of beach dwellers, fishermen, swimmers, picnickers, anglers and casual users of the sea.

Well organised and routine monitoring of discharge of radionuclides measurement of environmental levels in sea food and beach sands ensures that public will not be over exposed by any chance.

13.7. LIQUID EFFLUENTS FROM LARGE NUCLEAR POWER PLANTS

Before the first Indian Station at Tarapur was commissioned in 1969-70 operating experience with BWRs was limited to Dresden, USA and one or two stations in Europe. Pollution from activation products like ^{60}Co, ^{63}Ni, ^{55}Fe etc. was not so well recognised. Except the information on volumes of liquid effluents produced and types fell short of installed facilities under prevailing conditions.

(i) Measurements - Statistics, Procedures, Sequential Analyses

In India we have established independent laboratories to ensure strict surveillance (monitoring) by standard techniques to avoid hazards. These studies are carried out at Trombay, Tarapur, Hyderabad, Rajasthan, Kalpakkam and Jadugoda. This is a unique environmental monitoring network in the whole world.

Radioactivity measurements can be made with the available instruments. The instruments should be housed in cool and low humidity room free from dust and corrosive fumes. Beta, gamma counters require shielding from external radiation with lead or stainless steel.

(ii) Permissible limits

The ICRP and WHO have recommended maximum permissible limits for concentration (MPC_w) of the activity in drinking water and (MPC_a) for air and for unidentified radionuclides also in water used by general population.

	ICRP Specification	WHO Specification
Gross alpha activity	3 pCi/litre	10 pCi/litre
Gross beta activity	10 pCi/litre	10 pCi/litre
Unidentified radio nuclide activity in water used by general public	10 pCi/litre	10 pCi/litre

Check Your Progress : 1 & 2

1. Name three processes through which man made radioelements are produced.

2. What is the unit of radioactivity ? Write its value.

Note : (a) Write your answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

13.8. INSTRUMENTATION FOR MONITORING OF RADIOACTIVE POLLUTANTS

(i) Geiger Muller Tube

The Geiger Muller Tube (GMT) is frequently used for detection and measurement of Alpha, Beta and Gamma rays. This tube is a diode, consisting of a cathode which is a long metal cylinder and an anode which is a fine wire running through the centre of the cylinder. Both of them are mounted in an air tight, glass envelope, sealed by an extremely thin Aluminum Window through which radiations can enter. The air is evacuated from the envelope and a small amount of an inert gas, such as Argon at low pressure is filled. The schematic representation of the GM tube and the associated biasing circuit are presented in Fig. 13.1.

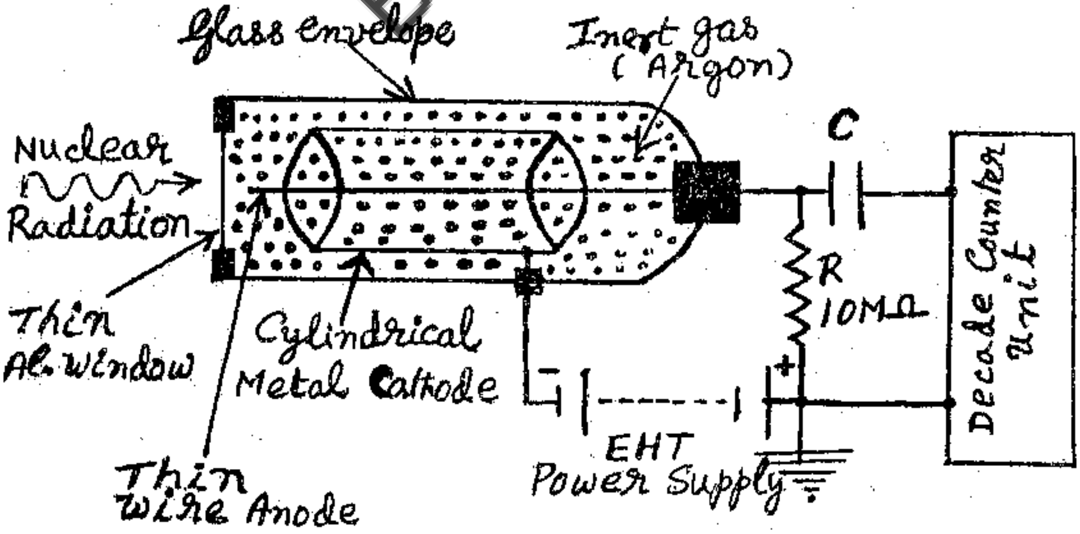

Fig.13.1. Geiger-Muller Counter

The extra high tension (EHT) Voltage is kept below the ionization potential of the gas. Any radiation penetrating through the window and enters the envelope it would ionize some of the gas atoms. The resulting negative ions go towards the anode and positive ions towards the cathode. In their passage, the ions are accelerated by the high electrostatic field produced by the EHT, collide with some of the neutral gas atoms and ionizing them in turn. This process continues till all the gas atoms are ionised. Complete ionization takes place in a very short time. A pulse of current thus flows through the tube and the high resistance R, which is connected in the anode circuit. The resulting voltage drop across R is the output voltage.

Once ionization is established, it is expected to continue indefinitely. However, the voltage drop across R is sufficiently large to reduce the anode voltage below the ionization potential and therefore ionization ceases. As long as the gas is not ionized no current flows through the resistance R and hence there is no output.

Now if radiation again enters the tube, the ionization starts and a pulse of current again flows through resistance R giving an output voltage. Thus a series of alpha or beta particles or bursts of gamma rays, produce a series of current pulses to pass through the anode circuit of the tube and hence through resistance R. The output pulses from resistance R are amplified and registered by a counting device. By counting the number of pulses one can know the number of particles entering the GM tube in a particular interval of time. The number gives the intensity of radiations. The pulses may be stored. The total count may be calibrated directly in terms of radio-activity.

The counting rate of this tube is seldom greater than 10^3 counts per second. Hence, it is not useful for high count rates.

(ii) Ionization Chamber

This is quite similar to the Geiger Muller tube. The Ionization Chamber is a metal cylinder (the outer electrode, cathode). It is permanently closed at one end through which a metal rod (the central electrode, anode) protrudes. The other end of the cylinder is sealed with thin aluminum window. The central electrode is grounded though a high resistance R. A large positive potential is applied to the central electrode, anode. The chamber is filled with a gas which may be Air, Carbon Dioxide, Nitrogen, Argon or Methane at low pressure. The schematic representation of the Ionization chamber and the associated biasing circuits are presented in Fig.13.2.

The action of this ionization chamber is identical to that of a Geiger Muller tube.

When a nuclear radiation enters the chamber through the window, some of the atoms of the gas are ionized, the resulting electrons and ions travel towards the central electrode and the positive ions towards the outer electrode. The ions accelerated by the High electrostatic field produced by the EHT supply collide with other neutral atoms of the gas causing ionization of these atoms. The action is instantaneous.

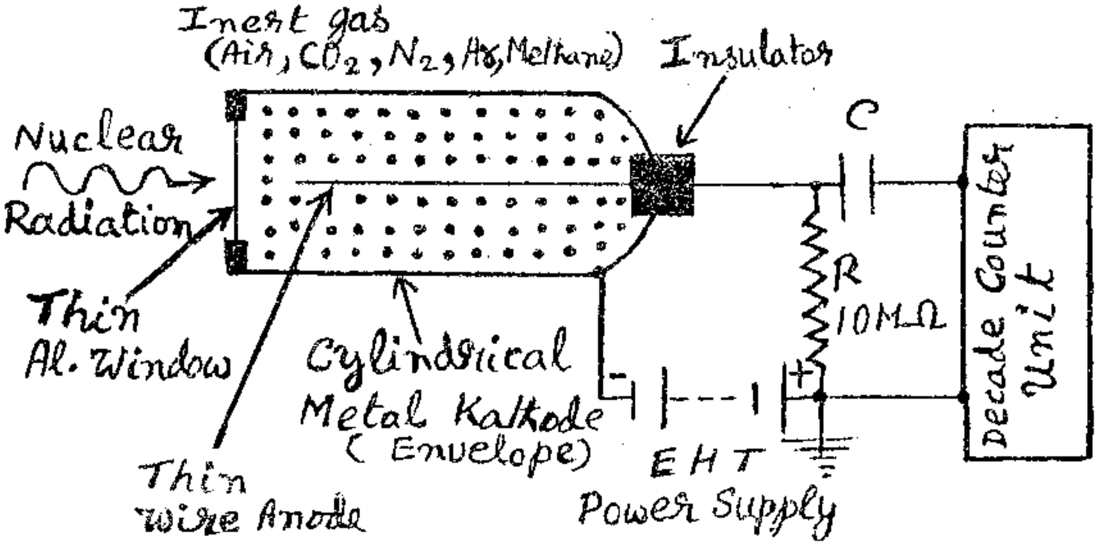

Fig.13.2. Ionization Chamber.

As a large pulse of current flows through the chamber and a high voltage drop is produced across R. This increased potential, which is the output signal of the chamber, is amplified and measured. Since the increase in the potential is a function of the number of radiation particles that have entered the chamber, the intensity of the nuclear radiations can be estimated. The main use of this chamber is to detect and measure alpha particles.

(iii) Scintillation Counter

Certain crystals such as Zinc Sulphide, Sodium Iodide, Anthracene and Napthalene etc., produce a tiny flash of light each time they are struck by an Alpha or Beta or Gamma particles. Production of a flash of light by striking the crystals with alpha or beta or gamma rays is called Scintillation. This principle is employed in the design of a nuclear radiation sensor called "Scintillation Counter".

The construction of a Scintillation counter is shown in Fig.13.3. Since the intensity of the tiny flash of light is very low, it has to be amplified. Hence, the scintillation chamber is directly mounted on the window of a Photo Multiplier Tube (PMT) which provides an amplification of $> 10^6$. Hence, this instrument is capable of detecting very weak radiations also. Every time a radiation strikes the scintillation crystals, a tiny flash of light is produced. Thus each particle produces a pulse of anode current at the output of the photomultiplier. The output of the photomultiplier is applied to a high speed electronic counter which counts each tiny flash generated by the Scintillation crystals. Thus by counting the number of pulses in a given period of time, the intensity of radiation may be estimated.

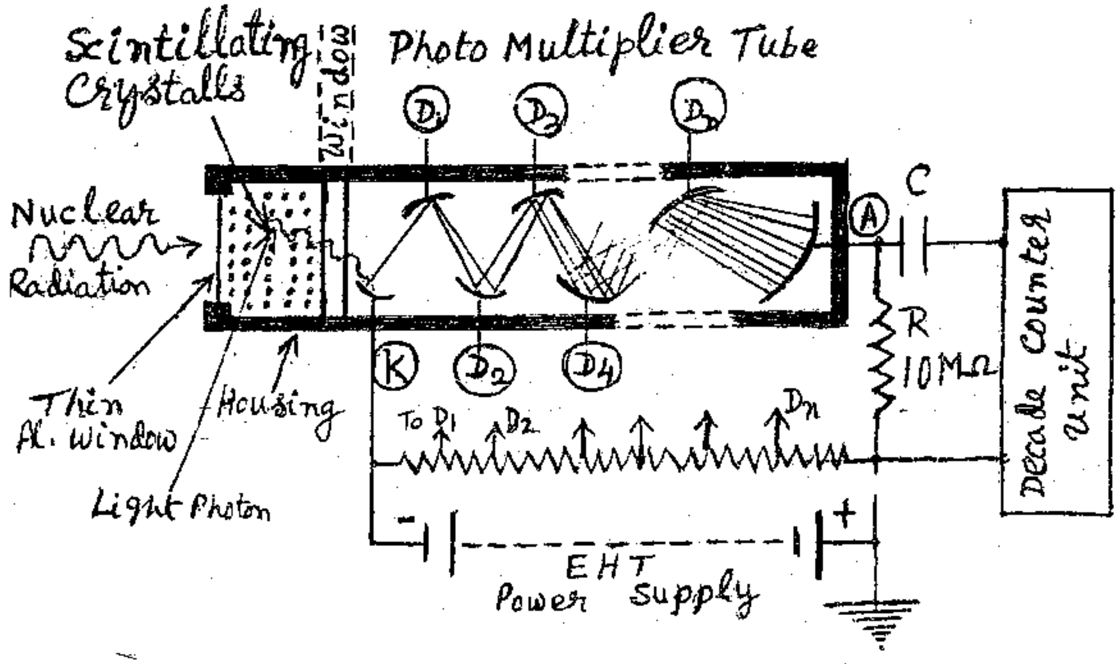

Fig.13.3. Scintillation Counter.

The advantages of a scintillation counter are :

(i) This is more sensitive than the Geiger Muller tube or the Ionization chamber and hence can detect lower energy radiations.

(ii) The crystals used in this device also produce a flash of light when struck by X-rays. Hence this transducer may be used to detect X-rays as well.

(iii) Since pulses of as short a duration as 2 nanoseconds may easily be recorded, the counting rate is at least 10^3 times faster than the other two instruments.

(iv) Operation of GM and Other Instruments

Switch the instrument ON as per working instructions. Place the reference source in the nuclear instrument. Determine the plateau region of voltage for most reliable counting. Determine background count of the instrument at each step. Note that the count rate rises first, becomes steady and rises again. The response characteristic is presented in Fig.13.4(a). The steady portion of the curve is the plateau region. To find the optimum voltage on the plateau a second curve is drawn with S^2/B against V, where S is the reference source count, B the background count and V the voltage value of each step. This curve is presented in Fig.13.4(b). The optimum voltage for counting is the plateau region that corresponds to the near maximum value of S^2/B.

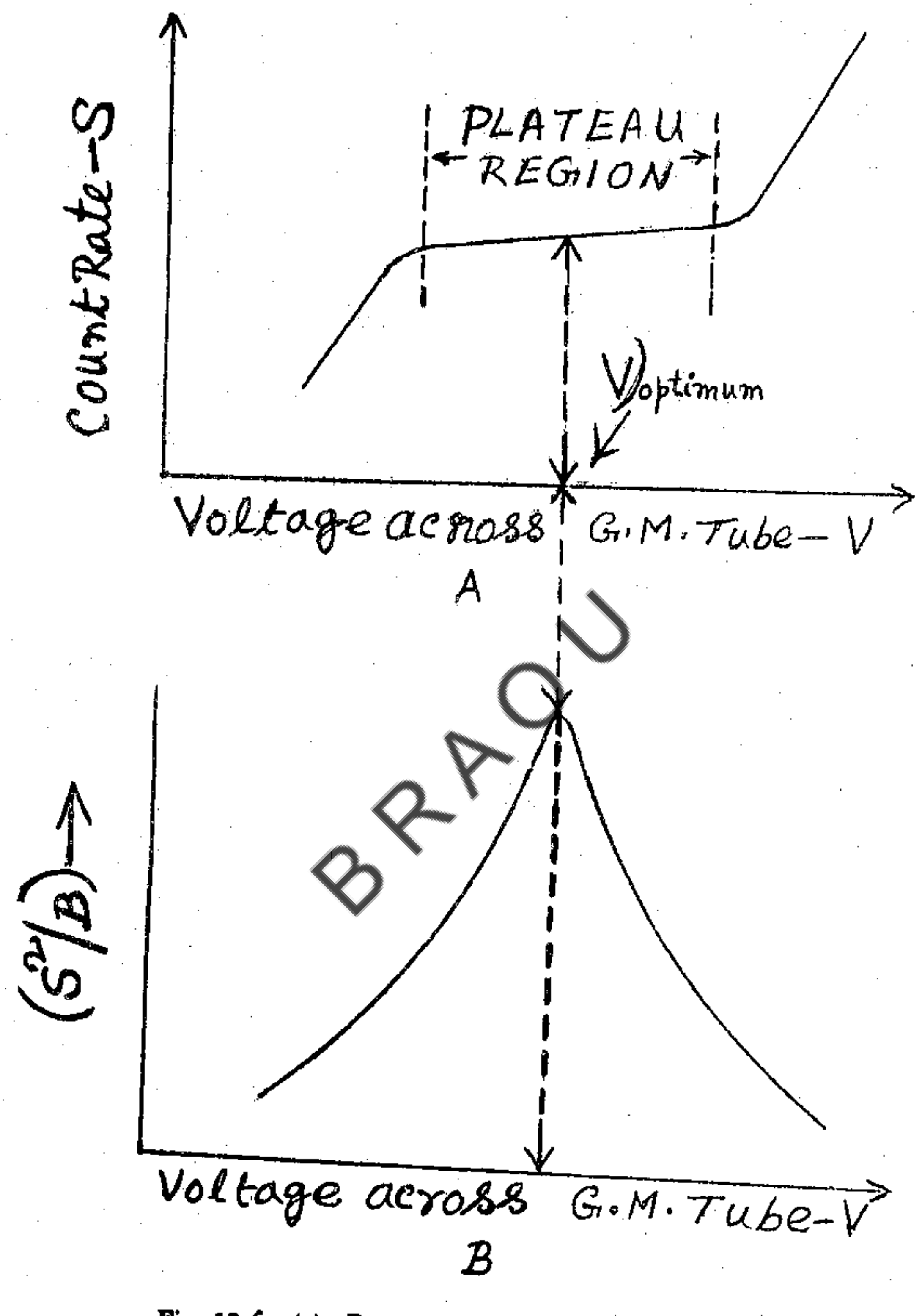

Fig. 13.4. (a) Response Characteristic of the G.M.Tube. (b) Signal to Back-ground relative Response.

(v) Alpha Radioactivity Measurement & Equipment

The basic requirement of containers recommended for water quality examination are adequate for gross activity determination.

Evaporate the sample to near dryness by mild heating and dry completely by evaporation under Infra Red Lamp. Determine alpha activity. The evaporation method recommended in this procedure is applicable to most "Alpha Emitters" and has sensitivity to detect as low as one pCi/litre above background of a water sample.

The detector for counting alpha particles may consist of a windowless proportional counter or a Silver activated ZnS Scintillation Counter with associated electronic circuitry, photomultipliers, high voltage unit, amplifier and scaler. Other requirements are an infra red lamp and some common laboratory chemicals.

(vi) Beta Radioactivity Measurement & Equipment

A large volume of water sample should be taken for evaporation than the volume taken for alpha determination since 100 mg of total residue spread over a 5 sq.cm area is required. The beta activity can be determined by a GM Counter or a Proportional Counter. The method is suitable for measuring beta rays with energies greater than 300 KeV and for a minimum concentration of 15 pCi per litre. For reliable measurements the variables should be kept constant for test samples and standards during counting.

Beta radiation counters are also sensitive to alpha and gamma radiations. The alpha interference is eliminated by cutting off with suitable aborbers; this also reduces gamma detection.

Liquid scintillation counters are intended to determine low energy beta emitters like ^{3}H, ^{14}C etc., and are not suitable for use in the evaporation method.

External shielding is required to reduce background count. Shield outfit with 5 cm thick lead bricks lined with 3 mm thick aluminum sheet and fitted with drawer assembly are used for this purpose.

Check Your Progress - 3

What are the instruments used for monitoring Radio active pollutants ?

Note : (a) Write your answer in the space provided below .
(b) Compare your answer with the one given at the end of this unit.

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13.9. CONCLUSION

It should be the responsibility of the Atomic Energy Agency to investigate the impact of radioactive pollution on the environment which should cover Aquatic, Land and Atmospheric sectors. In pursuance of this policy the Government of India has established Environmental Survey Laboratories and Micro Meteorological Laboratories at all the major nuclear installations at Jaduguda, Alwaye, Hyderabad etc.

With the advancement of nuclear techniques such as Activation analysis, X-ray fluorescence, spectrography and chromatography it is possible to detect these radioactive toxics at extremely low concentration levels and the emphasis is laid on achieving the objective of "Total Containment (elimination) or Zero Discharge" of radioactive toxics into the environment.

13.10. SUMMARY

The discovery of nuclear fission brought radioactivity into man's environment in abundant quantities. The phenomenon of radio active emission was identified to be connected with the instability of nuclei of heavy elements. Man made radio elements are essentially produced through three processes.

(i) Radioisotopes production through (i) reactor irradiation and in particle accelerators (ii) irradiated fuel reprocessing and (iii) nuclear weapons test. The hazards caused by radio active pollutants are classified as (i) Internal exposure Hazards (ii) External Exposure Hazards. The measurement of radioactivity is a curie. This is equivalent to 3.7×10^{10} disintegrations per second which is equal to the decay of 1 g of radium. Wastes are classified based on their strength and chemical nature.

The acceptable specific activity (uCi/g) is defined as

$$\text{uCi/g} = \frac{\text{Maximum Permissible Body Burden (MPBB) uCi (MPBB)}}{\text{Mass of stable element in the body (W) g}}$$

Radioactivity measurements can be made with the available instruments. The instruments should be housed in cool and low humidity room free from dust and corrosive fumes. Beta and gamma counters require shielding from external radiation with lead or stainless steel. (i) Geiger Muller Tube (ii) Ionization chamber (iii) Scintillation counters, are main instruments for monitoring of Radioactive pollutants.

13.11. CHECK YOUR PROGRESS : MODEL ANSWERS

1. (i) Radio isotopes production through reactor irradiation, and in particle accelerators. (ii) Irradiated fuel reprocessing and (iii) Nuclear weapons tests.

2. The unit of measurement of radio activity is curie. It is equivalent to 3.7 x 10^{10} disintegrations per seconds (dps.) which is equal to the decay of 1 g of radium.

3. (i) Geiger Muller Tube (ii) Ionization chamber (iii) Scintillation Counters.

13.12. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 20 lines each.

1. What are the sources of Radio active pollution ? Discuss their impact on Environment.

2. Explain the process of monitoring of Radio active pollutants with diagrams.

II. Answer the following questions in about 10 lines each.

1. How do you classify the pollutants ? Explain briefly.

2. Write a note on Beta Radio activity measurement & equipment.

Prof. S. Raja Ratnam.

BLOCK - 5
POLLUTION MONITORING

UNIT - 14 : REMOTE SENSING AND ENVIRONMENTAL POLLUTION

Contents

14.1. OBJECTIVES

After completing this unit, you will be able to :

- define the signatures of objects and resolutions
- describe the atmospheric windows and
- explain the applications of remote sensing in different fields.

14.2. INTRODUCTION

Remarkable developments in Space Technology and its applications during the last three decades have established its immense potential for human development. The very first application being Global Communications through Satellites even to remotest and in accessible areas. Mobile platforms (Orbiting Satellites) designed for keeping a close surveillance (observation) on our weather and for monitoring and management of our precious natural resources have contributed significantly to the development of the country. These satellites are known as Remote Sensing Satellites.

Remote sensing is a Multi-disciplinary science of acquiring information of an object through measurements made from a distance without the sensor actually coming into contact with it. The observations are carried out making use of the Reflected/Scattered/Self-emitted electromagnetic energy from the objects on earth in different wavelength-bands.

14.3. SIGNATURES OF OBJECTS AND RESOLUTIONS

Any set of observable characteristic features specific to that object such as Reflectance/Emittance which directly or indirectly lead to the identification of that object and/or its condition is termed as the signature of that object. Under different spectral, spatial, temporal, radiometric and polarisation conditions these signatures form the basis for the data interpretation.

i. Spatial Resolution

It is a measure of the size of an object of the smallest dimensions or a smallest area on earth's surface over which an independent measurement can be made by a system on board a satellite.

ii. Spectral Resolution

The spectral resolution of the remote sensor characterizes the ability of the sensor to resolve the energy reflected/emitted from an object in a given spectral bandwidth to characterize different constituents of the earth's surface.

iii. Radiometric Resolution

The ability of the sensor to distinguish tne finer variations in the reflected/ emitted radiation from different objects is characterized as Radiometric resolution

iv. Temporal Resolution

Sun-synchronous-that the Polar Satellite crosses over the equator at the same local solar time in each orbit. The space craft can be made to cover the same area on earth at regular intervals of time which is defined as the Temporal Resolution.

v. Polarization

The electromagnetic radiation undergoes changes in the plane of Polarization when reflected from objects at angles close to Brewster angle. The ability of the sensor to detect the finer variations in the polarization characteristics is known as polarization resolution of the sensor.

The ability of Remote Sensing Technology for obtaining- systematic,, synoptic, rapid and repetitive coverage of vast areas on the globe in different spectral windows (wavelength bands) of the electromagnetic spectrum from a vantage (position giving a good view) point in space is the fundamental character which makes this Remote sensing technology unique and a very powerful tool for communications, weather monitoring and natural resources management.

The spectral resolution obtained with this Remote sensing technology is about 20-30 meters. Multi-spectral imagery from satellite Remote sensing with a repetitive cycle of about 18-22 days over the same areas of interest has virtually revolutionized the resource monitoring and management system.

With adequate support of the ground data and aerial photography, the space Remote sensing has established itself as a potential tool to provide vital inputs for moitoring of our precious natural resources, such as Agriculture, Forestry, Water-resources, Soil- classification, Mineral-exploration, Wasteland-delineation, Occean resources monitoring, Drought management etc. Microwave Remote sensing has the special ability to critically look at ocean resources due to its un-impaired penetrating power through cloud cover and provide data under all weather conditions.

Rapid developments in Computer Science for data handling capability combined with advances in sensor technology have resulted in the realisation of progressively increasing on-board resolution of equipment on Remote Sensing Satellites. These developments could reduce the turn around time for data handling which is crucial for dealing with disaster forecast and disaster management situations.

Aerial survey using multi-data sensors and instruments such as Infra-red scanners, multi-spectral scanners and radiometers for monitoring the health and yield of crops has become a common practice now a days.

Establishment of Landsat receiving station at National Remote Sensing Agencies (NRSA), Hyderabad in 1979 was an important step taken by ISRO. Further, ISRO conceived and produced dedicated Remote Sensing Satellite series which could provide uninterrupted and assured operational services.

Check Your Progress - 1

What is meant by polarisation resolution?

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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14.4. ATMOSPHERIC WINDOWS FOR REMOTE SENSING

The most important constituents of the atmosphere viz. the water vapour (H_2O), oxygen (O_2), Ozone (O_3), carbon dioxide (CO_2), etc. absorb electromagnetic energy at characteristic wavelengths. Hence only certain window's (bands in the electromagnetic spectrum) are available for Remote sensing with very little attenuation. The absorption spectrum of earth's atmosphere is presented in Fig. 14.1. and the details of the atmospheric windows are presented in Table - 14.1. Wavelengths less than 0.3 μm are completely absorbed by Ozone layer in the upper atmosphere.

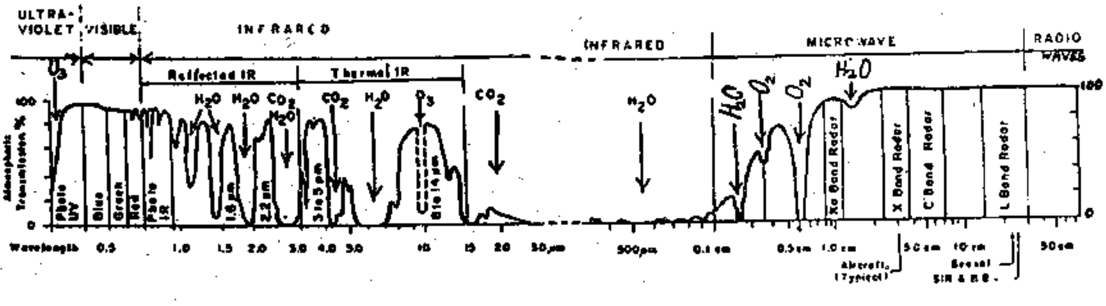

Fig. 14.1. Generalised absorption spectrum of earth's atmosphere.

Table - 14.1. Spectral Windows in the Earth's Atmosphere.

Spectral Region	Wavelength Range
UV	0.30 μm
UV and Visible	0.30 - 0.75 μm
Near IR	0.77 - 0.90 μm
	1.00 - 1.12 μm
	1.19 - 1.34 μm
Mid IR	1.55 - 1.75 μm
	2.05 - 2.44 μm
Thermal IR	3.50 - 4.16 μm
	4.50 - 5.00 μm
	8.00 - 9.20 μm
	10.20 - 12.40 μm
	17.00 - 22.00 μm
Microwave (MW)	2.06 - 2.22 mm
	3.00 - 3.75 μm
	7.50 - 11.50 mm
	20.00 mm and above

14.5. APPLICATION OF REMOTE SENSING IN DIFFERENT FIELDS

Application of remote Sensing Technique in different fields and the corresponding wavelength regions employed are presented in Table - 14.2.

A detailed description of these applications is presented in this section.

i. Agriculture

The Remote sensing is being operationally used to predict acreage of different crops and their yield estimates (of wheat, rice, sorghum, oil seeds, cotton, mulberry etc.). Information on the production of major crops will greatly assist in "formulating policy decisions" like the level of buffer stock, quantum of imports, fixing of support prices etc. Timely detection of pests, and diseases as well as for assessing crop stress conditions are also possible with Remote Sensing Technology.

ii. Drought Management

Remote sensing satellites provide data on advance information at village/district level on the extent and severity of agricultural drought conditions. Such bulletins are proved to be extremely useful for planners in drought management. Integrated land and water resource management enables us to combat drought on long and short term basis. This programme also provides long term solutions for conservation of soil and water resources towards mitigating drought.

iii. Forest Cover Mapping and Forest Management

Satellite Remote sensing plays an important role in the survey and monitoring of forests. Forest Survey of India, is now carrying out biennial forest mapping for the entire country using Satellite Remote sensing data. New techniques for estimation of forest density and volume are also being developed.

iv. Wasteland Mapping

About 20% of India's land area is considered as wasteland due to salinity of soil caused by excessive use of fertilizers, improper irrigation procedures, degradation due to prolonged agricultural usage, use of slash and burn clearance techniques and also due to the spreading of desert. Under the aegis of National Wasteland Development Board, a project has been taken for Wasteland Mapping of 140 critically affected districts in India. Detailed satellite mapping of Wasteland has helped in identifying 13 recognizable wasteland categories. Almost half of them can be reclaimed for agriculture with apropriate Agricultural practices. Estimation of the extent and type of recoverable and non-recoverable wasteland at microlevel, from space imageries assumes great importance.

v. Ground Water Mapping

The "National Drinking Water Mission", established in 1987, aims to supply adequate potable water to every one of the 6.00,000 villages in India.

Table - 14.2. Applications of Remote Sensing in Different Fields

S.No	Area	Application	Wavelength Regions employed	Resolution required	Repetition period
1.	Agriculture and Forestry	Plant diseases and Insect infestation	0.4 - 0.9 μm & 6.0 - 10.0 μm	40-70 mts	weekly/Monthly
		Natural vegetation, Crop and Fresh Inventories	0.4 - 0.9 μm & 6.0-10.0 μm		
		Assessment of plant growth and vigour for forecasting crop yield	0.4 - 0.9 μm		
		Soil moisture content	0.4-0.8 μm		
		Soil moisture beyond the surface	3-100 mm (MW Radar)		
		Study of Arable and Non-arable lands	0.4-0.9 μm		
		Soil types and characteristics	0.4-1.0 μm		
2.	Hydrology	Surface water inventories	0.4-1.0 μm & 6.0-12.0 μm	40-100 mts	
		Flood control and water management	0.4-1.0 μm & 6.0-12.0 μm		
		Seepage of underground water along the river streams and sea coasts	6.0-12.0 μm		
		Location of water wasting weeds	0.4-0.9 μm		

Contd.

S.No	Area	Application	Wavelength Regions employed	Resolution required	Repetition period
		Glaciers, Snow cover, Ice accumulations and their changes	0.4-0.7 μm & 3-100 (MW Radar)		
		Out-crops and mineral mapping Fault lines and plate tectonics	0.4-1.0 μm, 7-12.0 μm 3-100 mm (MW Radar)		
3.	Geology	Detection of structural features associated with hidden mineral deposits including petroleum	0.4-1.0 μm & 7.0-12.0 μm and 3-100 mm (MW Radar)	100-150 metres	Monthly or more
		Soil and rock types and conditions favourable for hidden mineral deposits	0.4-1.0 μm & 7.0-12.0 μm		
		Detection of iodine gas associated oil source rocks	0.4-0.5 μm		
		Geothermal mapping	3.0-12.0 μm		
		Detection of vegetation affected by mineral content of the soil	0.4-0.5 μm		
4.	Cartography and Geography	Topographic mapping	0.4-1.0 μm, 7-12 μm and 3-100 mm (MW Radar)	20 metres	Yearly

Contd.

S.No	Area	Application	Wavelength Regions employed	Resolution required	Repetition period
		Study of urban areas and areas of development	0.4-1.0 μm, 7.0-12.0 μm and 3-100 mm (MW Radar)		
		Mapping of rivers, lakes etc.	0.4-1.0 μm and 7.0-12.0 μm		
		Delineation of wet lands (mashes etc.)	0.4-1.0 μm, 7.0 - 12.0 μm and 3-100 mm (MW Radar)		
5.	Oceanography	Wave heights and thence winds Surface temperatures and thence Location of fish schools	3-100 mm (MW Radar)	70-100 metres	Monthly or more
		Estimation of ocean currents Estimation of evaporation Forecast of cyclone development Water color tones and thence Coastal under water topography Coast line monitoring	6-12 μm	100-150 metres	Monthly or more
		Water pollution Estimation of bio-mass Location of Fish schools etc.	0.4-1.0 μm		

Contd.

S.No	Area	Application	Wavelength Regions employed	Resolution required	Repetition period
		Wave refraction and thence bottom topography	0.4-0.7 μm & 3-100 mm (MW Radar)		
		Oil slicks of petroleum origin or fish origin	0.4-0.7 μm		
		Chlorophyll concentration (algae, plankton)	0.4-1.0 μm		
6.	Environmental control	Monitoring of atmospheric pollution	0.4- 12.0 μm		Monthly or more
		Monitoring of sea water pollution Study of aquatic eco-systems.	0.4-1.0 μm and 7.0-12.0 μm		
		Study of terrestrial eco-systems	0.3-12.0 μm and 3-100 mm (MW Radar)		
7.		Coastal environmental studies (Coastal morphology and sedimentation studies)	0.45-0.52 μm	70-100 metres	Monthly or yearly

The Hydrogeomorphological maps, generated using Satellite Remote sensing data are being extensively used for locating borewells. The maps on a scale of 1:50,000 have been completed for about 1,60,000 villages and on a scale of 1:250,000 are completed for the rest of the country. These maps serve as the starting points for identifying underground aquifers for providing basic drinking water.

A success rate of 88-95% has been achieved for striking bore wells for ground water using Satellite Remote sensing data whereas only 45% success rate is achieved with conventional ground based water location procedures.

vi. Snow-Melt Run-off Estimates

Specific models have been developed for mapping the seasonal snow cover areas and to estimate the "Snow-melt-run-off"during summer season. These estimates are provided at least 3-4 months in advance of the actual run-off period.

These mappings and the estimates are accurate to within +4%, which have been utilized for optimizing the use of water for power generation and irrigation.

vii. Surface Water Mapping and Monitoring of Major Reservoirs

Remote sensing data are being used for identification and prioritisation of erosion-prone areas in various watersheds as well as to provide inputs for undertaking desiltation plans.

Monitoring of seasonal changes in the volume of major reservoirs and agricultural crops in their command areas is being carried out to devise suitable plans for optimum-utilization of water for irrigation and other uses.

viii. Flood Monitoring and Management

Remote sensing satellites are being successfully used for obtaining real-time data/information on areas affected by major floods and to plan for rehabilitation measures.

Quantitative estimation of flood damage to infrastructure and crop losses are provided by this Remote sensing technique. Ministry of Water Resources and Central Water Commission are also making use of these data for their planning.

Methodologies are also evolved for-

(a) Flood Prediction and Control including the identification of flood risk zones

(b) Identification of River migrations

(c) Watershed prioritisation

(d) Strengthening embankments

(e) Organising training programmes to combat flood damages etc.

ix. Mineral Prospecting (Survey)

Geological Survey of India has been making use of data from Remote sensing satellites for mineral prospecting on a regional scale. An area of 4,00,000 Sq.Km. of South India has been covered which consist mainly of granulates, granite-greenstones and Proterozoic basins etc.

Geophysical Information System is being developed for creation of "Digital Cartographic Data-Base" and the development of Geostatistical Models".

Mapping of underground coal fires is being carried out for major coal fires occurred in Jharia-Raniganj area to provide inputs for capping of mines and prevention of spreading of fire.

Mapping of major mines and their surrounding environments is helping in arriving at suitable protection plans needed for overcoming the effects of mining on environment.

x. Urban Sprawl Mapping

Shrinking of forest cover and mushrooming of concrete structures in urban areas resulted in ecological disaster. This can be overcome by proper planning of the Urban Development.

Analysing the digital data acquired through Remote sensing satellites, Land use and Urban sprawl maps for all the Metropolitan cities in India have been prepared. Vigorous follow- up actions for all cities in India has been initiated.

A specific example of how the Remote sensing data can be used for city planning is demonstrated recently by conducting a survey of aligning the proposed ring road for Bangalore Development Authority.

The IRS-IA data has been extensively used for different geological and geo-morphological applications. Geological mapping of inaccessible terrains like the Himalays has also been carried out with these Remote Sensing Satellites.

IRS data has also been used in mapping and monitoring Urban- sprawl, Urban land use, Transport Network-Zoning and Demographic studies. Detection of unauthorized constructions and encroachments of slums and other residential areas onto good agricultural lands. Estimation of total population (through assigning a settlement index) is also being carried for urban areas. The accuracy of these results has been found to be of the order of 91%.

xi. Coast Line Monitoring and Ocean Resources Mapping (Survey)

Remote sensing technology is a potential tool in monitoring of coast line and Coastal resources such as mangroves (shrubs growing in sea-shores), estuaries (mouths of large rivers) and other land forms.

This Remote Sensing Technology also enables us to understand the erosion (wearing-away gradually) and accretion (growth or accumulation of matter) processes in Coastal areas.

Under a "Coastal Management Project", India's entire Coast line has been mapped on a scale of 1:250,000. Identification of brackish water and inland water bodies suitable for inland fisheries has also been carried out through Remote sensing technique.

Using Remote sensing data, methodologies for identification of areas rich in fish through the estimation of phytoplankton density and ocean temperature distribution have been developed.

Forecasts on "Fish School Locations" are now broadcast on AIR to enable fishermen to go for fishing in these locations. Study of Degradation/Improvement in Mangroves and Coral Reefs is also carried out.

Specific experiments were also conducted for estimating several parameters related to surface waters, wind swells, internal waves etc. using Microwave Radar data from Remote Sensing Satellites. These data are extensively being used by Ocean Development Department.

xii. Land Use Mapping for Agroclimatic Zonal Planning

The Remote sensing information on land use/land cover prepared in the form of maps and statistical data are very vital for the planning Commission for devising special plans for management and utilization of land under different sectors like the - Agriculture, Forestry, Urban-habitat, Industry etc.

The Remote sensing techniques provide information on all natural resources like the Forests, Crops, Wastelands, Land use, Mineral wealth, Water resources, Geology, Soil condition, Topography and Terrain conditions etc. Remote sensing data can be utilized for developing a National Natural Resources Management System and integrated development planning at village, mandal and district levels.

xiii. Desertification Studies

The fragile habitat of our desertic tract is witnessing an accelerated degradation of its natural endowments (resources) as a result of over-exploitation, wind erosion and generation of drift sands, manifested in the form of (i) degree of stability of land surface and (ii) degradation of vegetation cover are the two major desertification processes.

The IRS data can be a very powerful tool in monitoring the rate of incidence and the extent of desertification. The "Soil Brightness Index" data obtained through Remote sensing is the best parameter in separating land surfaces of different degrees of stability and also can identify the incidence of wind erosion.

xiv. Glacier Inventory and Mass Balance Studies

A Systematic study of Himalayan Glaciers is useful for the planning of over-all development of the mountainous regions of Himalaya. This information is particularly useful for

(a) Planning and operation of mini and micro hydroelectric stations

(b) Disaster warning

(c) Glaciers also provide records of the past climatic conditions which serve as valuable clues for predicting future climatic changes.

IRS data on 1:250,000 scale was collected and maps were prepared on toposheets on one degree intervals. A different index scheme other than Muller is adopted in the present exercise as the Himalayan region is different from other regions. Various Glacier features such as - Glacier boundary, Ice-divide, Snow-equilibrium line, Glacier lakes. Accumulation and ablation zones are mapped. Glacier water equivalents and Glacier mass balance studies (loss or gain in its mass at the end of the hydrological year) is estimated by the Accumulation Area Ratio (AAR).

XV. Meteorological Mapping

Quantitative estimates of ground and sea surface temperature and humidity profiles. cloud level, wind speeds, precipitation and thunderstorm growth parameters etc. are also completed using Remote Sensing Satellites.

xvi. Environmental Impact Assessment (EIA)

Environmental Impact Assesment is potentially one of the most valuable, interdisciplinary, objective decision-making tools with respect to alternate routes for Development. Process technologies and Project sites.

xvii. Defence Application

The Remote sensing technology is also being used in the defence sector for

(a) Erosion estimation for advanced ballistics re-entry systems due to precipitation and cloud drop elements present in the atmosphere.

(b) Surveillance (Monitoring) of enemy movements etc.

14.6. ECONOMICS OF REMOTE SENSING

Remote sensing is now being used as an alternative technology for the - Inventory. Survey. Planning and Management of natural resources and monitoring of environmental change. The cost-benefit analysis is more difficult than cost-effectiveness analysis. Case studies provide a set of guidelines to determine the most remunerative alternative for implementing a remote sensing project for solving problems of natural resources management. The emphasis here is to help the users in making suitable judgments to ensure definite returns from their investments and enable them to utilize the limited financial resources for deriving the maximum benefits.

14.7. FUTURE PERSPECTIVE

India has achieved self reliance in Remote Sensing Technology. With the indigenous development of the first generation Remote Sensing Satellites IRS-IA, IB and the second generation Satellites IRS-IC, ID. They incorporated improved cameras operating in three spectral bands in visible and near infrared regions with ground resolutions of 20 mts and in the middle infrared region with a ground resolution of 70 mts. The second generation Remote sensing Satellites also incorporate camera with a resolution better than 10 mts. In the panchromatic band besides a wide field sensor operating in visible and near infrared region with resolution of 188 m and a swath of 774 km.

The Remote sensing data with better resolution in the Infrared band throws open many new applications like information on Water stress and extent of Pest infestation in plants which is useful for better agriculture management.

The higher resolution data will help in arriving at locale specific solutions for complex problems in microlevel development planning at Village/Mandal/District levels. Essentially, it comprises of data analysis and integration at two levels viz.

(i) Resource region analysis to ascertain resource potential and limitation for the suitability for various resource management activities, and

(ii) Programme region, aimed at identification of socially and economically backward areas lacking in basic amenities of life.

14.8. CONCLUSION

The areas of microwave remote sensing using "Side Looking Air- Borne Radar (SLAR)" and Air-borne "Synthetic Aperture Radar (SAR)" development is planned to receive Remotely sensed data from the European Satellite ERS-1.

The remote sensing technology is useful for predicting the crop yield, extent of pests, extent of crop stress conditions, extent of drought, changes in the forest cover, identification of wastelands, monitoring of floods, Mineral and groundwater mapping, urban sprawl, coast line, deserts etc. The predictions will help in formulating the plan for the alround development of the country as well as for initiating preventive measures to cumbating drought, floods, cyclones etc.

The continued and sustained efforts over the last two decades have significantly contributed in developing a viable, self-reliant Remote sensing programme for National development.

14.9. SUMMARY

Remote sensing is a multi-disciplinary science of acquiring information of an object through measurements made from a distance without the sensor actually coming into contact with it.

Any set of observable characteristic features specific to that object such as Reflectance/Emittance which directly or indirectly lead to the identification of that object and/or its condition is termed as the signature of that object. Under different conditions the signatures form the basis for the data interpretation.

Only certain bands in the electromagnetic spectrum are available for remote sensing because the most important constituents of the atmosphere like H_2O, O_2, O_3, CO_2 etc absorb electromagnetic energy at characteristic wavelengths.

Remote sensing techniques are used in many different fields.

14.10. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The electromagnetic radiation undergoes changes in the plane of polarization when reflected from objects at angles close to Brewster angle. The ability of the sensor to detect the finer variations in the polarization characteristics is known as polarization resolution of the sensor.

14.11. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write notes on signatures of objects and resolutions.
2. What are the applications of Remote Sensing in different fields ? Explain.

II. Answer the following questions in about 10 lines each.

1. How are the Remote Sensing Satellites used for obtaining real time data on floods ?
2. Describe the method of using remote sensing technology in monitoring of coast line and coastal resources.

Prof. S. Raja Ratnam.

UNIT - 15 : ENVIRONMENTAL POLLUTION MONITORING

Contents

15.1. OBJECTIVES

After going through this unit you should be able to :

- explain air pollution, sources and pollutants, water pollution- sources and pollutants and solid wastes-sources and wastes,
- discuss the monitoring of air pollutants, and
- explain the role of instruments in monitoring of carbon monoxide, sulphur dioxide, hydrocarbons, oxides of nitrogen and smog.

15.2. INTRODUCTION

Environmental monitoring and analysis are extremely useful and play a great role in Policy formulations of any country. They allow for rational planning of various developmental policies with minimum disruption to the environment and ecological balance.

Our environment is being polluted due to several factors like industrialization, urbanization etc. The major environmental pollutions are :

i. Air Pollution

ii. Water Pollution

iii. Pollution due to Solid Waste Materials

iv. Noise Pollution

v. Thermal Pollution

vi. Nuclear Radiation Pollution etc.

The problem of environmental pollution cannot be compartmentalized but the combined influence of all these segments must be considered for the survival of the ecosystem.

Hence, environmental surveillance (monitoring) in any specified location is essential and it provides information on the nature and concentration of pollutants. The data thus collected can help the "Environmental Protection Agencies" to device methods to cleanse and stabilize the environment to a point where human beings can live in this ecosystem in a safe and comfortable manner.

15.3. AIR POLLUTION : SOURCES AND POLLUTANTS

The primary sources of Air Pollution and the pollutants generated by them are presented in Table 15.1 and 15.2.

i. The fuel combustion in stationary and mobile sources

ii. Industrial processes

iii. Evaporation of organic substances like the paints, thinners, other volatile solvents and gasoline

iv. Incineration (open-burning) of agricultural and other wastes generate pollutants like - CO, CO_2, SO_2 and Flyash.

v. Grit and Dust - Suspended particulate materials in the air such as - unburnt solid fuel, flyash, wind-blown dust etc.

Table 15.1. Pollutants from fuels.

Sources	Pollutants generated
Coal, Coke, Fuel oil,	CO_2, CO, NO_x, SO_x
Gasoline, Diesel oil,	Hydrocarbons, Smoke, Fly-ash,
Natural gas, Wood etc.	Particulate matter, Heavy metals like Pb, Hg, As etc.

Table 15.2. Pollutants from Industries.

Industry	Pollutants
Leather	Chlorides, sulfides, organic matters, lime, chromates, alkaline pH effluents, Boron. In addition they generate : High BOD, High COD, and High TDS
Textiles	Alkaline pH effluents, sodium, organic matters, colouring dyes, High TDS and High SS.
Milk and Food products	Colloidal solids, Very slowly bio-degradable offensive odours, High BOD, High COD, High TDS and High SS
Drugs and Pharmaceuticals	High and Low pH effluents, Total Solid wastes, Toxic organic materials, Metal pollutants (Hg, Ag, Cr, Pb), Cyanides, Sulphides, Phosphates, Phenols.
Electroplating	Acidity and Toxic metals, Cd, Zn, Ni, Cr, Cu, Pb, Fe. Cynanides ammonium nitrides, Chlorides, High SS, Oil and Grease.
Pulp and Paper	pH 6 - 8 effluents Strong colouring matters, Sulphides of sodium, alkaline - earths, Lignin sulphate, Black liquor.
Slaughter Houses and Meat Industries	Proteins, Toxic solvents, Phosphate, very bad odours, very high BOD.
Cement	Particulate matter. CO, CO_2.
Synthetic Fibres	SS, BOD, pH 5 to 9, effluents.
Iron and Steel	CO, particulate matter.
Synthetic Rubber	BOD, COD, Oil and Grease. Na, B, Sulphides.
Petroleum (Oil refinery)	SO_2, CO, Cr, Oil and Grease. Phenol, sulphide, cyanide, High BOD, High SS.
Petrochemical	High/Low pH effluents, Phenol, sulphide, cyanide, fluoride, Cr.
Sugar	Cr, SS, High BOD
Fertilizers	Particulate matter, fluoride, phosphate, urea.

Industry	Pollutants
Pesticides	Benzene-hexachloride, Carbaryl, DDT, Endosulphan, Dimethoate, Fenicro, Malathion, etc.
Chemical	Metals like - Mn, Cu, Zn, Hg, Sn and Sulphates, Oxychlorides, Phenols etc.
Caustic Soda	Hg, Cl, HCl
Dyes and Dye intermediates	Hg, Cr, Cu, Zn, Ni, Cd, Chloride, sulphate, phenolic compounds, oil and grease.

where

BOD = Biological oxygen demand
COD = Chemical oxygen demand
TDS = Total dissolved salts
SS = Suspended solids
SPM = Suspended particulate
TOC = Total organic matter content.
T = Turbidity
TH = Total hardness
DO = Dissolved oxygen
DN = Dissolved nitrogen
PV = Permanganate Value

15.4. WATER POLLUTION : SOURCES AND POLLUTANTS

The main sources of water pollution are :

i. Sewerage and waste water discharges

ii. Industrial effluent discharges into lakes, rivers and seas

iii. Agricultural activities - the fertilizers and pesticides washed into the water sources

iv. Insecticides, herbicides, rodenticides, miticides, nematicides, and fungicides etc. also washed into the water sources.

The water pollution due to the above sources increases/ decreases the pH, reduces the dissolved oxygen level thereby producing a large biological oxygen demand (BOD) for the survival of the aquatic life. The pollutants also increase chemical oxygen demand (COD), increase turbidity, total dissolved salts and suspended solids (SS) content in the water. Discharge of toxic materials, and metalloids like Fe, Cu, Mn, As, Pb, Cd, Hg, Na, Li, K, Ca, Mn and ions like sulphate, nitrate, ammonia, phosphate, fluoride, chloride and silica, when present beyond certain levels severely affect the aquatic life (both animal and plant). This inturn affects the human beings who consume them.

15.5. SOLID WASTES : SOURCES AND WASTES

Innumerable kinds of solid waste materials are accumulating on earth at an alarming rate. The main sources of solid waste materials and the wastes generated are presented in Table 15.3.

Table 15.3. The main sources of solid waste and the wastes generated.

S.No.	Main sources	Wastes generated
i.	Domestic refuse	Food, textiles, paper, cardboard, plastics, ash, cinders, glass, porcelein, pottery, steel, rubber, all types of packing materials etc. Detergents, cans, bottles, tyres.
ii.	Refuse from Hospitals	This refuse is hazardous and disease causing. It has to be disposed - off carefully.
iii.	Street sweepings	All types of refuse
iv.	Industrial refuse	Oil, grease, metal, wood etc.
v.	Garbage and refuse from stock yards and slaughter houses.	All types of Rubbish Proteins, Toxic Solvents, Phosphates, Very bad odours, very high BOD
vi.	Agricultural refuse	Fertilizer, pesticide, animal and plant wastes (Bagasse)
vii.	Construction sites	Excavated soil, rock, wood, rubbish, cement, steel, plastic etc.
viii.	Rubbish from Auto-garages	Oil, Grease, Metal scrap and Rubber Tyres etc.
ix.	Sludge from waste treatment plants	Toxic Organic and Inorganic materials etc.

15.6. MONITORING OF POLLUTANTS

(A) The data of different pollutants is normally acquired through the following "techniques" *viz.,*

i. Rapid surveys

ii. Comprehensive surveys

iii. Continuous monitoring

iv. Integrated sampling

(B) The data are monitored "geographically" as

i. Area totals

ii. Grid zone values

iii. Point source values

(C) The data are also monitored "temporally" as

i. Diurnally

ii. Seasonally

iii. Annually

iv. At random intervals.

Several techniques and instruments are available for monitoring of different pollutant emissions.

(D) Instruments designed for *"Qualitative Monitoring"* of pollutants are -

i. Deposit gauges

ii. Sulphur dioxide candles

iii. Liege spheres

They will not provide Quantitative estimation of different pollutants.

(E) More sophisticated instruments are developed for the *"Quantitative Estimation"* of different pollutants. They are broadly classified into two categories -

i. Samplers fitted with filters/bublers

ii. Quality measuring instruments

The second category of instruments are extensively used for accurate and reliable measurements.

(a) Colorimeters and Spectrophotometers

(b) Chemiluminescence meters

(c) Photometers

(d) Chromatographs

(e) Mass spectrometers.

15.7. MONITORING OF POLLUTANTS IN AIR

A. Haze

Suspensions of fine particles in the air obscure light and are visually objectionable. On settling, they lead to soiling (soot on clothes), discolouration (of buildings), and sometimes corrosion (if particles are active chemically). Particle size distributions vary between 0.25 μm - 1000 μm. Normally over 90% of suspended particles have diameters greater than 30 μm.

The larger particles rapidly settle down under the influence of gravity, but the smaller or microscopic components (size $< 100\ \mu m$) can be maintained as a suspension by eddies and air currents for indefinite periods.

Particles in diameter range of 0.25 to 5 μm are effectively retained in the lungs and cause infections etc.

(i) Haze density readings are measured by a *"Nephelometer Unit"* presented in Fig.15.1. They provide comparative information on the effect of suspended particulates on light transmission.

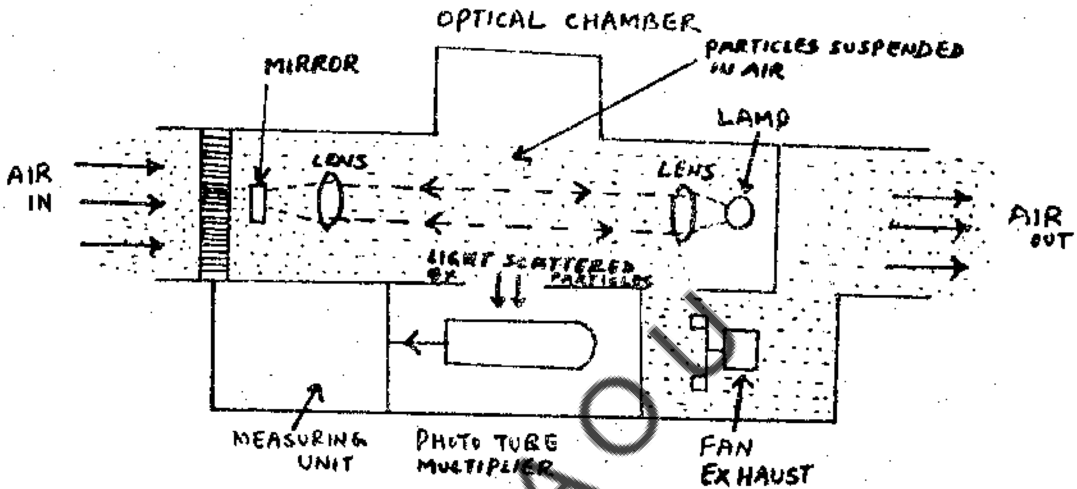

Fig.15.1. Nephelometer Unit for the Measurement of Haze Density.

Air is drawn at a fixed rate of 0.01 m^3/Min through an optical maze into a chamber illuminated by a light beam. Some of the light is scattered by the fine ($<20\ \mu m$) particles present, and the intensity of this scattered radiation is measured by a photomultiplier mounted at right angles to the primary light beam.

The instrument response accurately reflects changes in dust concentrations, if the suspensions examined are similar with respect to particle nature and size distributions. Calibration in absolute units is very difficult.

(ii) Total sampling technique : In this procedure a large volume of air is drawn through a filter which traps all particles with diameter $> 0.01\ \mu m$. The darkness of the stain on the filter gives the quantitative information of the suspended particulates in the atmosphere. The amount of material retained is weighed and reported (as $\mu g/m^3$). Using high-powered optical and/or electron microscopes, the collected material can be identified by type (species) and appropriate size distribution patterns are evaluated.

(iii) For rough comparison of the total fallout in one area with another, some crude procedures often suffice. In one approach a funnel (of known diameter) is placed in the neck of a large bottle mounted about 5 ft. above the ground in some open space.

Dust falling into the funnel gravitates into the bottle or is washed by rain. At the end of a pre-determined period of about one month, the collected material is weighed and subsequently treated to ascertain the proportions of water soluble and organic matter. The amounts involved are mg/cm^2 of the funnel area. But the values are often scaled upto units of Tons/Km^2/Month

B. Specific Particulates

Industrial processes can realease very fine particles of a wide range of compounds (e.g., acid mist, asbestos, silica, lime, metal compounds etc.) and the extremely small ($< 1\ \mu$m) lead bearing particles produced on combustion of leaded gasoline. The normal concentrations of lead are very small ($< 1\ \mu$g/m^3 to 3 μg/m^3) in unpolluted zones and go up to very high levels (50 to 70 μg/m^3) on city roadways with heavy vehicular traffic.

(i) Atomic Absorption Spectroscopy : For average specific particulate values in a given area, large volumes of air are drawn through filter pads over a prolonged time period. A fraction about (10%) of the pad is dissolved in acid and the filtered extract is examined for several compounds by standard trace analysis techniques viz.,

Atomic Absorption Spectroscopy shown in Fig.15.2. In some surveys, the lead, zinc, and iron contents of suspended matter are observed to fall in the range of 0.1 to 6 μg/m^3

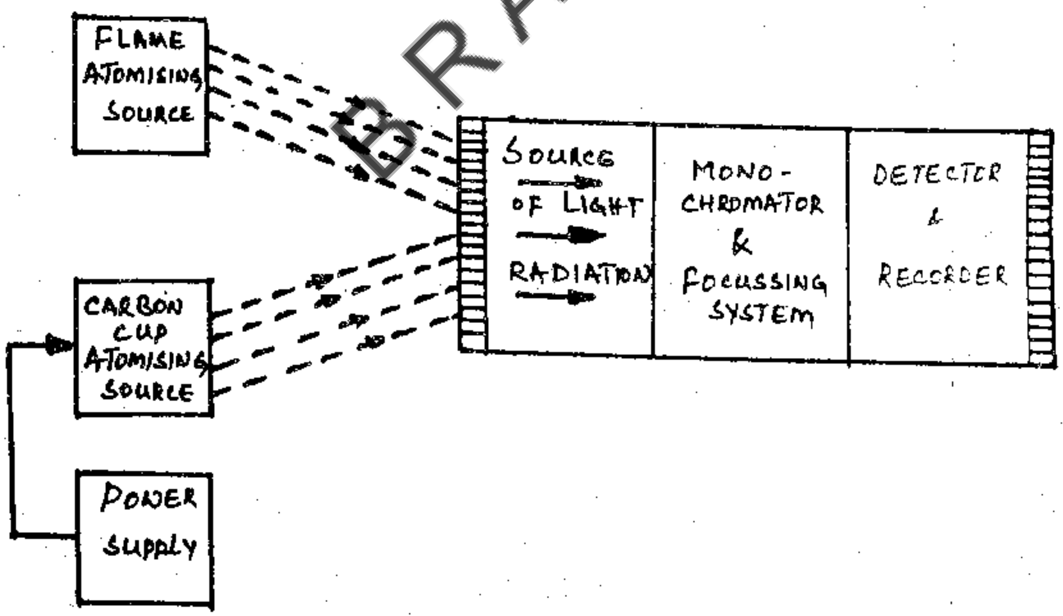

Fig.15.2. Atomic Absorption Spectroscope.

Figure 15.2. shows the basic components of an atomic absorption spectrometer unit, except for the addition of a carbon cup and electrodes (used for producing atomic vapour) in place of conventional hot gas flame into which solutions are

sprayed. The nebulization of solutions from dissolved filters into a hot flame allows detection and measurement of solution concentrations (mg/ml).

(ii) Flame photometry :For estimating the instant values of particulate concentration, the proposed method uses a sample of the air to support a hydrogen flame. Components of the particulate matter which are sufficiently excited by high temperature of the flame, emit characteristic radiations. Schematic representation of a flame photometer is shown in Fig.15.3.

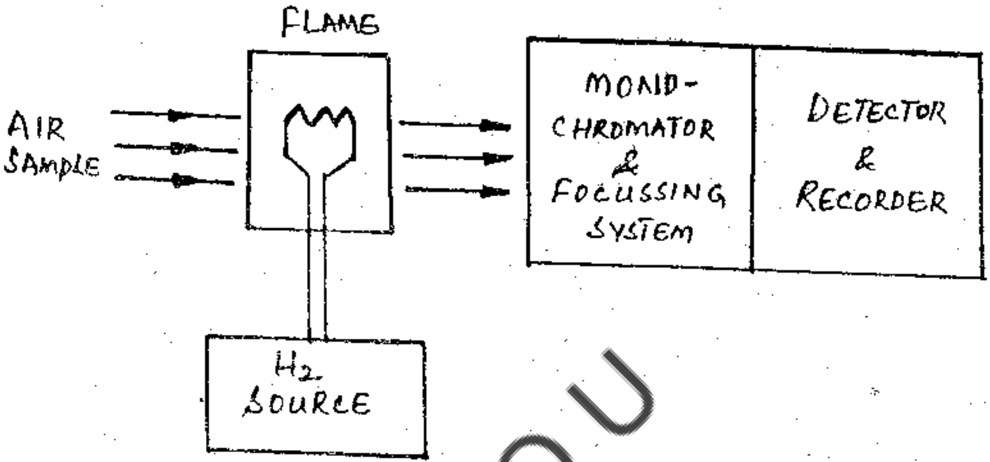

Fig.15.3. Flame Photometer.

(iii) An alternative approach utilises a microsampling technique. For lead determinations, a fixed volume of air (50 to 200 ml) is drawn through a small disc of Millipore filter medium, held in a perforated carbon cup. The cup is subsequently placed between the electrical leads. By gradually increasing the applied voltage, the microsample and filter are dried and ashed. A final heavy electrical impulse volatilizes the residue and releases a puff of metal vapour. If a beam of light radiation characteristic of some metal, is focussed on to the vapor causes a sharp diminution in intensity. The signal change can be correlated with total metal content through calibration with standards. Picograms (10^{-12} g) of metal particles on the disc can yield measurable signals but errors due to contamination or bad technique can be large.

Check Your Progress - 1

What is the unit of Haze density ?

Note : (a) Write your answer in the space provided below.
(b) Compare your answer with the one given at the end of this unit.

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15.8. MONITORING OF CARBON MONOXIDE AND SULPHUR DIOXIDE

Motor vehicle exhausts contain at least five components which pollute the atmosphere : lead compounds, carbon monoxide, sulfur dioxide, oxides of nitrogen, and unburnt hydrocarbons. The gas composition varies with engine efficiency and mode of operation. For example, maximum release of oxides of nitrogen occurs during acceleration (up to 3000 ppm) while the maximum content of unburnt hydrocarbons (up to 4000 ppm) is observed during deceleration.

A. Carbon Monoxide (CO)

The major toxic component is carbon monoxide. The exhaust gases from Petrol (gasoline) and diesel vehicles generally contain $< 1\%$ of CO, but when engines are idling or accelerating, concentrations increase to 5% or more.

Carbon monoxide levels in the air are thus very much influenced by traffic density and the frequency of stopping and starting of vehicles.

The Environmental Protection Agencies in different countries have recommended safe levels as < 9 ppm average for an 8 - hr period or < 35 ppm for an hour of exposure. Great harm to human health occurs when these levels are exceeded.

One analytical procedure widely employed for monitoring of CO utilises the selective absorption of some bands of infrared radiation. The schematic representation of the CO monitoring unit is presented in Fig.15.4 and the diurnal variation of CO concentration in a busy city street with large number of traffic signals is presented in Fig.15.5.

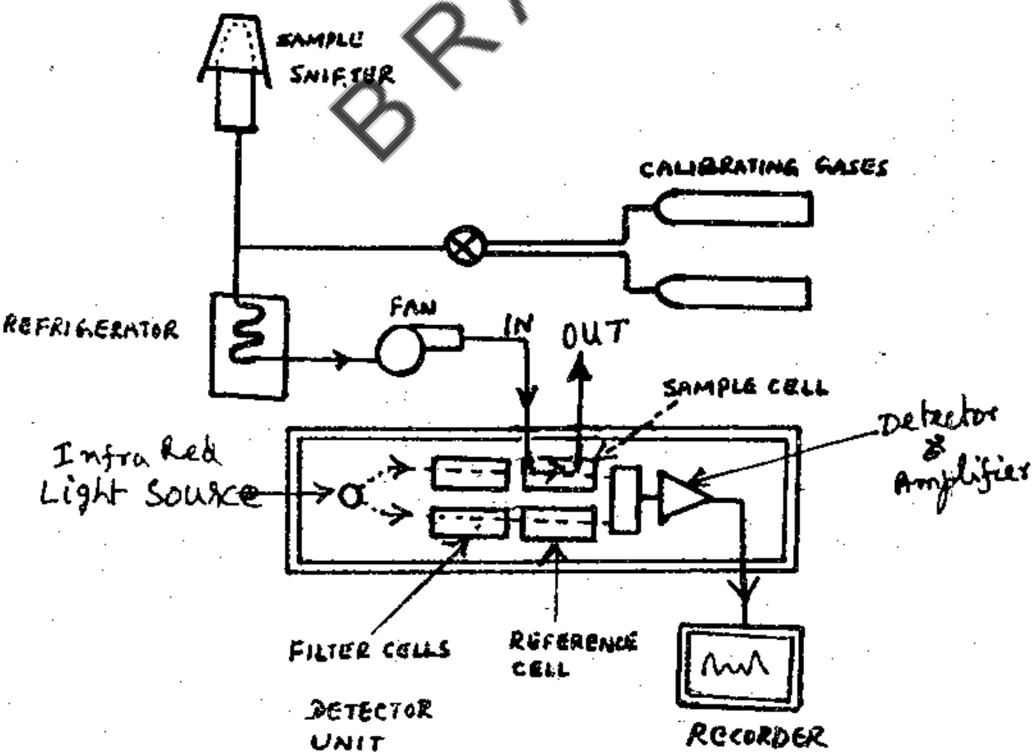

Fig.15.4. Carbon Monoxide Monitoring Unit.

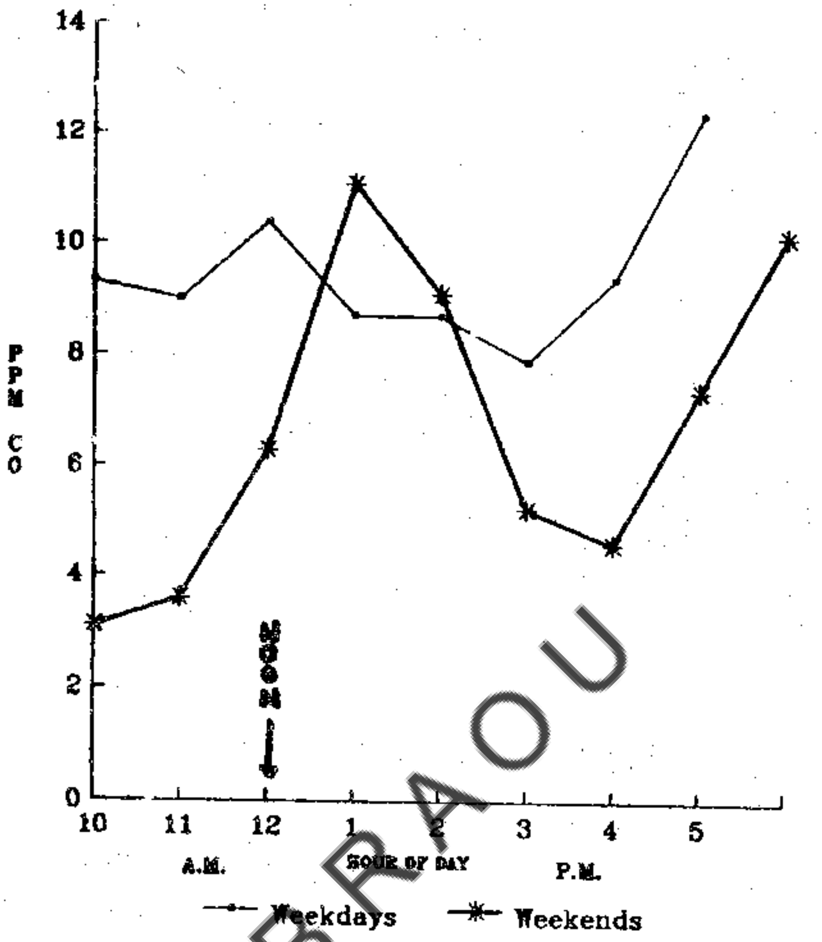

Fig. 15.5. Diurnal Variations of Carbon Monoxide Levels.

The gas sample is drawn (by a pump) through a coarse filter into a refrigerated zone (to condense water vapour if there is any) and from there into a measuring cell. A similar reference cell is filled with nitrogen, and both are irradiated with infrared radiation. The amount of energy reaching the detector system from the two cells is unequal if the sample contains carbon monoxide (due to molecular absorption). This difference is detected, amplified, and fed to a recorder.

With mobile, commercial units, errors associated with measurement of about 10 ppm can be of the order of ± 1.5 ppm.

B. Sulphur Dioxide (SO_2)

The sulphur dioxide content of the atmosphere receives contributions from industry, power stations, and motor vehicles, is indicated in Figure 15.4. This exhibits a marked diurnal variation.

The recommended control levels are therefore based on time averages (e.g., 0.02 ppm/hr; 0.10 ppm/24 hr period).

Figure 15.6. is a schematic representation of a unit used for monitoring sulfur dioxide levels and Fig.15.7. shows the diurnal variation of the SO_2 concentration in air.

(i) Air is drawn into the apparatus (at about 0.01 m^3/hr) through a filter to remove dust, and then over a heated silver wire to eliminate substances such as hydrogen sulphide, ozone, and chlorine. The purified gas is then bubbled through an aqueous solution of bromine. Some bromine is reduced by the sulphur dioxide content and this is continually replaced by an electrolytic generation process. The current flow during the electro generation step is correlated with the SO_2 content of the gas.

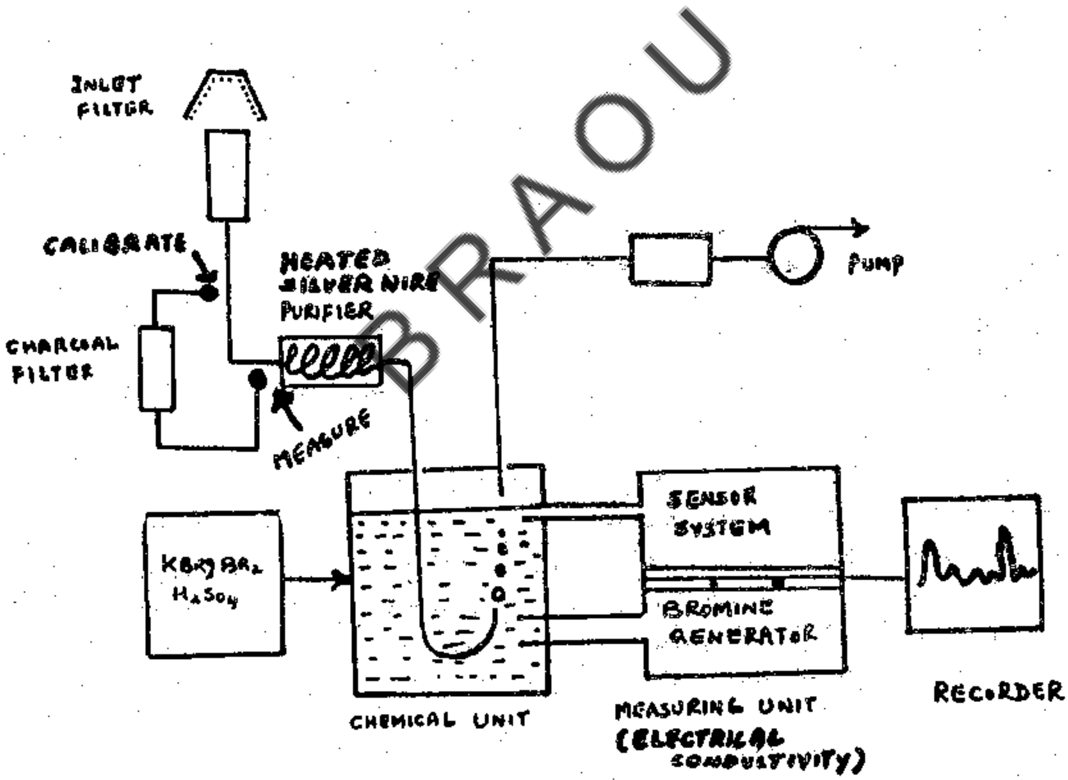

Fig.15.6. Sulphur Dioxide Monitoring Unit.

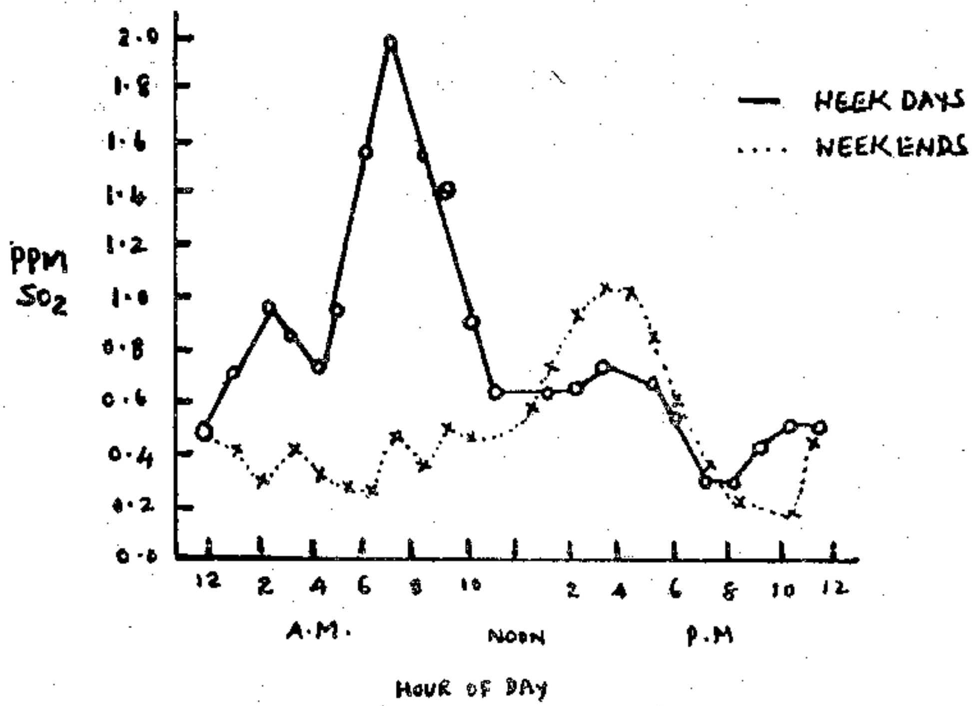

Fig.15.7. Diurnal Variations of Sulphur Dioxide Levels.

Zero measurements are made by diverting the sample gas stream through an activated charcoal filter to remove SO_2, and for calibration a predetermined flow of SO_2 gas is admitted to this purified stream. If sufficient care is taken in calibration and control of flow rates, and if absorption of SO_2 in the sample line and dust filters can be kept to a minimum, an overall accuracy of better than $\pm$ 1.5% may be achieved using this *Coulometric Procedure*

(ii) An alternative approach brings the filtered gas sample in contact with hydrogen peroxide solutions. As the sulphur dioxide is converted to sulphuric acid, there is an increase in electrical conductivity which can be readily recorded. This technique is subject to errors if the gas sample contains components (hydrogen halides) which dissolve to form electrolytes or ammonia which reacts with acid.

For occasional check one can determine the amount of sulphur dioxide solution and subsequently determining the acid content by titration, or, the sulphate ion content by precipitation as barium sulphate.

15.9. HYDROCARBONS, OXIDES OF NITROGEN AND SMOG

A. Hydrocarbons in Exhaust Gases

The unburnt hydrocarbons present in engine exhaust gases consist mainly of alkanes, alkenes, and aromatic compounds together with their products of partial oxidation (formaldehyde, acetaldehyde, etc.). Since the concentration of these hydrocarbons reaches a peak with early morning traffic flows, the quality control limit is specified (a mean value of 0.24 ppm between 6 and 9 a.m).

At later hours of the day sunlight promotes a series of photochemical reactions and leads to the formation of secondary pollutants such as nitrogen dioxide, ozone, aldehydes, ketones, peroxyacyl nitrates (PAN) and alkyl nitrates. These secondary products give rise to photochemical smog.

Figure 15.8 indicates the sequence of reactions for the formation of photochemical smog. With such a complex mechanism, the concentration of individual components varies widely during the day. Hence values recorded in Table 15.4. are only indicative of relative magnitudes.

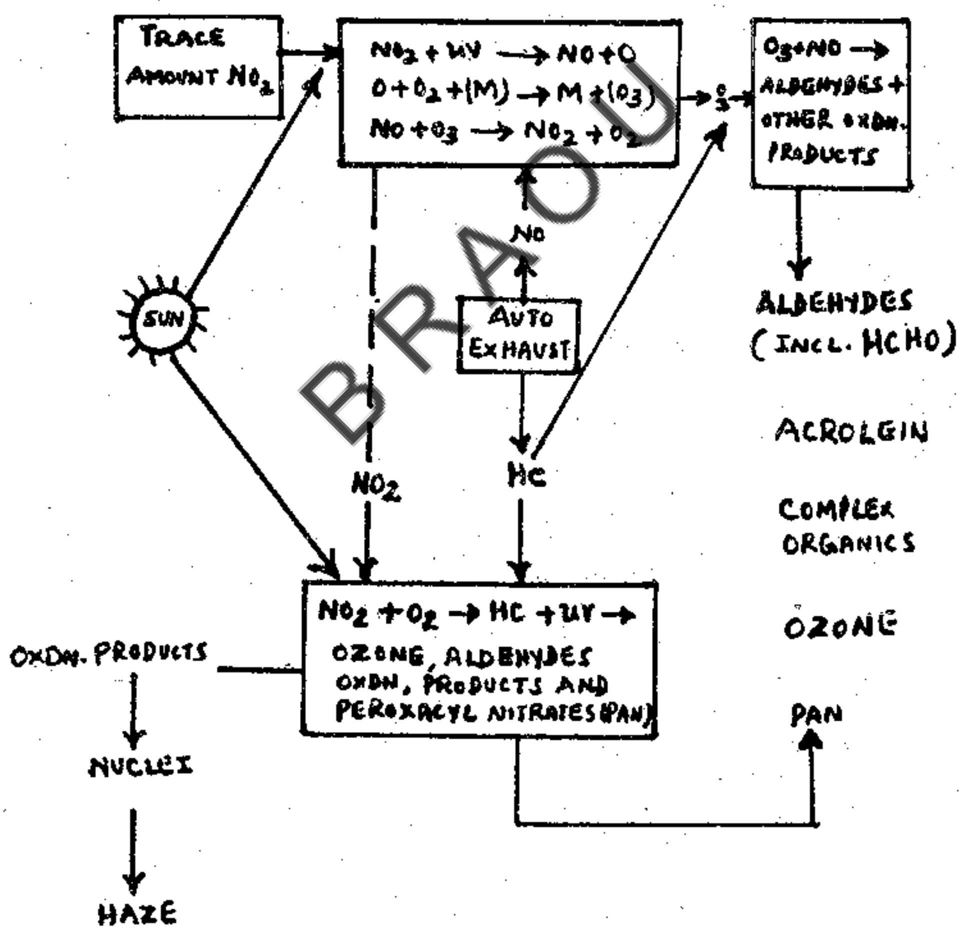

Fig.15.8. Reaction Cycles Associated with the function of Photochemical Smog.

Table - 15.4. Typical Concentrations of Pollutants in Photochemical Smog*

Pollution	Concentration range (pphm)**
Carbon monoxide	200-2000
Total hydrocarbons (excluding Methane)	20-50 (Max. 100-500)
Aromatics	10-30
Aldehydes	5-25
Alkenes	2-6
Nitric oxide	1-15
Nitrogen dioxide	5-20
Peroxyacyl nitrates	1-4
Ozone	2-20
SO_2	1-15

** Parts per hundred million.

The separation and identification of the hydrocarbon species is generally based on gas chromatography or mass spectrometry.

(i) In a gas chromatograph shown schematically in Figure 15.9, minute amounts of sample mixture are injected into a stream of carrier gas (nitrogen or helium) flowing through a long tubular column which has been filled with an inert porous powder coated with a nonvolatile oil. Each component in the mixture then flows through the column at a different speed, due to its interaction with the coating on the tube packing. A detector at the other end of the column gives an amplified signal as each component emerges. Under accurately controlled conditions of flow and temperature, each component can be identified on the basis of the time it takes to pass through the column. With careful calibration, the area or intensity of each recorded signal peak gives a measure of the quantity of the component present.

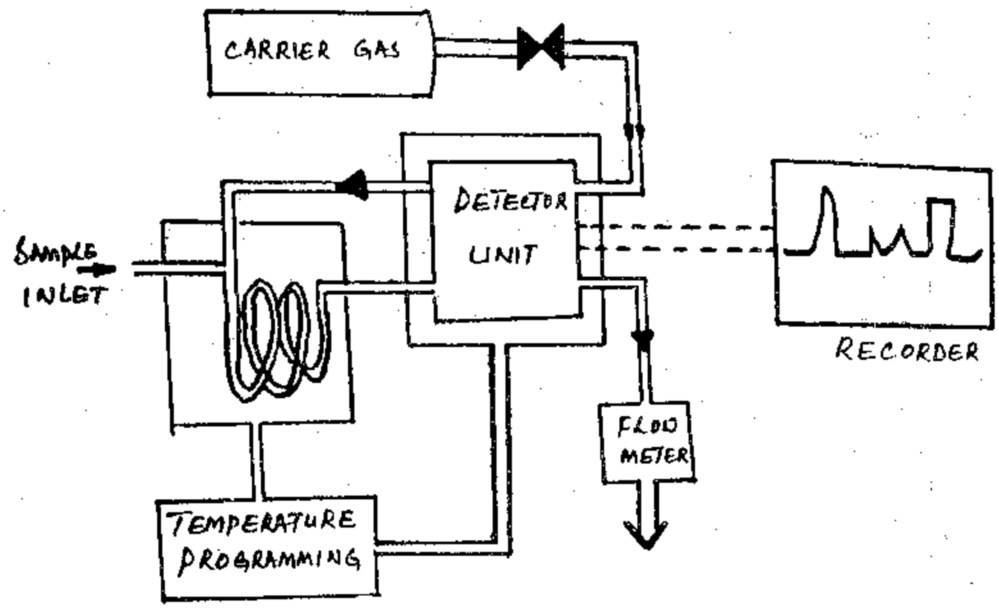

Fig.15.9. Typical Gas Chromatograph Unit.

(ii) Diversion of the stream leaving the column into a mass spectrometer unit shown in Fig.15.10 allows identification of the separated components. The individual molecular species are first separated from the carrier gas and are then admitted via a "leak" into a high vacuum system. In the ionization chamber, the organic materials are exposed to accelerated electrons which on impact convert molecules into charged ions. All the charged particles are accelerated through electrostatic and magnetic fields and are separated on the basis of their (Mass/Charge) Ratio. The separated components are sequentially focussed onto a detector to yield a characteristic mass spectrum. To identify the initial molecular species, the spectrum is compared with the spectrum of pure compounds.

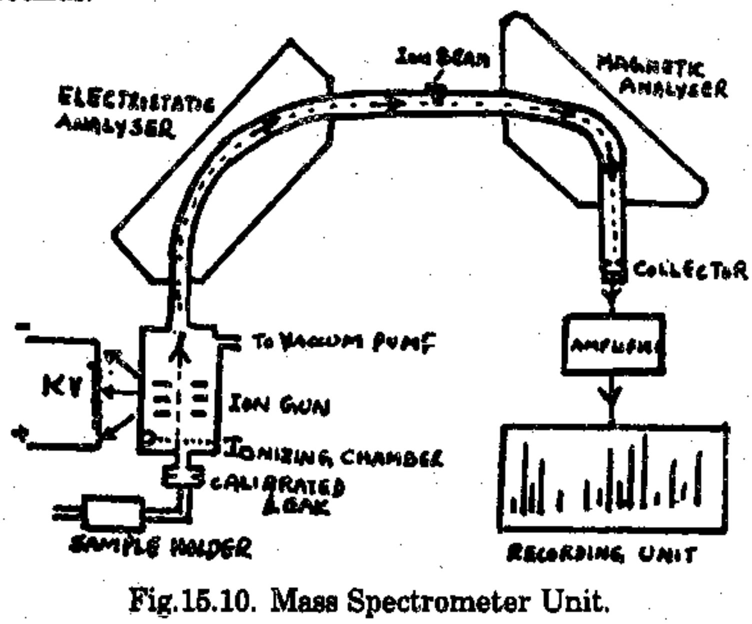

Fig.15.10. Mass Spectrometer Unit.

B. Nitrogen Oxides (NO_x)

Nitrogen oxides (NO_x) are produced in engine exhausts with concentrations ranging from < 30 ppm during idling to > 1000 ppm during acceleration. Fig.15.8 indicates the important role played by these oxides in smog formation, despite their low concentrations in air (0.055 ppm/hr.).

Nitrogen dioxide contents may be determined by "Scrubbing" this component out of an air sample with a reactive solution capable of converting it into a highly coloured species. The colour-forming reaction usually involves diazotization of sulfanilic acid followed by coupling to an aromatic amine [N-(1-naphthyl) ethylene-diamine dihydrochloride]. The equipment used for determining NO_x is shown in Fig.15.11. The discharge from the column is fed into a flow type measuring cell so that the intensity of the colour can be determined using UV/V/IR spectrophotometer shown in Fig.15.12.

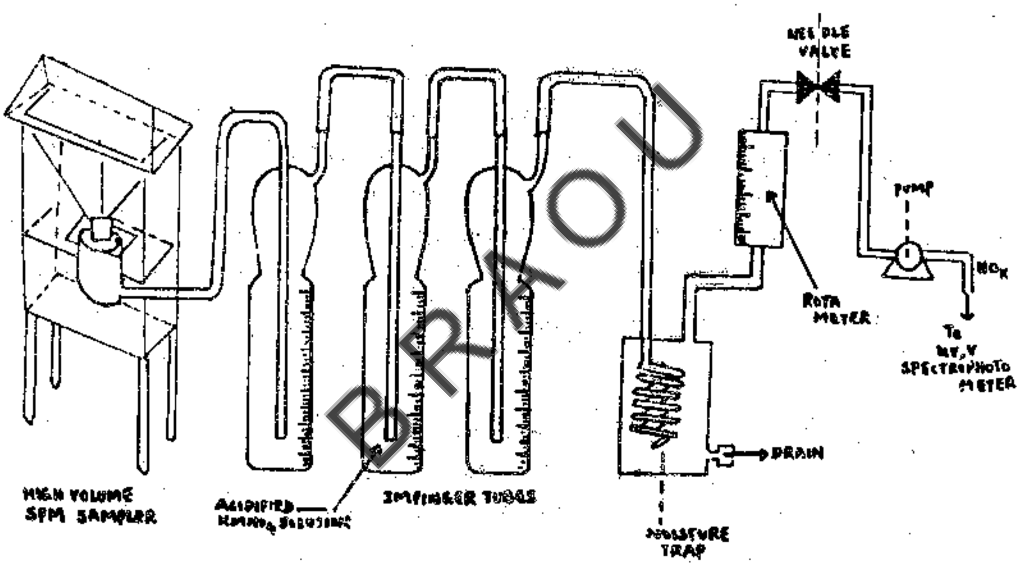

Fig.15.11. Nitrogen Oxide Monitoring Unit.

Basically this consists of a monochromator (prism/grating), isolating slits, an absorption cell, and a detector system. A beam of light is dispersed by a monochromator and different wavelengths are brought to focus on the exit slit. For a given solution, held in the absorption cell, some wavelengths are absorbed more strongly than others. To make quantitative measurements, a narrow beam of the characteristic wavelengths (in the maximum absorption region) is passed alternatively through a *'solvent-blank'* and the *'test solution'*. Absorption by the test solution decreases the amount of light reaching the photoelectric detector. The resultant change in meter reading is then calibrated in terms of the amount of absorbing species present. The calibration factor of 0.72 is used here.

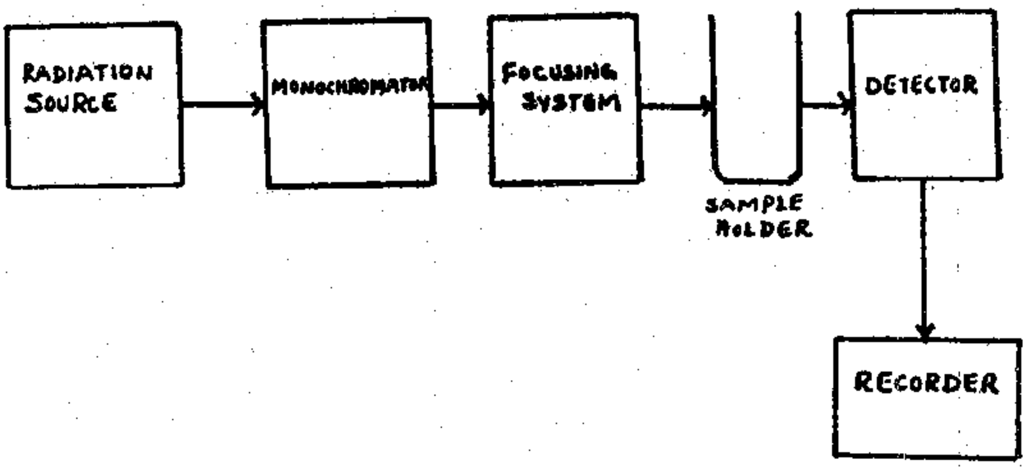

Fig.15.12. UV/VIS/IR Spectrophotometer Unit.

Since the efficiency of the colour-forming process varies between different columns, the procedure should be calibrated by means of standard gas mixtures. But since handling nitrogen peroxide for dynamic calibration operation is difficult, standard solutions of sodium nitrite are more frequently used for routine calibrations. However, with the latter standard, appropriate empirical relationship between nitrite concentration and nitrogen dioxide values have to be established. One widely used factor is 0.72, since, one mole of gas produces the same colour intensity as 0.72 mole of nitrite.

The nitric oxide content of gas samples may be determined by first oxidizing it to the dioxide, e.g., by passing it through acidified potassium permanganate solution. A more sensitive procedure is based on *"molecular chemiluminescence"*.

The gas sample is mixed with freshly generated ozone, to yield *"Excited Nitrogen Dioxide"*.

$$NO + O_3 \rightarrow NO_2^{*} + O_2 \qquad \text{—— (1)}$$

Normal deactivation is accompanied by radiation emission.

$$NO_2^{*} \rightarrow NO_2 + h\ (\text{light}) \qquad \text{—— (2)}$$

The intensity of the emitted light is measured with a sensitive detector. The apparatus is calibrated against standard gas mixtures.

Check Your Progress - 2

List out the five components which pollute the atmosphere due to motor vehicle exhaust.

Note : (a) Write your answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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15.10. MINOR COMPONENTS

While the major pollutant species considered in the preceding sections (viz, SO_x, NO_x, CO, etc.) receive the greatest amount of general observation, minor components also have greater impact on human beings.

These minor components can be subdivided broadly into the following categories, such as industrial toxicants (e.g., solvent vapours), corrosive agents (acid vapours), phytotoxicants (SO_2, ethylene, ozone, fluorides) lachrymators (aldehydes, acrolein, peroxy acyl nitrates), allergins, alkylating agents, pesticides, and carcinogens (arenes, alkanes, phenols). The physiological significance of a large number of these minor aerotoxicants has been the subject of a review.

(i) The techniques required for examining these materials are varied. For example, the ozone content of gases has been determined by absorbing it in potassium iodide reagent (buffered to pH 7) in a continuous flow counter-current absorption column. The ozone forms an equivalent amount of iodine, and the concentration of this product may be evaluated in several ways, including measurement of the colour intensity with a spectrophotometer.

Positive errors are introduced by compounds such as nitrogen dioxide (10 ppm NO_2 having similar effect to 1 ppm O_3) and Negative errors are introduced by the presence of reducing agents (e.g., SO_2).

(ii) Many of the aerotoxicants are determined spectrophotometrically. That is, they are made to undergo specific reactions with selected reagents to yield products which absorb strongly in some part of the visible or ultraviolet regions of the spectrum.

An alternative approach (which is often more sensitive) involves conversion of the species of interest into a fluorescent compound. When excited with ultraviolet light, the latter emit characteristic visible radiations. The intensity of these emissions is measured by mounting a photomultiplier detector at right angles to the exciting beam as shown in Fig.15.13.

$$\underset{\text{(UV light)}}{SR + h\,\upsilon} \rightarrow SR^* \rightarrow \underset{\text{(Visible light)}}{SR + h\,\upsilon 1} + \text{heat} \qquad \text{—— (4)}$$

The types of substances which exhibit fluorescence are mainly aromatic organic compounds (benzene, naphthalene, anthracene, and their derivatives) or a metal - fluorogenic reagent complex.

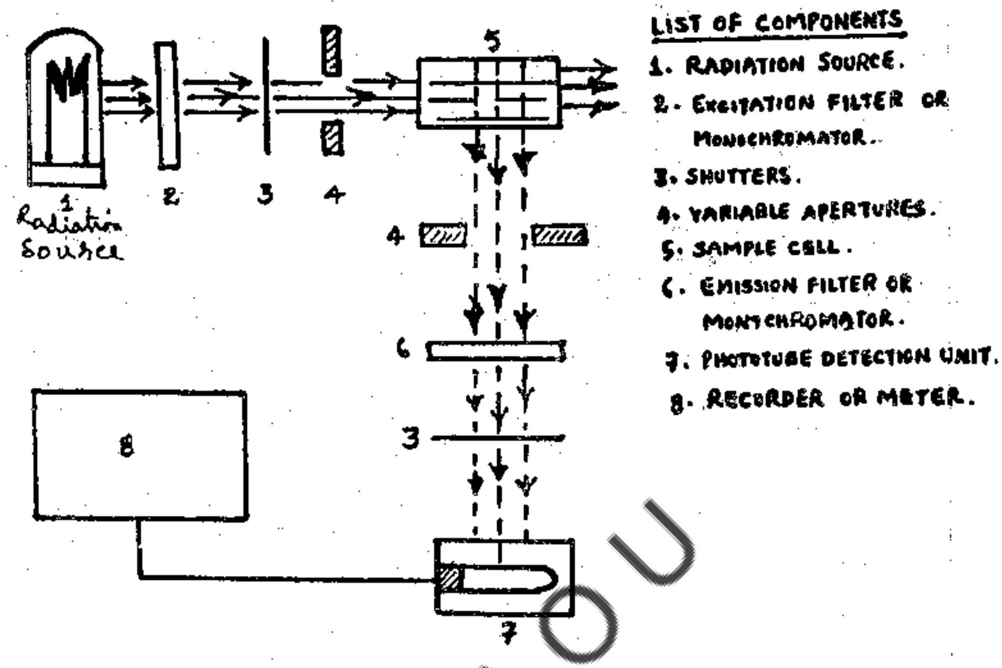

Fig.15.13. Flourimeter Unit.

With careful section of excitation wavelength and optimization of conditions, concentrations as low as 0.01 ppm may be determined. On the other hand, great care is required to prevent contamination of the sample. For example, common solvents often contain fluorescent substances; stoppers can contain extractable fluorescent materials; and grease or paper fibres can introduce interfering species. In every set of determinations, the analyst is well advised to run a blank and at least two standards of known contamination covering the concentration range of interest. With ideal systems, the intensity of emission (I) is directly related to the concentration of fluorescing material (C)

$$I \propto C \qquad \text{—— (5)}$$

As in the molecular chemiluminescence technique for nitric oxide, the accuracy depends greatly on the absence of species capable of quenching (That is, promote deactivation of the excited species with the liberation of light).

For mixtures of aerotoxicants, separation of the components by some form of chromatography is usually adopted. Gas chromatography is very useful as a separation procedure and for quantitative measurements, but as a tool for the identification of species it has limitations. This deficiency can be overcome through the use of accessories which permit collection of the various separated fractions. The latter can then be submitted to examination in a mass spectrometer or an infrared spectrophotometer.

An infrared spectrophotometer allows one to obtain molecular finger prints which can be used to identify compounds with a high degree of certainty. The instrument contains a source of infrared radiation (a heated bar), a dispersing medium (e.g., NaCl prism), a sample cell, and IR-detector as shown in Fig.15.14. By moving the dispersing medium, the sample can be exposed to a wide spectrum of infrared radiations. Different parts of molecules exhibit differing interatomic vibrational movements, and the amplitude of these vibrations can be increased through absorption of specific bands of infrared radiation. As a result, when the dispersed infrared radiations are successively passed through the sample, varying proportions are transmitted and the graph produced shows the extent of absorbance at specific wavelengths. The wavelengths at which absorption peaks occur are characteristic of particular types of atomic groupings, but the combined effect for a pure organic compound is exclusive to that compound, i.e., it is an IR finger print. If only one absorbing species is present, positive identification can be achieved through comparison with the spectra of pure known compounds.

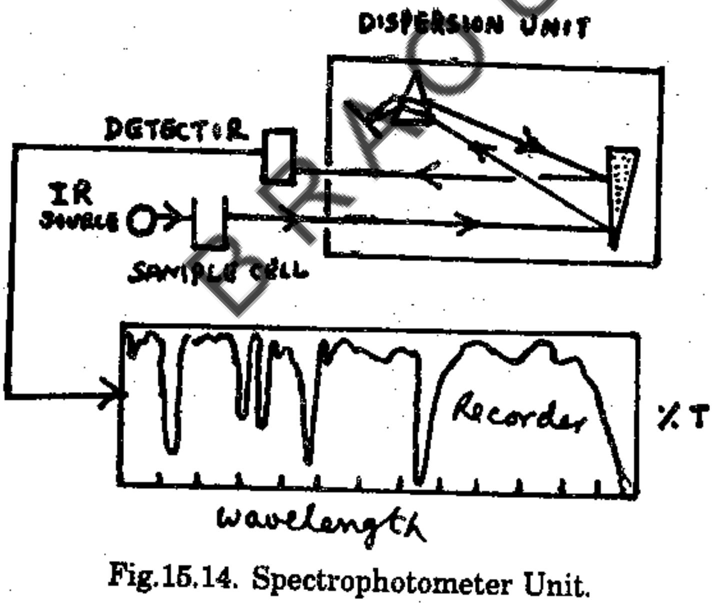

Fig.15.14. Spectrophotometer Unit.

Since the concentrations present in gas samples are normally extremely small, it is necessary to fit the infrared spectrophotometer with an accessory which increases the effective path length. For radiation absorption, the relationship between concentration (c) and effective path length (b) is of the form of :

$$\text{Absorbance} = a.b.c = \log \frac{P_o}{P} \qquad \text{—— (6)}$$

where P_o is the intensity of the incident radiation beam, P is the intensity after absorption by sample components, and **a** is a factor characteristic of the species. Using this relationship, a wavelength of radiation which is strongly absorbed, and 'a' values determined by calibration with standards, one can make a quantitative evaluation of the amount of pure substance present.

From a study of the absorption spectrum (usually covering the wavelength range 2 to 10 um) of a normal air sample, one can identify peaks which indicate the presence of particular chemical groups in the sample (e.g., -C- ; $-NH_2$; -CH-CH-). Almost equally important is the negative information that can be derived. For example, if no strong absorption bands are observed between the wave numbers 1600 and 1800 cm^{-1} (wavelength 6.26 and 5.55 μm), the presence of carbonyl groups can be ruled out and this eliminates from consideration all ketones, aldehydes, organic acids, esters, and similar compounds. The absence of bands above 3200 cm_{-1} (i.e., wavelength $< 3\ \mu m$) permits elimination of the presence of alcohols, amines, amides, and other substances.

The need for efficient separation procedures may become more apparent if one considers the composition of a material which has been widely investigated in recent years, namely, cigarette smoke. The solid components of the smoke are mainly tar and nicotine (an alkaloid) with some suspected carcinogenic compounds (such as benzpyrin and catechol) present as minor components. In the gas phase a wide range of compounds have been identified, including carbon monoxide (16000), acetaldehyde (1000), acetic acid (600), formic acid (500), nitric oxide (400), hydrogen cyanide (300), nitrogen dioxide (200), acetonitrile (140), phenol (120), ammonia (100), butadione (50), formaldehyde (40) and hydrogen sulphide (10). The values in parentheses indicate a relative or average concentration (expressed in the units μg/cigarette).

Besides the techniques mentioned in the preceding examples, others such as microtitrations or electrometric measurements are in widespread use. For example, fluoride vapors are scrubbed from gases with an alkaline solution, separated from interferent species by selective distillation, and finally determined by means of an ion-selective electrode.

For accurate, quantitative measurements of the trace components present in a given gas sample, it is necessary to have skilled operators, high-quality equipment, and efficient calibration. Unfortunately, the development of sensitive detectors for trace atmospheric pollutants has far surpassed the facility to calibrate them accurately.

In the past, standard gas mixtures (in the ppm range) were most conveniently prepared by mixing an aliquot of pure component with a large volume of diluent gas. The reliability of this method depends on the accuracy with which aliquot and diluent may be measured, the mixing compatibility of the components, and the magnitude of any surface adsorption losses, or chemical interaction effects.

A newer method makes use of the ability of gases or vapors to permeate through Teflon tubing. The rate of permeation is a function of temperature, length and diameter of tube, and wall thickness; hence by operating under standard conditions, constant amounts of sample vapour can be added to a stream of diluent gas.

The analytical problems of air pollution monitoring are continually being resolved, and the errors in most cases are far below the variance of sample collection.

It is perhaps appropriate to conclude this brief introduction to air monitoring, with mention of a technique which has proved very useful for routine monitoring of a range of industrial vapours or toxicants, i.e., specific absorption tubes.

15.11. SUMMARY

The major environmental pollution are : (i) Air pollution (ii) Water pollution (iii) Pollution due to solid waste materials (iv) Noise pollution (v) Thermal pollution (vi) Nuclear radiation pollution. Therefore environmental monitoring and analysis are extremely useful and play a great role in policy formulations of any country. The primary sources of Air Pollution are (i) The fuel combustion in stationary and mobile sources (ii) Industrial processes (iii) Evaporation of organic substances like the paints, thinners, other volatile solvents and gasoline (iv) incineration (open-burning) of agricultural and other wastes generate pollutants like - CO, CO_2, SO_2 and flyash. (v) Grit and Dust suspended particulate materials in the air such as unburnt solid fuel, flyash, wind-blown dust etc. The water pollutants increase chemical oxygen demand, turbidity, total dissolved salts and suspended solid content in the water. Air particles in diameter range of 0.25 to 5 μm are effectively retained in the lungs and cause infections. Haze density readings are measured by a 'Nephelometer Unit'. Industrial processes can release very fine particles of a wide range of compounds like acid mist, asbestos, silica, lime, metal compounds etc. and the extremely small ($< 1\ \mu$m) lead bearing particles produced on combustion of leaded gasoline. These are monitored by using (i) Atomic absorption spectroscopy (ii) Flame photometry and microsampling technique.

Motor vehicle exhausts contain at least five components which pollute the atmosphere. They are lead compounds, carbon monoxide, sulphur dioxide, oxides of nitrogen, and unburnt hydrocarbons. Carbon monoxide and sulphur dioxide can be monitored by using suitable instruments.

The separation and identification of the hydrogen species is generally based on gas chromatography or mass spectrometry. There are minor components also which have greater impact on human beings. They can be subdivided into (i) Industrial toxicants (ii) Corrosive agents (iii) Phytotoxicants (iv) Lachrymators, (v) Allergins, alleylating agents, pesticides and carcinogens.

15.12. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Haze density readings are measured by a "Nephelometer Unit".
2. Lead compounds, carbon monoxide, sulphur dioxide, oxides of nitrogen and unburnt hydro carbons pollute the atmosphere.

15.13. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Explain the process of monitoring of pollutants in the Air.
2. Describe the process of carbon monoxide and sulfur dioxide.

II. Answer the following questions in about 10 lines each.

1. Write a note on sources of water pollution.
2. Discuss different methods used for data monitoring of pollutants.
3. Describe the process involved in monitoring hydrocarbons in exhaust gases.

Prof. S. Raja Ratnam.

DR. B.R. AMBEDKAR OPEN UNIVERSITY
FACULTY OF SCIENCE
P.G. DIPLOMA IN ENVIRONMENTAL STUDIES
COURSE IV A : PHYSICAL SCIENCES
MODEL EXAMINATION PAPER

Time : 3 Hours Max. Marks : 100

Section - A 4 X 15 = 60

Answer any four of the following questions.
Each question carries 15 marks.
Answer the following questions in about 30 lines each.

1. Write briefly about industrial Air Pollution.
2. Explain the term Mateorology and its role in Air Pollution studies.
3. Discuss about Automobile pollution control with specific examples.
4. Explain the sources of Industrial Effluents.
5. Describe different defluoridation techniques available along with the underlying principle.
6. Give a detailed account of the toxic substances likely to be thrown out from Agricultural practices and their ill effects.
7. What are the sources of Radioactive pollution?
8. What are the applications of Remote sensing in different fields?

Section - B 5 X 8 = 40

Answer any five of the following questions.
Each question carries 8 marks.
Answer the following questions in about 10 lines each.

1. What are the major hazards due to global warming?
2. How is Mercury poisonous to human beings?
3. Process change helps to control Air Pollution - Explain.
4. Define water pollution.
5. Explain about waste water treatment.
6. What is land pollution?
7. What is meant by incineration?
8. How do you control Noise Pollution?
9. Describe the process involved in monitoring hydrocarbons.
10. What are the effects of fluorine in higher doses to humans?

DR. B.R. AMBEDKAR OPEN UNIVERSITY
FACULTY OF SCIENCE

P.G. DIPLOMA IN ENVIRONMENTAL STUDIES
COURSE IV A : PHYSICAL SCIENCES

ASSIENMENT - 1

Time: 2 Hours

Note :

1. *Do not copy the answer directly from any of the books.*
2. *As far as possible, try to answer the questions independently in your own words.*
3. *If it is necessary to quote from any source, give the correct reference.*
4. *Use your own foolscap pages for writing the assignment.*
5. *Leave sufficient margin for the comments of the evaluator.*
6. *Completion of this assignment normally should not take more than two hours time*

I. Answer the following questions in about 30 lines each.

1. Write briefly about Industrial Air Pollution.
2. Explain the term Mateorology and its role in Air Pollution studies.
3. Discuss the Automobile pollution control with specific examples.

II. Answer the following questions in about 10 lines each.

1. What are the major hazards due to global warming ?
2. How is mercury poisonous to human beings ?
3. "Process change helps to control Air pollution". Explain.

DR. B.R. AMBEDKAR OPEN UNIVERSITY

FACULTY OF SCIENCE

P.G. DIPLOMA IN ENVIRONMENTAL STUDIES

COURSE IV A : PHYSICAL SCIENCES

ASSIGNMENT - 2

Time: 2 Hours

Note :

1. *Do not copy the answer directly from any of the books.*
2. *As far as possible, try to answer the questions independently in your own words.*
3. *If it is necessary to quote from any source, give the correct reference.*
4. *Use your own foolscap pages for writing the assignment.*
5. *Leave sufficient margin for the comments of the evaluator.*
6. *Completion of this assignment normally should not take more than two hours time*

I. Answer the following questions in about 30 lines each.

1. Explain the sources of Industrial effluents .
2. Describe different defluoridation techniques available along with the underlying principle.
3. Give a detailed account of the toxic substances likely to be thrown out from the Agricultural practices and their ill efects.

II. Answer the following questions in about 10 lines each.

1. Define water pollution.
2. Explain about waste water treatment.
3. What is land pollution ?

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P.G. DIPLOMA IN ENVIRONMENTAL STUDIES
COURSE IV A : PHYSICAL SCIENCES

ASSIENMENT - 3

Time: 2 Hours

Note :

1. *Do not copy the answer directly from any of the books.*
2. *As far as possible, try to answer the questions independently in your own words.*
3. *If it is necessary to quote from any source, give the correct reference.*
4. *Use your own foolscap pages for writing the assignment.*
5. *Leave sufficient margin for the comments of the evaluator*
6. *Completion of this assignment normally should not take more than two hours time*

I. Answer the following questions in about 30 lines each.

1. Define noise pollution ? Explain the sources of it.
2. What are the sources of Radioactive Pollution.
3. What are the applications of remote sensing in different fields ?

II. Answer the following questions in about 10 lines each.

1. What is meant by incineration ?
2. How do you control noise pollution ?
3. Describe the process involved in monitoring hydrocarbons in exhaust gases.

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PREFACE

This book deals with environmental biology included in the syllabus of P.G. Diploma in Environmental Studies offered by Dr.B.R.Ambedkar Open University. The topics included in this course generally cover the core area of the programme. The syllabus for the sake of convenience is divided into blocks each of which comprises a number of units. Each block generally covers a specific area of the subject. The units are written by the specialists in accordance with a format specially designed to enable the student to read and understand them without much difficulty. Each unit begins with a statement of its contents followed by objectives. Each unit has at its end summary, model answers for the questions given under check your progress and model examination questions. Three assignments are given at the end of the book and the student is expected to submit at least one assignment to the Coordinator/Asst. Director/Deputy Director of the concerned study centre.

This book deals with different aspects relating to various components of ecosystem, different types of Ecosystem, food chains and food webs, energy recycling by micro organisms, ecological succession etc. Various types of pollution such as air, water and soil and certain applied aspects of ecology such as soil management, forest wealth, silviculture, social forestry, water resources etc. are also included. Certain aspects of environmental physiology such as biological responses to osmotic condition, temperature as environmental factor, responses of animals to carbon dioxide and oxgen, biological effects of pollutants in addition to wild life management were also included.

The University hopes that this material will help the student to get acquainted with principal issues of biological environment. Critical suggestions for improving the text are most welcome and they will be incorporated in the future edition.

CONTENTS

BLOCK - I

ECOSYSTEMS

UNIT - 1 : COMPONENTS OF ECOSYSTEM

Contents

1.1. OBJECTIVES

After going through this unit, you will be able to:

* analyse the concept of ecosystem, and give a precise definition of the same,
* describe the abiotic components of the ecosystem,
* describe the biotic components of the ecosystem, and
* describe the relation between abiotic and biotic components of the ecosystem.

1.2. INTRODUCTION

The earth contains a variety of life forms ranging from microscopic, one-celled, floating and drifting phytoplankton to the largest of all living things, the giant *Sequoia* tree of Western North America. But none of these life forms can exist by itself. Each life form depends upon other life form(s) and the physical and chemical environment. It is the science of ecology that tries to study the inter-relationships between the various life forms and their environment. Ecology is concerned especially with the biology of groups of organisms and with functional processes of lands, in the oceans, and in fresh waters. This concept is given much emphasis and has led Eugene P. Odum(1971) to define ecology as the "study of the structure and function of nature". The definition treats both the life forms and the environment as an integral unit or an area functioning in coordination with their non-living environment. Odum further expresses that ecology is to be considered in terms of the concept of levels of organization. All matter found in nature is considerd as being organised in identifiable patterns or levels of organisation according to size and function. The three lowest levels of organisation of matter namely, sub-atomic particles, atoms, molecules make up the basic components of all higher levels. The five higher levels of organisation of matter namely, organisms, population, communities, ecosystems, and the ecosphere form the major concerns of ecology.

1.3. ECOSYSTEMS: MEANING AND DEFINITION

Ecology focusses on the levels of organisation beyond that of organism. Any form of life is an organism. A population is a group of organisms occupying a particular location. Each organism or population has a habitat i.e., the place or type of place where it naturally lives. When several populations of different species live together and interact with one another in a particular location, they make up what is called a community, or biological community. The community and the chemical and physical factors making up its non-living environment function together as an ecological system or ecosystem. So to speak, an ecosystem is comoposed of all the living organisms in an area plus the surrounding physical environment with which they interact. The 'eco'part of the word is derived from the greek oik meaning habitat or environment, and the 'system' part also derived from Greek 'systema' meaning an organised unit of many diverse parts in regular interaction and interdependence. All the earth's ecosystems together make up the ecosphere or biosphere.

A consideration of the radio and its functioning will enable better understanding of what a system means. A radio consists of various transistors, transductors, wires, or speaker, and control knobs among other things. Each part has a specific function, but the expression of the function depends upon the proper functioning of all other parts. The whole system fails to function unless there is some kind of input from outside which the system can use to produce some output. The outside input for the radio is electrical energy on which the system acts to pick up certain radio waves which are transmitted as an output sound. Thus, the radio with all its parts working in coordination, functions as total systems.

The ecosystem is similar to the radio. Every organism has a specific role to play, and the term 'niche' refers to this role. Habitat is the place where the organisam lives. To speak in common language,' habitat'is the address of the organism and 'niche' is the profession.

The cocept of an ecological ecosystem is by no means recent. As early as 1977 Karl Mobius mentioned the term biocoenosis while describing the community of organism in an oyster reef. A decade later S.A. Forbes used the word microcosm as a synonym to biocoenosis. The Russisan ecologists placed much emphasis on the concept of biocoenosis during 1846-1903, who later expanded it to geobiocoenosis. Thus biocoenosis is roughly equivalent to community and biogeocoenosis to ecosystem.

Check Your Progress - 1

What is meant by an ecosystem?

Note: a) Write the answer in the space provided below.

b) Compare your answer with the one given at the end of this unit.

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1.4. COMPONENTS OF ECOSYSTEM

Ecosystem is the basic functional unit for ecological studies. It has a shape, size and life-span. It is a live unit and as such it functions and develops. Components of the ecosystem are potential energy and materials organised either into the body of living or dead organisms or into inorganic salts in the soil and water or else. A part of the material in free state as gases and moisture in the environment of the habitat. The various structural attributes of an ecosystem can be conveniently grouped under two major categories: 1) Abiotic or non-living components and 2) Biotic or living components.

Check Your Progresss-2

What are the components of the ecosystem?

Note: (a) Write the answer in the space given below

(b) Compare your answer with the one given at the end of this unit.

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1.4.1. Abiotic Components.

According to Odum (1971), the abiotic components are classified into three major categories. 1) Inorganic subtances (C,N,CO_2, H_2O, etc.) 2) Organic Components (proteins, carbohydrates, lipids, humic substances etc.) and 3) Climate regime and other physical factors. Tyler Miller (1986) treats the abiotic component under two categories. 1. Physical factors, and 2.Chemical factors.

The major physical factors are as follows:

1. Sunlight and shade
2. Average temperature and temperature range
3. Average precipitation and its distribution throughout the year
4. Wind
5. Latitude (distance from the equator)
6. Altitude (distance above sea level)
7. Fire and nature of soil for terrestrial ecosystems
8. Water currents and suspended solid material for aquatic ecosystems

The major chemical factors are as follows:

1. Level of water and air in soil
2. Level of plant nutrients, both inorganic and organic dissolved in soil water in terrestrial ecosystems and in water in aquatic ecosystems
3. Level of natural or artificial toxic substances dissolved in soil water in terrestrial ecosystem and in water in aquatic ecosystem.
4. Salintly of water for aquatic ecosystems
5. Level of dissolved oxygen in aquatic ecosystems

1.4.2. Biotic Components

The major types of organisms forming the biotic or living components of an ecosystem are classified on the basis of the general nutritional habits of the organisms. They are: (1) producers, (2) macro-consumers or phagotrophs, and (3) micro-consumers, saprotrophs or osmotrophs according to Odum (1971).

Producers represent the autotrophic components where as consumers form the heterotrophic components from the trophic relations of the ecosystem.

Producers : These are the organisms that are endowed with the capacity to manufacture their organic compounds used as sources of energy. These oganisms are thus autotrophic, meaning self-nourishing. Most producers are green plants including algae and phytoplankton which synthesize oganic compounds they require through photosynthesis, using radiant energy from sunlight, carbondioxide from air and water as an electron source. In the process, oxygen gas is given off and carbohydrates (sugars, starch, cellulose) are synthesised, and the radiant energy from the sun is converted into chemical energy and stored in the chemical bonds of the carbohydrates. These carbohydrates are the food source for most organisms. Apart from the green plants, algae, and phytoplankton, there are bacterial phototrophs which are anaerobic and do not carry out photolysis of water with the production of oxygen, and are thus anoxigenic. The electron source for these phototrophic bacteria is organic sûlphur, hydrogen or thiosulphate. Some other bacteria are also autotrophs but do not need sunlight for the assimilation of CO_2. The bacteria oxidise the inorganic substances (electron donors), the chemical energy released is used in the process of carbohydrate synthesis, the process is called chemosynthesis. The nitrifying bacteria, sulphur oxidising bacteria, iron oxidising bacteria, hydrogen oxidising bacteria and methylotrophs are all chemoautotrophs. All acid tolerant ecosystems are dependent on the CO_2 fixing ability of autotrophic Thiobacillus spp. for the supply of carbon.

Only producers can make their own food by using radiant chemical energy. They are therefore called convertors or transducers (Kormondy, 1969). They provided food directly or indirectly or for animals and microorganisms.

Macro - Consumers: The organisms getting the nutrients and energy they required by feeding either directly or indirectly on producers are treated as macroconsumers. They are also called phagotrophs (Phago=to ingest). The macroconsumers that feed on living organisms are further classified into three major groups depending on their food sources as given below.

Herbivores: These are designated as primary consumers. They feed directly on all or part of green plants. They are present in both terrestrial and aquatic ecosystems. In terrestrial ecosystem rodents and ruminants are the common herbivores, small crustaceans and molluscs in the aquatic habitats. Birds eat seeds, buds and foliage; they help in dissemination of seeds. Deer and rabbits eat twigs and leaves. Many insects eat all parts of plants. The elephant, goat, sheep, rabbit,cattle are all herbivores.

Carnivores : These are either secondary consumers feeding on herbivores, or the plant eating animals, or higher-level consumers which feed only on animal-eating animals. The carnivores not preyed upon further are called top carnivores which are exemplified by tiger, lion and vulture. In terrestrial system, spiders and birds that eat plant-eating insects are secondary consumers. Hawks which eat snakes are tertiary consumers. In aquatic system, sharks which eat other fish are tertiary or higher-level consumers.

Omnivores : These are the organisms which can eat both plants and animals. The pigs, foxes, rats, cockroaches, crows, etc are some representatives of omnivores.

The macro-consumers that eat particulate dead organic plant and animal matter or the detritus are generally the small animals. These are commonly referred to as detrivores or scavengers. The earthworms, crabs, small insects like termites, wood-boring beetles, carrion beetles are some of the detrivores. The detrivores are essential for quick breakdown of dead bodies of organisms.

Micro-Consumers : These are also known as the decomposers. These include bacteria, actinomycetes and fungi. These excrete enzymes to hydrolyse the organic matter in their environment. The enzymes secreted bring about the breakdown of complex organic substances into simpler, soluble compounds. Some of these decomposition products are absorbed by the microorganisms and incorporated into their cells, and some are released as inorganic nutrients to be used by the green plants.

Check Your Progress-3

What are the biotic components ?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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1.5. FUNCTIONAL PROCESS OF ECOSYSTEM

The structural components of the ecosystem are coupled with the functional processes of the ecosystem. Odum (1971) gives six processes to be considered from the functional stand-point of an ecosystem. These are detailed below :

A. Energy circuits : These are related to the initial trapping of radiant energy, and its transfer through different levels of biotic community. Without energy transfers there could be no life and no ecological systems.

B. Food chains : These are related to the transfer of food energy from the source in plants through a series of organisms in the communities with repeated eating and being eaten. An ecosystem comprises a series of interwoven food chains, known as food web.

C. Nutrient cycles : These are concerned with the movement of nutrient element, particularly inorganic compounds, in circular paths. Each cycle consists of two compartments or pools, the reservoir pool, and the exchange or cycling pool.

D. Diversity patterns in time and space : These are related to the changes in composition and complexity of the biological community in time and space.

E. Development and Evolution : This concerns with how the ecosystem with its living organisms and, physical and chemical environment develops and evolves to maintain a steady state.

F. Control or cybernetics : The ecosystem maintains functional balance or a state of equilibrium among its various components. This phenomenon is called homeostasis, and it is achieved through a number of controls or cybernetics.

Check Your Progress-4

How do the abiotic and biotic components of ecosystems are related?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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1.6. CONCLUSION

The structural and functional aspects of the eecosystem reveal that there is a one-way flow of energy from the high enery input of the sun through the producer/organisms, through consumers, and through decomposers, and into the thermal sink of space as low-quality heat. Nutrient elements are transferred from one organism to another, and modified as needed. The decomposers breakdown the complex organic chemicals in dead organisms and in living organisms to simpler inorganic chemicals for use by producers to begin the nutrient cycle again.

1.7. SUMMARY

Ecosystem consists of abiotic and biotic components interacting with each other to form a unified, steady state system. The abiotic components include inorganic and organic substances, and the climate. The biotic components include producers, mostly the green plants, macroconsumers, large and small animals, and micro-consumers, the bacteria, actinomycetes and fungi. Energy of the sun is trapped by the green plants and transformed into chemical energy. The energy thus trapped flows from producers, through the consumers and the decomposers into the thermal sink of space. Nutrients are transferred from one organism to another. When the organisms die, they are decomposed and the inorganic substances are released into the environment for use by the producers to begin the nutrient cycle again.

1.8. CHECK YOUR PROGRESS : MODEL ANSWERS

1. An ecosystem refers to the community of organisms and its chemical and physical factors functioning together.
2. The ecosystem consists of two major components, the living or biotic and the non-living or abiotic.

3. The biotic components are classified on the basis of general nutritional habits of the organisms into 1) Producers 2) Macroconsumers or Phagotrophs and 3) Microconsumers, saprotrophs or osmotrophs (Odum, 1971).

4. These components are coupled through the functional processes whih include energy circuits, food chains, nutrient cycles, diversity patterns, development and evolution and controls.

1.9. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Explain the concept of ecosystem.
2. Describe the different components of ecosystem.
3. Describe the biotic components of ecosystem, giving suitable examples.

II. Answer the following questions in about 10 lines each.

1. Who proposed the term ecosystem? Give a proper definition of ecosystem.
2. Describe the abiotic components of ecosystem.
3. Describe the producer component of ecosystem.
4. Describe the macro-consumer component of ecosystem.
5. Describe the functional processes of ecosystem.

Prof. A. Janaki Bai

UNIT - 2 : TERRESTRIAL ECOSYSTEM

Contents

2.1. OBJECTIVES

After going through this unit you will be able to :

* describe the general structure of terrestrial communities,
* define epiphytes, phanerophytes, chamaephytes, hemi-chamaephytes, cryophytes and therophytes,
* list out and describe the major terrestrial ecosystems.

2.2. INTRODUCTION

Ecosystem or ecological system has been defined as 'sum total of living organisms, the environment and the process of interaction between and within all parts of the system'. The ecosystem comprises the biotic community and the abiotic environment. Ponds, lakes, forests, deserts and grasslands are a few examples of natural ecosystem.

There are two important basic features governing the ecosystem and these are common to all types of ecosystems. Energy is required for all the living organisms in an ecosystem for their growth and sustenance. Although, the nuclear energy is available to man today, all living organisms derive their energy from the sun, with the exception of a few chemosynthetic bacteria, which can derive their energy from the chemical reactions. The solar energy, sustaining all life on our planet, reaches the earth in the form of electromagnetic waves, with different wave lengths. Chloroplast pigments absorb radiation from 330-740nm. Sun's energy stored in plant foods never return to the sun; also the food (energy)utilised by animals and man does not return to the plants, as the plants are incapable of deriving energy from organic compounds. Water, carbon, nitrogen, phosphorus and other minerals are constantly recycled in nature. They are utilised by plants, later by animals and when they die the minerals are recycled by the microorganisms, especially the bacteria. Thus, the ecosystem is mainly governed by the two basic features : 1. The one-way flow of energy and (2) Cycling of minerals.

The ecosystem comprises of four recognisable constituents : 1. Abiotic sustances (basic elements and compounds of the environment) (2) Producers (autotrophic organisms), (3) Macroconsumers (animals), and (4) the microconsumers or decomposers (heterotrophic bacteria and fungi). In view of the enormous importance, extensive studies of terrestrial, fresh water and marine ecosystems have been taken up for a 10 year period (1964-74) under the International Biological Programme (IBP). Similar studies are also being carried out under the Man and Biosphere Programme (MAB).

2.3. GENERAL STRUCTURE OF TERRESTRIAL COMMUNITIES

(a) **Autotrophs :** Large rooted green plants play an important role. They are the chief food makers. They also provide shelter for other organisms.

One of the most widely used classification of plant life forms of ecologists is the one proposed by Raunkaier (1934). It is based on the position of the renewal bud or organ and the corresponding protection provided during adverse environmental conditions. The six major life forms are as follows :

1. **Epiphytes :** Air plants; no roots in the soil
2. **Phanerophytes :** Aerial plants, renewal buds exposed on upright shoots. Five subgroups include; trees, shrubs, stem succulents, herbaceous stems and lianas (vines)
3. **Chamaephytes :** Surface plants; renewal bud at the surface of the ground.
4. **Hemi-chamaephytes :** Tussok plants; bud in or just below soil surface.
5. **Cryptophytes or Geophytes :** Earth plants, bud below surface on a bulb or rhizome.
6. **Therophytes :** Annuals, complete their life cycle from seed in one vegetative period; survive unfavourable periods as seeds.

(b) **Phagotrophs or Macroconsumers :** Which include animals, eating or ingesting other organisms or particulate organic matter.

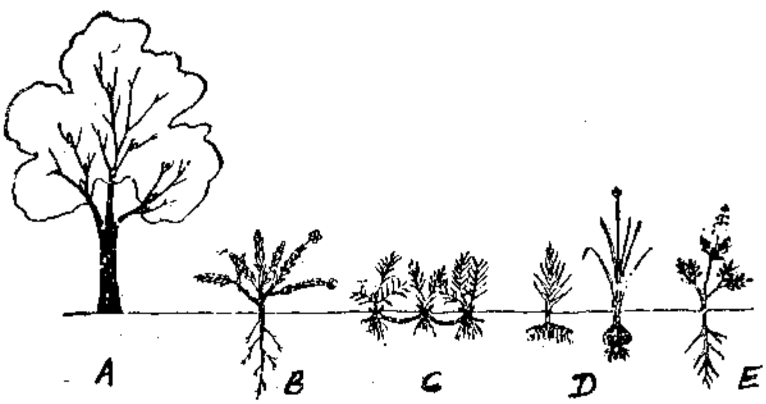

Fig. 2.1. Different life forms. A. Phanerophyte. B. Chamaephyte
C. Hemicryptophyte. D. Geophyte or Cryptophyte. E. Therophyte

(c) **Saprotrophs or microconsumers :** Include fungi and bacteria; heterotrophic and most of which decompose organic matter.

Abiotic Components : These include materials and energy (Odum, 1983). Materials are divided into three components : (1) inorganic substances (C, N, H_2O, P, K etc); (2) Organic compounds like protiens, carbohydrates etc which make the body of organisms and (3) climate (temperature and intensity and duration of light).

There are two broadly classified ecosystems: (1) Aquatic and (2) terrestrial (commonly called after the type of organism and habitat conditions, e.g., forest ecosystem, desert ecosystem etc). Ecosystems are also often referred to as biomes based on the occurrence in a large land area or region.

"Regional climates interact with regional biota and substract to produce large, easily recognisable community units called Biomes. In a given biome the life form of the climax vegetation is uniform. Thus, "the climax vegetation of the grassland biome is grasses, although the species of dominant grasses may vary in different parts of the biome" (Odum, 1971).

Biomes or ecosystems (or communities) may be classified as forests, deserts, grasslands, tundra and savanna. Latitude and altitude play an important role, influencing temperature and humidity regimes and in determining the distribution of terrestrial ecosystem. On the basis of latitude, Good (1953) classified forest biomes and they are given in Table 2.1.

Table - 2.1. Latitude, Altitude and Forest community

Latitude	Altitude (in meters)	Forest communities
0-20°	0-1000	Tropical
	1000-2000	Sub-tropical
	2000-4000	Temperate
	4000-6000	Alpine-Arctic
20-40°	0-1000	Sub-tropical
	1000-2000	Temperate
	2000 and above	Alpine-Arctic
40-60°	0-1000	Temperate
	1000 and above	Alpine-arctic
60-80°	in all altitudes	Alpine-Arctic and Anatarctic

Check Your Progress - 1

What are the six major autotrophic life forms?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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2.4. MAJOR TERRESTRIAL ECOSYSTEMS

Forest ecosystem can be considered as the extreme type in the biosphere, because of the importance in relation to biomass and physcial and biological regulation. Again forest ecosystem types are classified as - Tropical rain forest, temperate rainforest, Tropical, sub-tropical and deciduous forests and montane and boreal coniferous forests.

2.4.1. Tropical Rain Forests

This biome comprises of vegetation in its peak, with very well developed canopy. The annual rainfall is not only high (200 to 2250) but evenly spread through out the year (9-10 months). The relative humidity is also very high. As there is no prolonged adverse season, the biome remains evergreen although the year and the canopy is never naked. The trees may reach a height of about 20-40 meters. This ecosystem is very rich in flora and fauna; about two to three hundred different plant species occuring in a sq.km.

Under the canopy of dominent trees, several plants can grow in shade on the ground layer. These include many plant species belonging to Scitamineae, Piperaceae, Urticaceae, Aracaceae, Rubiaceae, mosses and variety of ferns. Epiphytes (autotrophic serial plants) are predominantly cover the crowns of large trees. Orchids and ferns are the dominent epiphytes. Lianas are common. The soil also supports many saprophytic microorganims (including large mushrooms) and fauna (Termites are abundant). The net primary production is high (about 30 tonnes/acre/year).

Tropical rain forests are found in India (Assam, Meghalaya, Arunachal Pradesh, Karnataka, Tamilnadu and Kerala), South America (Amazon river basin), East indies, south-east Asia and in some parts of Africa and Australia. In India, the trees in Tropical rain forests show luxurient growth, often reaching greater heights (about 200 ft.). Most commonly encountered tree species in Indian forests include *Dipterocarpus indicus, Hopea parviflora, H. wightiana, Calophyllum elatum, C. tomentosum, Cedrella toona, Callunia excelsa, Artocarpus hirsuta, A. integrifolia, Sterculia elata, Hidnocarpus sp* and others. One important aspect with this type of foress is that it is very difficult to regenerate the vegetation, once destroyed. The rain forests are classified as 1. moist tropical, 2. montane subtropical and 3. montane wet temperate forests.

2.4.2. Temperate Rain Forests

Temperate rain forests are found in the North America (north-western pacific coasts), in southern Chile, the west coasts of New Zealand and Tasmania. In India, usually these forests are seen above 1600 metres altitude (Himalayas and Nilgiries). The amount of rainfall during winter is an important factor. The annual precipitation may be as high as 800 cm (in New Zealand) or 350 cm (in North America) including snow. The most dominant coniferous trees include *Pseudotsuga menziesii* in the southern part and *Sequoia semipervirens* (red wood) in southern part of USA. In New Zealand, *Podocarpus dacrydiodes and Dacrydium cupressinum* are the predominant trees. In addition *Picea bitchensis Thuja plicata, Tsugo heterophylla,* are commonly seen in temperate forests. Species of *Abies, Larix* and *Pinus* are also found, accumulating a biomass of about 2000 tons per hectare. These trees live for more than 500 years.

The red wood tree, the tallest, grows upto 100 metres or above and its life span is from 1000 to 2000 years. The girth of the wood is so wide. A restaurant has been carried out on the tree trunk in USA attracting many visitors. Epiphytic Bryophytes and ferns are also seen. Mycorrhizal fungi play very important role in nutrient dynamics; in *Alnus spp* actinorhizae help in Nitrogen fixation.

In the temperate forests, two types of biomes are recognised : (1) evergreen biome (canopy is never naked; leaf fall continuous); (2) deciduous biome (usually in March-April leaf fall is more resulting in naked canopy for a brief period).

In Eastern Himalays in India, the Temperate zone extends from 5000 to 12000 ft where the lower belt (5000-9000 ft.) comprises of deciduous forests harbouring common trees like *Quercus lamellosus, Q.lineata, Q. pachyphylla, Michelia exelsa, Eugenia sp., Cedrela bucklandia,* maples, alder, birch and others. The upper belt (9000-12000 ft.) is temperate zone with conifers like *Abies sp., Picea marinda* (spruce), *Larix griffithii, Tsuga brunoniana* and others. Rhododendrons, Junifers and dwarf willow plants include the shrubby vegetation.

Check Your Progress - 2

What are the two types of Biomes in temperate forests?

Note: (a) Write the answer in the space provided below

(b) Compare your answer with the one given at the end of this unit.

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2.4.3. Tropical Deciduous Forests

The trees in these forests shed their leaves, hence are deciduous. The summers are warm, winters cold and rainfall ranges from 75 cm to 100 cm. Most important tree genera present in tropical deciduous forests of India are *Terminalia, Pterocarpus, Michelia, Emblica, Syzigium, Odina, Dillenia, Artocarpus latifolia, Boswellia serrata, Diospyros melanoxylon, Buchnania lanzan* and *Dalbergia* spp are very common. These are all timber yeiding plants. Besides, the important timber trees *Tectona grandis* and *Shorea robusta* are present in moist regions; *Bambusa* spp are also common. The decomposition rate is high and the primary productivity is also high.

In addition, Boreal coniferous forests (also called the north woods) comprising of *Picea glauca, Abies balsamea, Pinus resinosa,* and *P. strobus* are also present. In Eurasia, these forests are known as Taiga forests. The chaparral forest is a 'fire type'; it is naturally subjected to fires and adapted to such factors. These are found in Chile, California (USA) and western Australia. The vegetation comprises of small trees, large shrubs, herbs with underground stems. Rodents and reptiles are the main consumers.

In all types of forest ecosystems, the food chain comprises of plants, which are grazed by herbivores, which in turn are predated over by a carnivore; again another carnivore may attack the primary carnivore. After death, all are decomposed by soil microorganisms.

2.4.4. Grassland Ecosystem

Grasslands are commonly seen in temperate regions. The vegetation is predominantly grasses, legumes and members of compositae. Those are referred to as 'prairies' in North America, 'steppes' in Euracia, 'Pampas' in South America, 'Puszta' in Hungary and so on.

Grasslands, occupying 20% of the land surface of this planet, can be recognised into 3 types: (1) Temperate, (2) Alpine and (3) Tropical.

Temperate grasslands occur, where rainfall is about 75 cm per year (e.g., Europe, North America and Asia). Alpine grasslands are found at higher altitudes. In India, *Deschampsia sp* is commonly found in alpine and subalpine regions of Kashmir, Himachal Pradesh, Assam, U.P. and West bengal. *Arundinella sp* is associated with temperate climate (e.g., H.P., Punjab, Jummu and Kashmir and Assam). Tropical grasslands are situated 20° away from the equator. The rainfall ranges from 40 to 100 cm. White (1957) divided Indian grasslands into 8 major types. Four main types of grass cover have been recognised in our country (Dabadghao and Shankernarayan, 1973), which are as follows :

(a) **Sehima - Dichanthicum type:** This is present in Peninsular south India, dominated by the two grass species. The shrubs include *Mimosa rubicaulis, Acacia catechu* and *Euphorbia spp.*

(b) **Dicanthicum - Cenchrus - Lasiurus type :** In addition to these three grass species, several others are also found in parts of Gujarat, Rajasthan, Delhi, Punjab and West U.P. The shrubs include few legumes, *Acacia senegal, Calotropis gigantea, Prosopis cineraria* and *Salvadora sp.*

(c) **Phragmites - Saccharum - Impertata type :** This is characteristic of sub-humid or humid regions of Gangetic plains. The other important grasses associated with the above grass species are *Dicanthicum sp, Bothriochola sp* and *Cynodon dactylon.* Common shrubs include *Zizyphus sp., Acacia arabica* and *Butea monosperma.*

(d) **Themeda Arundinella type :** This type is usually found in humid hills of Assam, Manipur, H.P. and Jammu & Kashmir.

In Western ghats and parts of Eastern Ghats, where the rainfall is more than 375 cm, the dominant grasses in grasslands are *Andropogon pumilus* or *Heteropogon contortus,* or *Eragrostis amabilis* (West of Eastern Ghats). Low rainfall grasslands (upto 125 cm) are present in Western Ghats (below 600 metres); these are dominated by *Heteropogon contortus, Apluda varia, Lophogon tridentatus, Aristida funiculata, Cymbopogon sp* and *Themeda triandra.* Large herbivores are characteristic consumers of grasslands. Man replaces these native herbivores with his sheep, cattle or goats. The tall grass prairies are the richest in nutrients and the most fertile in the world. The pH varies from neutral to alkaline.

Misra (1983) eminent ecologist of our country, regarded all tropical graslands of India as Savannas.

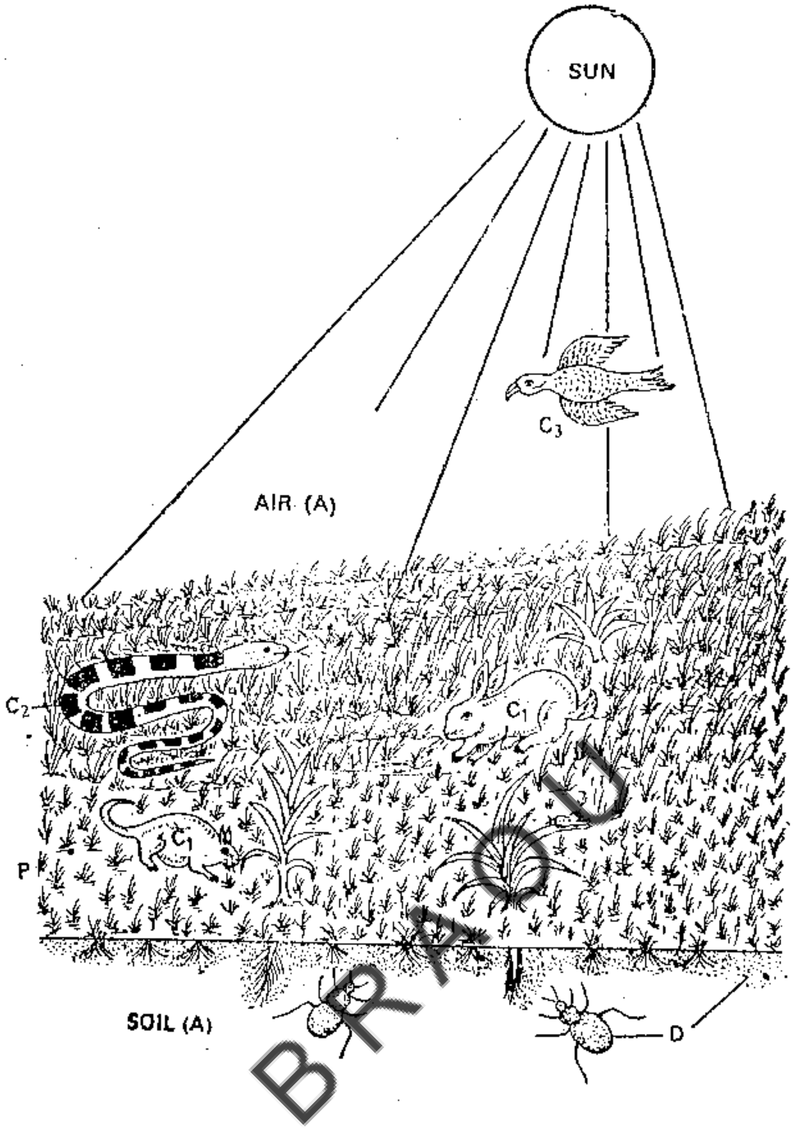

Fig.2.2. Food chain in a grassland ecosystem. A. Abiotic components. P. Producers. C_1. Primary Consumers. C_2. Secondary Consumers. C_3. Tertiary Consumers. D. Decomposers

2.4.5. Savannas

Tropical savannas are grasslands intermingled with small trees and these Savanna ecosystems are found in India, Africa and South America. Due to indiscriminate destruction of rain forests by man, the climate changes from mesic to xeric, thus, thorny shrubs become scattered. The common shrubs include *Acacia arabica, A. senegal, A. catechu, Mimosa rubicaulis, Calotropis gigantea, phoenix sylvestris* and *Zizyphus nummularia*. Due to the clearing of forests in Western as well as Eastern Ghats, *Andropogon pumilus or Heteropogon contortus* dominate above 600 m with rainfall above 375 cm or so; while in low rainfall areas, which are below 600 m, the savanna type grass lands are dominated by *Heteropogon ontortus, Apluda varia, Lophopogon tridentatus, Aristida funiculata, Thenuda triandra, Cymbopogan sp.* and others.

Check Your Progress - 3

What are tropcal Savannas? Where do you find them?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

2.4.6. Tundra Ecosystem

Tudras lie north of 60° N. These are treeless and are found between forests to the South and the Arctic ocean and Polar ice caps to the North. This is the Arctic tundra. Only a few species of grasses, sedges, low flowering herbs, and lichens are seen here. *Cladonia rangiferina,* the reindeer moss is the characteristic plant (lichen).

Very low temperature, low precipitation and permafrost are the important factors governing the ecosystem. It is heat that is in short supply. This type can best be described as a wet arctic grassland, which is in frozen state for a long period in a year. The net primary production is very low. But during the long daylight hours of the brief summer the primary production rate goes up; and this is of great help to the migratory birds. The resident consumers which are active althrough the year include animals such as reindeer, musk ox, caribou, wolves, polar bears etc.

Alpine tundras are also similar, but are found above the tree limit on high mountains. The soil is better drained and the growing season is longer. There is a gradual transition from arctic to alpine tundra.

In both the types of tundras, because of the slow decomposition rate, soils are rich in organic matter; plant species belonging to Caryophyllaceae, Compositae, Cruciferae, Cyperaceae, Gramineae and Rosaceae are the dominant ones.

Check Your Progress - 4

What is the most common lichen present in tundras?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of the unit.

2.4.7. Deserts

In desert ecosystems, the annual rainfall is less than 25 cm and as such the soil is dry. Deserts are seen all over the world, excepting in Europe. In India, deserts covering 2 lakh sq. miles are found in Rajasthan, parts of Gujarat and Haryana. Although some of the deserts receive some rain year after year, it is not uniform. The ground appears barren in some deserts, where there is no rain for several years.

There are two types of deserts: 1. Warm (hot) and 2. Cold (temperate). Thar desert in India, Sahara and Kalahari of America are important hot deserts. Deserts of Turkey, the Gobi of Mongolia and some in Argentina are considered as temperate ones.

In the desert ecosystem, large areas of land are barren, without any trace of vegetation. In some places, thorny shrubs and bushes grow. Succulent cacti, Euphorbiaceae members and *Agave* are the characteristic plants, Insects, reptiles (lizards and snakes), rodents are the consumers in deserts. The camel, commonly called the 'ship of the desert' is most significant desert animal, as it can survive drought conditions for several days. Camels help in transporting people and food. Primary productivity in deserts is low.

Various types of ecological modifications are seen in desert plants. Leaves are often reduced to scales or spines to reduce the loss of water through transpiration. Phylloclades help in food synthesis. Latex is present in many succulents and euphorbias. Waxy coating on the leaves, thick cuticle, epidermis in multiple layers sunken stomata (e.g., *Nerium*) are other important characteristics in desert plants (Fig. 2.3). In some plants (e.g., desert melon) the roots are 12m long and penetrate deep into the soil, searching for ground water.

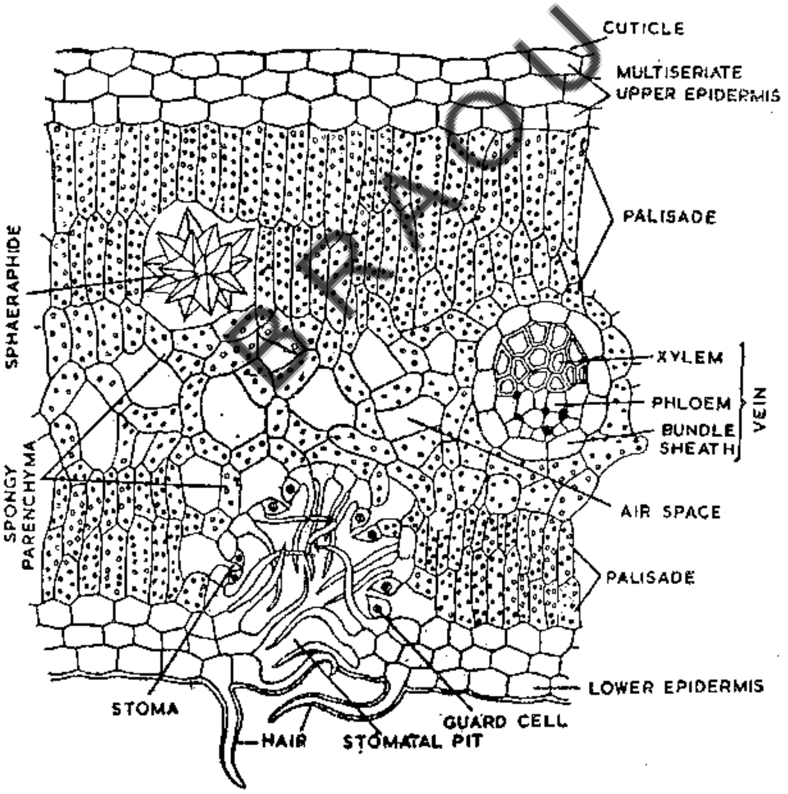

Fig. 2.3. Fig. 2.3. Section of *Nerium* leaf with multiseriate :n stomata and stomatal epidermis, sunken stomata and stomatal pit with hairs.

Plants are capable of making suitable adjustments to face the severe drought condition or the water stress. Photosynthetic activity decreases and aminoacid metabolism increases. It is of significance to note that proline, a free aminoacid, accumulates in the leaves of water stressed plants. The proline utilization also increases.

Xeromorphic adaptations and certain physiological properties help in drought resistance by xerophytes or the desert plants. In *Ruscus, Asparaius, Casuarina* and others the leaves are greatly reduced. Stems have smaller or no internodes. Often stems are modified into phylloclades (e.g., *Opuntia*).

Some of the most common xerophytes include *Acacia arabica, A. modesta. A. americana, Aloe vera, Argemone mexicana, Calotropis procera, Echinops echinatus, Euphorbia prostrata, Opuntia dillens, Solanum xantho-carpum, Tribulus terrestris, Zizyphus jujuba etc.*

Plants growing in extremely dry or arid conditions, like deserts are commonly called 'Xerophytes' Based on the habitat, the xerophytes are again recognised into the following four categories:

1. Plants growing in sand or small pebbles under dry conditions -***Psammophytes*** *(e.g., Acacia senegal)*
2. Plants growing on rocky surfaces - ***Lithophytes*** (e.g., Lichens, some *Selaginella spp.*, some *Euphorbia spp.)*
3. Plants growing on very cold soils; due to frequent freezing, water is not available to the plant - ***Psychrophytes*** (Plants restricted to Himalayas).
4. Plants growing on highly saline soils - ***Halophytes*** (or mangrove plants like *Avicinia spp. & Rhizophora spp.)*

Check Your Progress - 5

Give some examples for hot and cold deserts?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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Some plants have drought escaping machanism. Their vegetative and flowering life coincide with the favourable wet conditions. In the unfavourable period, the aerial parts die; some parts are buried in the soil and escape drought e.g., *Tribulus terrestris, Argemone mexicana, Solanum xanthocarpum, Echinops echinatus.*

Some plants exhibit an important adaptation to tide over drought under arid conditions. e.g., stem succulents and leaf succulents. Stem succulents include cacti. They possess succulent stems with spine like leaves. The anatomical features are well suited for greater reduction of transpiration. They use the stored water during relatively severe drought conditions. The cacti are slow growing due to lower rates of photosynthesis and transpiration. The stomata are closed by day and are open during the night. This is a feature peculiar to cacti and they produce acids during the night which decompose to form CO_2 in the presence of sunlight.

In Aloe and Agave, the leaves are succulent with a reduced stem. In *Bryophyllum* both the stem and the leaves are succulent. Succulents are definitely drought resistant.

2.4.8. Mangroves (Halophytes)

Although plenty of water is present, it is not readily available to these plants. This condition is referred to as physiological drought. Plants in saline habitats are under physiological dryness and are known as halophytes. Halophytes exhibit prominent xerophytic characters. In tropical and sub-tropical countries halophytes occupy regions near sea shore, forming densely packed trees, called magrove forests. Mangrove ecosystems are distributed all over the world. In India, mangrove ecosystems are seen in the Western and Eastern coast of India and the Gangetic delta (sunderbans) in Bengal. Pitchavaram near Tanjavur has beautiful mangrove forest. In Orissa, near Bhittar kanika sea coast and in Andamans, mangroves are present. The predominent plants found in mangroves are *Avicennia alba, A. officinalis, Acanthus ilicifolius, Rhizophora etc.*

The halophytes exhibit significant anatomical and physilogical modifications, often seen in xerophytes. The leaves are succulent, thick with predominantly developed palisade tissue and also epidermis is highly cutinised. Many plants develop prop roots, hanging down from the stem branches (e.g., *Rhizophora* sp.), and special negatively geotrophic roots arise from the normal subterranean roots. These are called pneumatophores and possess lenticels and aerenchyma with large intercellular spaces; they help in respiration (e.g., *Sonneratia sp.*).

Check Your Progress - 6

What is meant by physiological drought?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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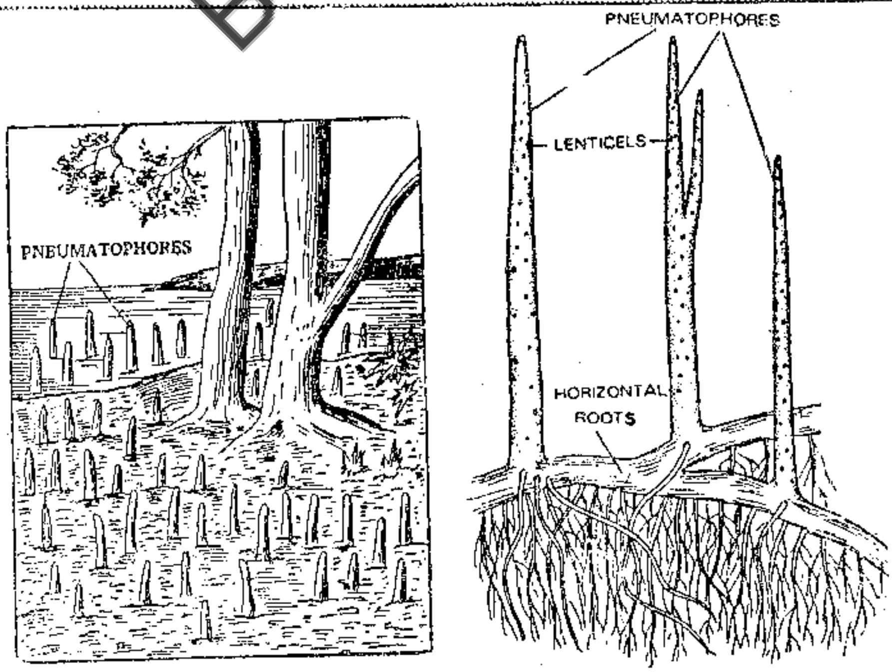

A B

Fig.2.4. Pneumatophores of Magroves. A. Several Pneumatophores arising m
t from the roots under the mud. B. Few pneumatophores showing lenticels

The interesting character of marshy halophytes is the process of germination of seed. The seed germinates while still it is attached to the parent tree. This type of germination is known as 'Vivipary'. In *Rhizophora,* the hypocotyl elongates to a length of 10-15 inches, pushing out the radicle before it falls down vertically into the marshy soil like a dart.

Mangroves are highly productive and the primary net production is usually high. Animals like snakes, lizards, turtles, jackals, hyaenas and tigers form the consumers.

2.5. SUMMARY

Ecosystem is nothing but the sum total of living organisms, the environment and the process of interaction between and within all parts of the system. The ecosystem comprises of biotic and abiotic components.

There are six major autotrophic life forms (food makers) in the environment. They are epiphytes, phanerophytes, chamaephytes, hemi-chamaephytes, cryptophytes and therophytes. The animals eating other organisms are called phagotrophs. The fungi and bacteria which decompose organic matter are called saprotrophs or micro-consumers.

The major terrestrial ecosystems are tropical rain forest, temperate rain forests, tropical deciduous forests, grasslands, savanna, tundra, deserts and mangroves.

2.6. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The six types of autotrophic life forms are epiphytes, phanerophytes, chamaephytes, hemi-chamaephytes, cryptophytes and therophytes.
2. The two types of biomes in temperate forests are evergreen biome and deciduous biome.
3. The grasslands intermingled with small trees are called Savannas. These are found in India, Africa and South America.
4. The commonly found lichen in Tundras is *Cladonia rangiferina* and it is commonly called reindeer moss.
5. The examples for hot deserts are thar desert in India, Sahara and Kalahari of America and the cold deserts are deserts of Turkey, the Gobi of Mongolia and some in Argentina.
6. Although plenty of water is present, it is not available to mangrove plants. This condition is called physiological drought.

2.7. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write briefly about the general structure of terrestrial communities.
2. Write a brief account on forest ecosystems.
3. Briefly write about grassland, Savanna and Tundra ecosystems.
4. Write briefly about desert and mangrove ecosystems.

II. Answer the following questions in about 10 lines each.

1. What are biotic components in an ecosystem? Write briefly about them.
2. Write briefly about tropical rain forests.
3. Briefly write about temperate rain forests.
4. Write a brief account on tropical deciduous forests.
5. What are the four main types of grass cover in India? Write briefly about them.
6. What are Savannas? Write a brief account on them.
7. What are two types of Deserts? Write briefly about desert ecosystem.
8. What is meant by physiological drought? Write a brief account on mangrove ecosystem.

Prof. Pannuri Rama Rao

UNIT - 3 : OPEN WATER ECO SYSTEM

Contents

3.1. OBJECTIVES

After going through this unit you will be able to:

* list out main categories of aquatic ecosystem,
* list out the major oceans and the components of marine waters,
* describe the various layers of ocean basin,
* list out the five machanisms and conditions suggested by Odum that maintain the energy flow,
* list out different types of inland waters ,
* list out different types of plants present in different zones of inland waters,
* describe the pond ecosystem ,
* define and describe lotic waters.

3.2. INTRODUCTION

Aquatic ecosystems cover about three fourth of planet earth and play very important role in cycling of chemical substances. Further, they have profound influence on the activities of terrestrial ecosystems. Seas form the largest and the most stable ecosystem. Presumably, life originated in the seas. Three main categories can be recognised in aquatic ecosystems. They are: 1.oceans (salt water) 2. fresh water or inland waters, comprising of ponds, lakes, rivers etc. and 3. Esturine waters, which differ in the salt content. As such, salt content helps us in distinguishing aquatic ecosystem from the terrestrial ecosystem.

3.3. OCEANS OR MARINE ECOSYSTEM

The major oceans (Atlantic, Indian, Pacific, Arctic& Antarctic) occupy over 70% of the earth's surface. Of the total water resources avilable on earth, oceans comprise some 97.2% and inland waters occupy 2.8% only. Life in oceans, in some form or the other, extends to the greater depths in seas and as such the oceans are the largest and 'thickest' ecosystems. Sea water contains many mineral substances (3.5%), which are derived from the earth's crust. Sodium chloride is the major mineral in addition to salts of potassium, magnesium,calcium, boron, strontium, sulphur, silicon and others constitute the mineral component of sea water. The salinity varies from sea to sea, depending on the latitude. The temperature of surface sea water varies between 0° C (Arctic and Antarctic oceans) and 30° C (seen in equatorial waters).

Temperature influences the population densities of phytoplankton and zooplankton (Hansen in 1937 coined the terms 'which refers to floating organisms found in surface waters). Physical factors like waves, tides, currents,temperature, light intensity and salinity determine the biological communities.

The food chain of the sea begins with the minute autotrophs and ends with whales, giant fish, sharks etc. Oceans are rich in protein food and minerals. Now a days, 'Oceanography' (science dealing with physics, chemistry, biology and geology of the seas) is becoming increasingly popular in the universities in view of the importance of seas as valuable reservoirs of lost minerals from the earth, and also as regular in moderating the CO_2 and O_2 in the atmosphere, and principal sources of sea foods like fish, shrimps, prawns and edible algae.

Check Your Progress-1

What is meant by oceanography?

Note: (a) Answer your question in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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Based upon the abiotic and biotic features, the ocean ecosystem can be divided into three divisions viz., (i) pelagic environment (the open sea), (ii) benthic c environment (ocean bottom) and (iii) coastal waters. A diagramatic representation of the ocean environment is presented in fig.3.1

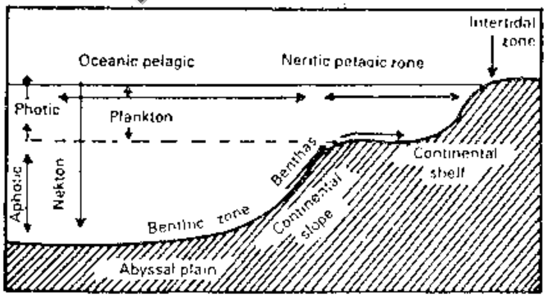

Fig.3.1. The oceanic environment and its stratification.

Coastal waters: The ocean basin is the form of an inverted hat with the gentle slope, *continental shelf* extending from the coastline to about 160 km. The slope becomes a steep slope and referred to as 'continental slope', which levels off with the floor of the ocean; this is called the *abyssal plain*, which is situated at a depth of thousands of feet. The *littoral* zone includes a narrow *intertidal* belt between the high and low tide lines. Littoral zone extends as sea floor from the shore to the edge of the continental shelf. The benthic environment comprises the sea floor beyond the littoral zone and along the continental slope and abyssal plain. The open water filling the ocean is divided into *neritic, pelagic and ocean pelagic zones*. In other words, the marine ecosystem is divisible into *tidal* and *neritic zones* and *continental shelf*.

The vertical zone through which sunlight can penetrate (up to 50m) is called the photic zone; this is the littoral zone and life is abundant here. In case the coast is rocky, brown, red and green algae grow luxuriantly. Planktonic life forms are also abundant. Primary productivity is much lower in marine ecosystem compared to terrestrial ecosystem. However, the estuaries are highly productive. The coastal waters harbour various types of animal life (crabs, chitons, starfish, limpets etc). *Fucus, Laminaria, Ulva, Enteromorpha, Grassillaria* are some of the sea weeds occurring in this zone.

The biotic community of the sea is classified as 1. Plankton, 2. Nekton and 3.Benthos. Plankton is divided based on their size: a) **Nannoplankton:** Phytoplakton includes diatoms, silicoflagellates, unicellular algae, zooplankton like protozoa and bacteria come under this category and their size is less than 0.06mm . b) **Microplankton:** Organisms, ranging in their size from 0.06m to 3.0mm are called the *Microplankton*. (c) *Macroplankton* includes oganisms larger than 3.0mm (jelly fish, mysids, salps etc.)

Nectons comprises of larger molluscs, crustacea, fish, turtles, sea birds and mammals. Most of them are plankton feeders. Many birds are capable of swimming and are surface dwellers feeding on fish and other oganisms. Mammalian fauna includes Dolphins,whales, seals etc which feed on plankton, fish, turtles and others.

Benthos includes the bottom dwellers. These are sessile forms (e.g., oysters, sponges, corals, hydroids, limpets, anemones, echinoderms etc. The creeping forms are known as the *epifauna* and the burrowing forms, the *infauna*.

Check Your Progress-2

What are the differences between nannoplankton, microplankton and macroplankton?

Note: (a) Write your answer in the space provided below

(b) Compare your answer with the one given at the end of this unit.

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Pelagic Environment or Open Sea: In this zone, the primary producers belong to the phytoplankton (diatoms, uni or multi-cellular algae, dinoflagellates). These organisms are distributed upto a depth of 70m. The vertical distribution depends upon the penetration of light, resulting in photosynthesis. In the oceanic pelazic zone, permanently dark zone is shown in fig.3.1 extending upto the end of continental slope and from here spreads the oceanic pelagic zone.

The Benthic Environment or Ocean Depths: This zone is cold and dark; producers are almost absent. The organisms, living in this zone, exhibit very special adaptations to survive under great water pressure, darkness and the carnivore food chain. Animals are usually black or red in colour and possess receptors or sensitive eyes. Some are capable of bioluminescence. Since the body in some is flat, the eyes uaually move to one side only. These oganisms are called benthos. *Macropharynx* a kind of fish, lives 3500 meters below the water surface. These are carnivores or detritus feeders. Fish, echinoderms, worms, molluscs and others are able to survive at the ocean depths. Marine pollution is an important problem as toxic chemicals and oil are discharged into the sea water. Mercury, cadmium, arsenic, zinc, cyanides, crude oils, foam forming detergents are being discharged continuosly. However, microbes present in seas are capable of degrading or depolluting some of them, but others cause serious problem.

3.4. ESTUARIES

Closely connected with the sea and the land lie a band of diverse ecosystem. Estuary refers to a river mount (coastal bay), where the salinity is less than sea water and more than fresh water. The tidal action in this region is an important regulator. The biological energy flow is often more here than the adjacent fresh water or sea. Odum (1963) has listed five mechanisms and conditions that maintain the energy flow. They are given below.

1. Tidal action promotes a rapid circulation of nutrients and food and aids in the rapid removal of the waste products of metabolism.
2. A diversity of plant species and life provides a continuous photosynthetic carpet despite variable physical conditions. The three major life forms of autotrophs that work together to maintain a high gross production rate are: (a) phyto-plankton (b) benthic microflora-algae living in and on mud, sand, rocks or other hard surfaces and bodies or shells of animals and (c) large attached plants- the sea weeds, submerged eel grasses and emergent marsh grasses.
3. An estuary is often an efficient nutrient trap that is partly physical and partly biological.
4. A year-round primary production by a succession of 'crops'.
5. Close contact between autotrophic and heterotrophic layers.

3.5. INLAND WATERS

Inland waters comprises of fresh water available in rivers, streams, lakes and ponds; also include artificial tanks. Inland waters can be grouped into two, depending on their habitats. They are Lentic or standing water and Lotic or running water.

Lentic Water: In the Lentic water bodies (lakes, ponds, ditches etc) three zones are recognised: (a) *Littoral zone* (shallow water region; light penetrates upto the bottom; rooted vegetation is present along the shore); (b) *Limnetic zone* (open water zone dominated by plankton; upto a depth of effective light penetration); (c) *Profoundal zone* (deep waters and bottom area; beyond the depth of effective light penetration, contains only heterotrophs).

Mesophytic herbs (e.g., *Polygonum, Rumex, Marsilea* etc) and phytoplakton are usually present in the littoral zone. Sedges are also present. Diatoms are the dominiating phytoplakton. Pond snails, dragon fly nymphs, rotifers, damsel fly nymphs, Hydra, flat worms and Bryozoans are the common consumers distributed in this zone. In addition, frogs, turtles, water snakes, diving beetles and others are also found.

The limnetic zone harbours the primary producers like Hydrophytes and phytoplankton (diatoms and dinoflagellates). *Lemna, Ceratophyllum, Utricularia, Wolffia* are the floating hydrophytes occurring in this zone. The submerged hydrophyes are *Hydrilla, Vallisnaria* and *Zannichelia*. A marked seasonal variation in the population of primary producers is seen; and the factors influencing the seasonal changes are temperature, pH of the water, availability of nutrients and the dissolved gases. Zooplankton and fish are the usual consumers of this zone. The Zooplakton also exhibits seasonal changes in population and also in their vertical distribution. *Cyclops, Diaptomus, Bosmina* and *Sida* are some of the common genera of Zooplankton.

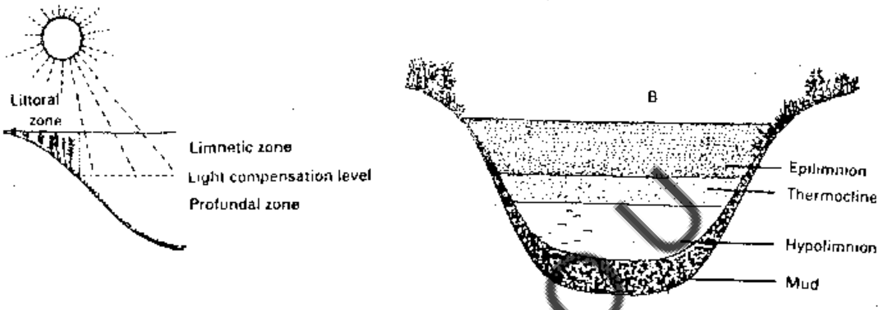

Fig.3.2. A. Three zones of lentic water. B. Thermal stratification in a lentic water body.

In view of absence of light, producer organisms are absent in the profoundal zone. Crabs, prawns, flat fish, midge larvae and others are the consumers present in this zone, consuming primary consumers of the upper two zones or detritus (Fig.3.2.).

Due to differential heating and cooling, lakes often become thermally stratified in summer and winter. In summer months, the surface water becomes warmer than the other zones; as such only the surface water circulates (Fig.3.2.). The surface warm water is referred as *epilimnion* and the colder bottom layer as *hypolimnion*. The upper water layer (emilimnion) and the bottom hypolimnion, get temporarily isolated in summer months due to the formation of a temperature gradient called the thermocline. As a result, thermocline acts as a barrier for exchange of materials; and does allow the supply of O_2 to hypolimnion and nutrients to epilimnion. Similarly, when the surface water cools to below 4° C during winter months, especially in temperate countries, the water freezes, preventing the circualtion. However, when spring and fall set in, the entire body of water attains the same temperature; mixes well and the ecosystem regulates. Due to the availability of nutrients, population density of phytoplankton increases leading to the formation of 'blooms'

Check Your Progress-3 & 4

3. What is meant by profoundal zone?

4 What is the difference between epilimnion and hypolimnion?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with those given at the end of this unit.

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Primary production in lakes depends on the depth, chemical nature and the nature of supplies from streams or land. Shallow lakes are more productive than deeper lakes, as the light penetration is more in the shallow ones. Lakes are classified as (1) *clear water* lakes and (ii) *brown water* lakes. Due to the presence of high humus and humic acid concentration, the waters turn brown in brown water lakes. Again, clear water lakes are often classified into three types: (a) oligotrophic (few foods) (b) eutrophic (good foods) and (c) mesotrophic (intermediate between few and good foods). Ecutrophic lakes are very rich in nutrients and help in the unwanted growth of microorganisms and hence, are considered polluted lakes. Oxygen becomes limiting factor and fish have to compete.

On the other hand, ponds are small water bodies with a large littoral zone. The limnetic zone may be small or absent. The same is the case with profoundal zone. Temporary ponds are formed during rainy season. No distinct stratification is seen in ponds.

In a pond ecosystem, abiotic subtances include water, O_2, CO_2, and other nutrients like nitrogen, phosphorus, potassium, calcium etc, dissolved in water. Many organic compounds like humic acid and aminoacids also occur in the bottom mud. Primary producers are phytoplankton (mainly algae like *Chlamydomonas, Euglena, Eudorina, Volvox* and *Diatoms*; larger algal genera like *Chara, Cladophora, Hrdrodictyon and Spirogyra* are common. Free floating and rooted aquatic angiosperms are present in shallow waters near the bank. The primary consumers (C_1) are zooplankton (water fleas, nymphs and other floating fauna). Small fish, frogs, rotifers and crustaceans are the secondary consumers (C_2). The top carnivores include larger fish, ducks, gulls and predatory birds like stark. The decomposers (fungi, bacteria, protozoans, worms etc) live near or in the mud at the bottom.

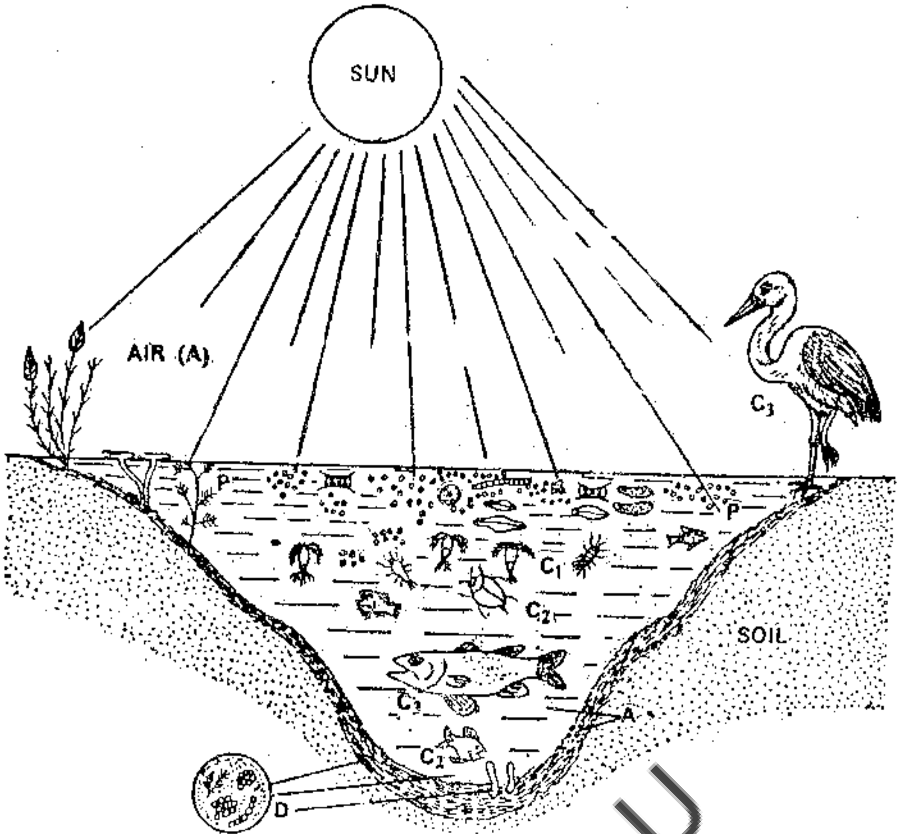


Fig. 3.3. Diagram of pond ecosystem.

Lotic Waters: Lotic waters are running waters and include rivers, streams, creeks, brooks etc. Rivers and streams are small when compared to seas; however, they are most useful to man for providing drinking water for transportation, for agriculture and waste disposal. The speed of river water becomes slow as they reach the plains. A number of rivulets join at a point to form into a big river. River bed and water volume increase; organic matter and sediments accumulate. The entire water body is exposed to sunlight, which can penetrate to the bottom. As such, there is no clearcut zones in river ecosystem.

Streams exhibit two types of habitat i.e., rapids and pools. The upper water habours plankton and nectons. The bottom of the pools harbour small benthic organisms. In rapids the velocity of water current is the limiting factor. The animals with the help of hooks or suckers remain attached to rocks or other substrates in rapidly flowing streams.

The primary producers are phytoplankton and the zooplankton and forms the primary consumers (herbivores). Secondary cosumers include snakes, turtles etc. In India, there are many rivers and the important are Ganges, Godavari, Krishna, Kaveri, Brahmaputra etc. The rivers are often polluted with dumping dead bodies, industrial effluents and other types of waste materials. Only recently, the Government agencies are trying to depollute the waters of Ganga river and Hussainsagar lake in Hyderabad.

For recreational purpose, man is constructing artificial ponds and lakes. These are required to be free of microorganisms, as man wants for swimming, boating and other recreational purposes.

Fresh water marsh ecosystem is similar to estuaries. They are very fertile. Indeed, rice cultivation, devised by man, is the most significant fresh water marsh ecocystem. Year after year the rice fields are flooded and drained to maintain the fertility and the higher yield.

Hydrophytes : Plants, with roots (when present) and with the whole or a part of the shoot, submerged in water, are known as hydrophytes. They can be recognised into the following categories:

1. **Submerged plants :** Examples are *Hydrilla verticillata, Elodea canadensis, Potamogeton spp., Utricularia, Vallisnaria, Zannichelia palustris etc.*

2. a) **Free - floating plants :** Examples are *Lemna polyrrhiza, L. paucicaustata, Eichhornia crassipes, Azolla imbricata, Pisita, Salvinia natans, Wolffia arrhiza, Ceratophyllum, Jussiaea repens, Neptunia etc.*

   b) **Floating plants with rhizomes/roots fixed to mud :** *Trapa bispinosa, Nymphaea lotus, Nelumbium speciosum, Victoria regia, Marsilea quadrifolia* are the examples

3. **Amphibious or Emergent plants :** Common examples are *Ranunculus aquatalis, Sagittaria, Alisma plantago, Pontederia, Limnophylla heterophylla, Myriophyllum heterophyllum etc.*

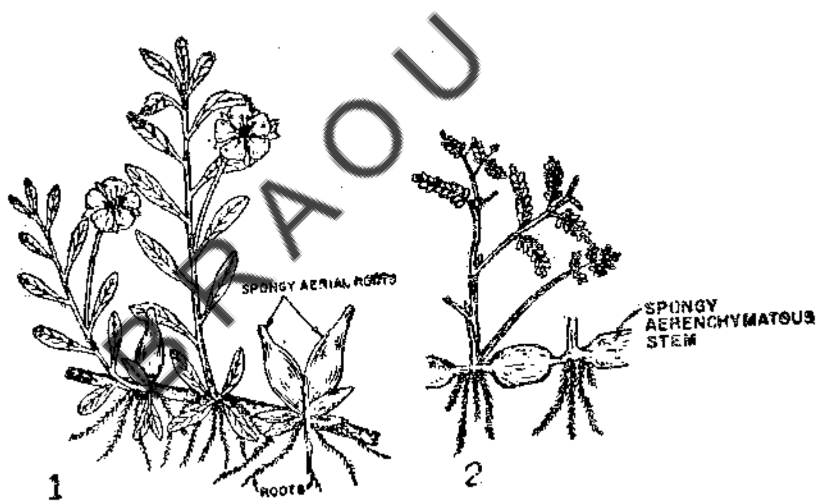
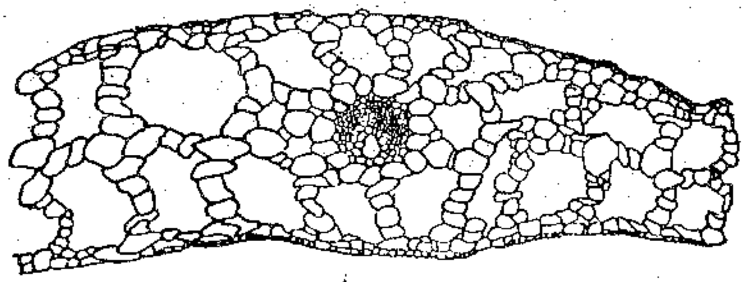


Fig.3.4. Free floating plants. 1. *Jussiaea* with spongy roots. 2. *Neptunia* with spongy stems. with spongy stems.

Transpiration is the main problem in submerged plants. Water is available in plenty. Excretion of water is by guttation through hydathodes (water pores). Hydrophytes exhibit various anatomical adaptations. The absorbing and conducting tissues are reduced to a minimum; mechanical tissues are also reduced or underdeveloped. The endodermis and pericycle are usually absent.

The roots are totally absent (e.g., *Utricularia, Wolffia, Ceratophyllum*); roots show limited growth and do not branch (e.g., *Lemna, Azolla*); do not possess root cap (e.g., *Eichhornia*); roots are devoid of root hairs (e.g., *Lemna*). Xylem elements are thin walled. Stomata are absent in submerged plants. The epidermis is thin and cuticle is absent. Sometimes the leaves are covered with mucilage. Aerenchyma is very prominent in stem and leaves (Fig.3.5)



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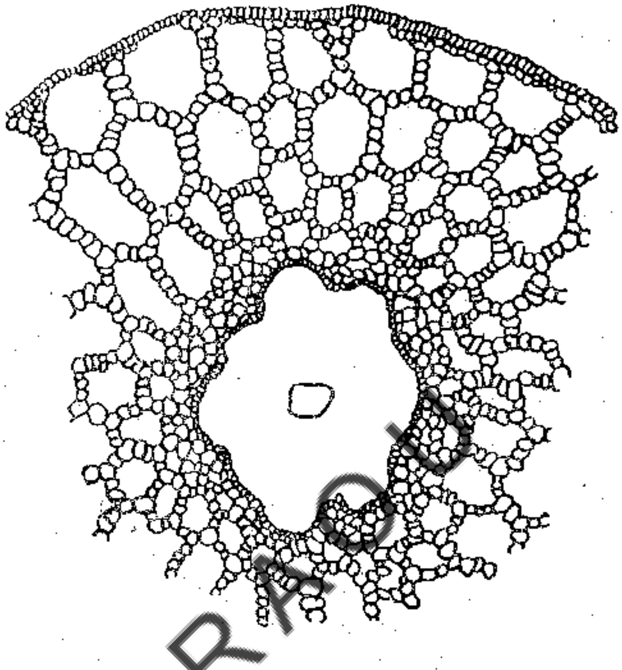

B

F Fig. 3.5. T.S. of leaf of Vallismeria showing Acrenchyma. of sterm of
P B. T.S. of sterm of Potamogeton showing prominent aerenchyma

Leaves often are very small and reduced (e.g., *Hydrilla*) and long and ribbon-like (*Vallisnaria*). Vegetative propagation is very common. *Eichhornia* reproduces by runners, while *Elodea* by fragmentation.

Amphibious plants have their roots, parts of shoots under water, but a large part of shoot is aerial. As they grow in two types of habitats, they exhibit a mixture of mesophytic and hydrophytic characters. Like mesophytes, they possess well developed conducting and mechanical tissue. They also possess, like the hydrophytes, large air chambers in submerged parts for better internal aeration. Due to presence of mechanical and conducting tissues, the plants grow erect and the green stem or the leaves grow vertically straight above the water level for photosynthesis.

The leaves of amphibious plants show morphologically different types of leaves (heterophylly), submerged leaves are thin, dissected, without cuticle or stomata *(Limnophylla heteropnylla, Myriophyllum sp.)*

3.6. SUMMARY

Aquatic ecosystem play an important role in the recycling of chemical substances. Seas are the largest ecosystem and it is assumed that life originated in the seas. There are three main categories in aquatic ecosystems and they are oceans, fresh water and Esturine ecosystem.

Oceans occupy 70% of the earth's surface and the major oceans are Atlantic, Indian, Pacific, Arctic and Antarctic. The oceans are the largest and thickest ecosystems. The waters contain many mineral substances and the major mineral is sodium chloride. Based upon the abiotic and biotic components, the ocean ecosystems can be divided into pelagic enviornment (open sea), the benthic environment (ocean bottom) and coastal waters. The Biotic Community is classified as plankton, necton and benthos.

Estuary is nothing but the river mount where the salinity is lesser than sea water and more than fresh water. The three major life froms of autotrophs in the region are phytoplankton, benthic microflora and large attached plants.

Inland waters comprise of fresh water available in rivers, streams, lakes, pond and artificial tanks. Inland waters are grouped into two categories i.e., lentic and lotic waters. Lentic waters are nothing but the standing waters and lotic waters are flowing waters.

3.7. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The science of dealing with physics, chemistry, biology and geology of the seas is known as oceanography.
2. The planktons which are less than 0.06mm are called nannoplankton and the planktons which are in between 0.06 to 3.0 mm are known as microplankton where as the macroplanktons are the organisms which are more than 3mm in size.
3. The profoundal zone is the zone beyond the depth of light penetration which contains only heterotrophs.
4. The surface warm water is referred as epilimnion and the colder bottom layer is known as hypolimnion.

3.8. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write briefly about the marine ecosystem.
2. Write a brief note on inland waters and their ecosystem.

II. Answer the following questions in about 10 lines each.

1. Briefly write about coastal waters.
2. Write briefly about the biotic community of the seas.
3. Briefly write about estuaries.
4. Write briefly about the ecosystem of lotic waters.
5. What are hydrophytes? Write briefly about them.

Prof. Pannuri Rama Rao

UNIT-4 : FOOD CHAINS AND FOOD WEBS

Contents

4.1. OBJECTIVES

After going through this unit you will be able to:

* define food chain and food web,
* list out and describe different types of food chains and
* describe different types of food webs.

4.2. INTRODUCTION

A greater part of life forms are green plants which produce food material from simple nutrients and these are called producers. The animals depend upon plants for their food material and they are called consumers. The consumers are classified into primary consumers (herbivores), secondary consumers which live on primary consumers and tertiary and quaternary consumers which live on secondary and tertiary consumers respectively. This chain of events where the living substance is exchanged from one form to the other is called food chain.

In natural conditions food chains never operate is isolated sequences. In the ecosystem the same organism may be present at more than one trophic level deriving its food from more than one source. Further same organism may be eaten by several organisms of different higher trophic levels of one organism may feed several other organisms of a lower trophic level. The food material or one organism may be changed with the age of the organism and also on the availability of food. Thus several food chains are operating together and intersecting with each other to form a web-like structure. This interlocking mechanism is known as food web.

4.3. FOOD CHAINS

The transfer of food energy from the producers, through a series of organisms (herbivores to carnivores to decomposers) with repeated eating and being eaten is known as food chain. Plants utilise the radiant energy of sun which is transformed to chemical form (ATP) during photosynthesis. Thus green plants occupy the first trophic level in any food chain. These are called primary producers. The food materials stored by green plants are utilised by the plant eaters -the herbivores-which constitute the second trophic level and these are called primary consumers. Herbivores inturn are eaten by the cornivores which constitute the third trophic level and these are called secondary consumers. These secondary consumers are still eaten by other carnivores at tertiary consumers level i.e., tertiary consumers. Some organisms are omnivores eating the producers as well as carnivores at their lower level in the food chain. Such orgnisms may occupy more than one trophic level in the food chain. The classification of all the living organisms of any ecosystem is one of their functions and not of species. Taxonomically widely different species such as *Typha, Nymphaea, Chara, Volvox, Nostoc,* Photosynthetic bacteria belong to the same trophic level - the producers level - as all have a common function i.e., the fixation of radiant energy into chemical form. In any food chain energy flows form primary producers to primary consumers to secondary consumers to tertiary consumers and so on. This simple chain of eating and being eaten is called food chain. A food chain in grass land ecosystem starts with grasses and goes through grasshoppers, frogs, snakes, hawks in an orderly manner based on the food habits. In a pond, it starts with phytoplanktons going through water fleas, smaller fish, bigger fish, birds, larger animals and so on.

The most simplified energy flow model of three trophic levels is given in fig 4.1. This diagram illustrates how energy flow is greatly reduced at each successive level

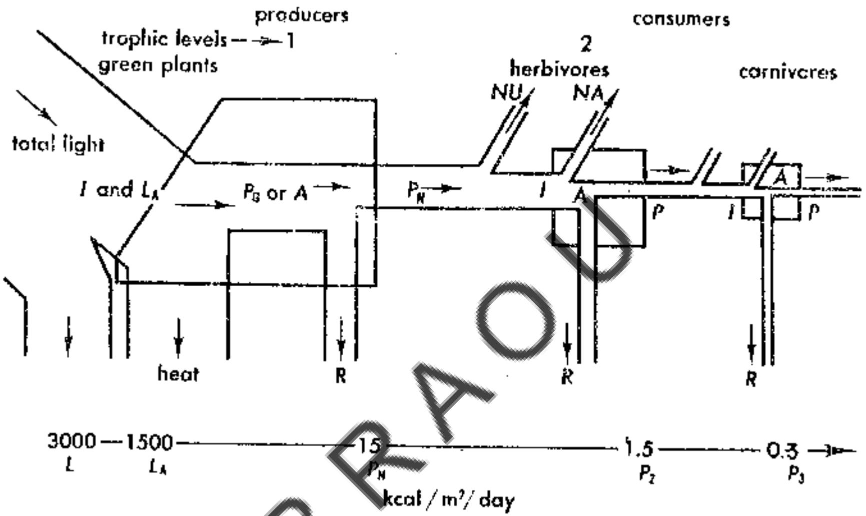

Fig. 4.1. A simplified energy flow diagram depicting three trophic levels (boxes numbered 1, 2, 3) in a linear food chain. Standard notations for successive energy flows are as follows: I = total energy input; L_A = light absorbed by plant cover; P_G = gross primary production; A = total assimilation; P_N = net primary production; P = secondary (consumer) production; NU = energy not used (stored or exported); NA = energy not assimilated by consumers (egested); R = respiration. Bottom line in the diagram shows the order of magnitude of energy losses expected at major transfer points, starting with a solar input of 3000 kcal per square meter per day. (After E. P. Odum, 1963.)

Check Your Progress - 1 & 2

1. What is the difference between Primary Pproducers and Primary Consumers?
2. What are Omnivores?

Note: a) Write the answers in the space given below.

b) Compare your answers with those given at the end of this unit.

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In nature two types of food chains can generally be distinguished. They are grazing food chain and detritus food chain.

4.3.1. Grazing Food Chain

Grazing Food Chain starts from the living green plants goes to the grazing herbivores and onto carnivores. This type of food chains in an ecosystem are directly dependent on solar radiation. The plants with the help of solar energy, water and carbondioxide prepare their own food material and store in different parts of it depending upon the plant. These stored food materials are consumed by the primary consumers viz., herbivores. These primary consumers are inturn are consumed by the carnivores. Most of the ecosystems in nature follow this type of food chain. These chains are very important from energy stand point. The grasses - rabbit-fox sequence in terrestrial ecosystem or phytoplankton - Zooplankton - fish sequence in aquatic ecosystem are the examples of grazing food chain.

4.3.2. Detritus Food Chain

Detritus food chain goes from dead organic matter into microorganisms and then to organisms feeding on detritus (detritivores) and their predators. Such ecosystems are not dependent or less dependent on solar energy. These depend chiefly on organic matter produced in another system. This type of food chain operates in the decomposing accumulated litter in a temperate forest. A good example of detritus food chain is based on mangrove leaves described by Heald (1969) and W.E. Odum (1970). In the brackish zone of Southern Florida the leaves of *Rhizophora mangle*, the red mangrove fall into the warm shallow waters. The fallen leaf fragments are acted on by certain fungi, bacteria, protozoa etc. are eaten and re-eaten by a key group of small animals such as crabs, copepods, insect larva, grass shrimps, mysids, nematodes, molluscs etc. All these animals are detritus consumers. These animals are then eaten by minnows and small game fish etc. i.e., the small carnivores which inturn are eaten by larger game fish. The mangroves which are generally considered as less economic value make a substantial contribution to the food chain that supports fishes which are the important economy in that region. Similarly in many esturine areas the seagrasses, salt marsh grasses and seaweeds support the fishes.

Check Your Progress - 3, 4 & 5

3. How many types of food chains are there ? what are they ?
4. Define grazing ford chain.
5. What is detritus ford chain ?

Note: a) Write the answers in the space given below.

b) Compare your answers with those given at the end of this unit.

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4.4. FOOD WEB

It is already mentioned that the food chains under natural conditions never operate as isolated sequences. They are interconnected with each other forming some sort of interlocking pattern which is referred to as a food web.

A simple food web in a grassland ecosystem is given below in Fig.4.2 in which there are five linear food chains interlocking with each other.

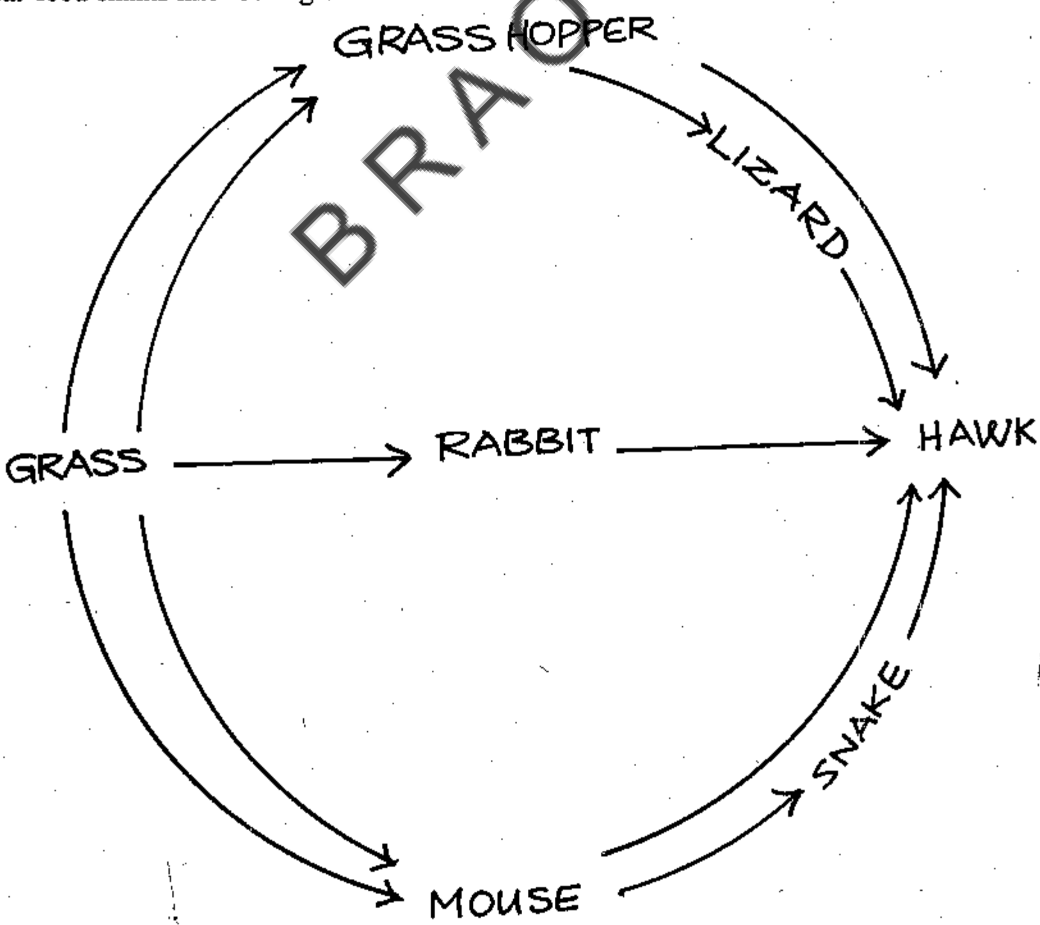

Fig. 4.2. A simple food web in grassland ecosystem.

The sequences in the five linear food chains are:

1. Grass ——> Mouse ——> Snake ——> Hawk
2. Grass ——> Mouse ——> Hawk
3. Grass ——> Rabbit ——> Hawk
4. Grass ——> Grasshopper ——> Lizard ——> Hawk
5. Grass ——> Grasshopper ——> Hawk

In addition to the organisms shown in fig 4.2, there may be some other organisms such as fox, valture, man etc. in a grassland ecosystem and if so, the food web may become more complex than the one shown in fig. 4.2. All these five food chains are interlinked with each other at different points forming a simple food web.

A similar food web in a pond with different interlinked food chains is shown in fig. 4.3. In nature the food webs are very very important in maintaining the stability in an ecosystem. For example decrease in the population of a herbivore like rabbit will naturally cause increase in the population of another herbivore, the mouse. This may decrease the population of the consumer which prefers rabbit.

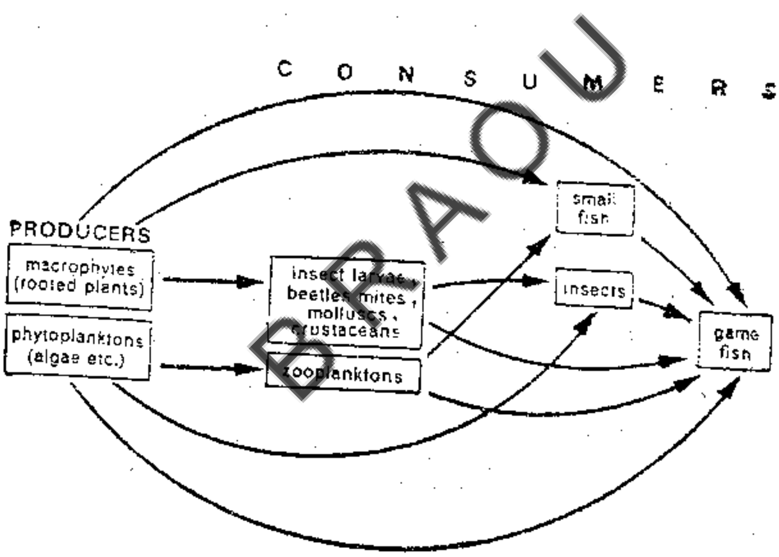

Fig. 4.3. Diagrammatic sketch showing the food web in a pond.

A balanced ecosystem is essential for the survival of all living organisms. For example, if the primary consumers had not been in nature, the producers would have perished due to over crowding and competition. In a similar way, the survival of the primary consumers is linked with the secondary consumers and so on. So, each species in any ecosystem is kept under some sort of a natural check to keep the system in a balanced state.

The complexity of any food web in an ecosystem depends upon the diversity of the organisms in the system. Accordingly it would depend upon two main points 1) Length of the food chain: Diversity in the organisms based upon their food habits would determine the length of food chain. More diverse the organisms in food habits, more longer would be the food chain. 2) Alternatives at different points of consumers in the chain: If there are more alternatives more would be the interlocking pattern. In deep oceans and seas where there are variety of organisms, the food webs are much complex.

A simplified diagram of an Arctic terrestrial food web is given in fig.4.4 and an Antarctic aquatic food web is given in fig.4.5. In both cases one can see the relative simplicity of ecologic system in the polar regions. This is one reason why ecologists like to work in polar regions. In these regions ecologic relationships are relatively simple and amenable to study.

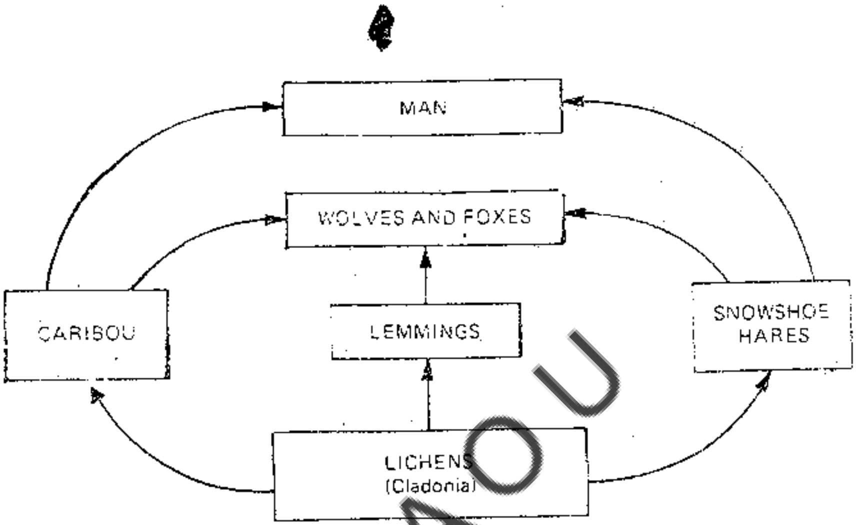

Fig.4.4. A simplified food chain for an Arctic terrestrial, ecosystem.

In the high arctic terrestrial ecosystem, the primary producer is represented mainly by lichens, a symbiotic combination of algae and fungi. These lichens form the main food for the primary herbivores *viz.*, caribou, lemmings and snowshoe hares. These inturn are the major foods for the predators such as foxes, wolves and man. However, this is not the complete story of life forms in the arctic terrestrial ecosystem. Other plants and animals are present as well including some flowering plants, musk oxen, birds, polar bears etc but all of them fit into a relatively simple trophic structure.

In the antarctic seas there is also a relatively simple trophic structure in which all primary productivity depends upon phytoplankton. The primary herbivore is a small shrimp, *Euphausia superba* which is also known as "Krill". These shrimps form the primary food source for fish, birds such as penguins and baleen whales. Baleen whales may also directly consume some of the phytoplanktons, thus forming omnivores.

The major predators at the top of the trophic structure are seals, squid, sperm whales, smaller toothed whales and man.

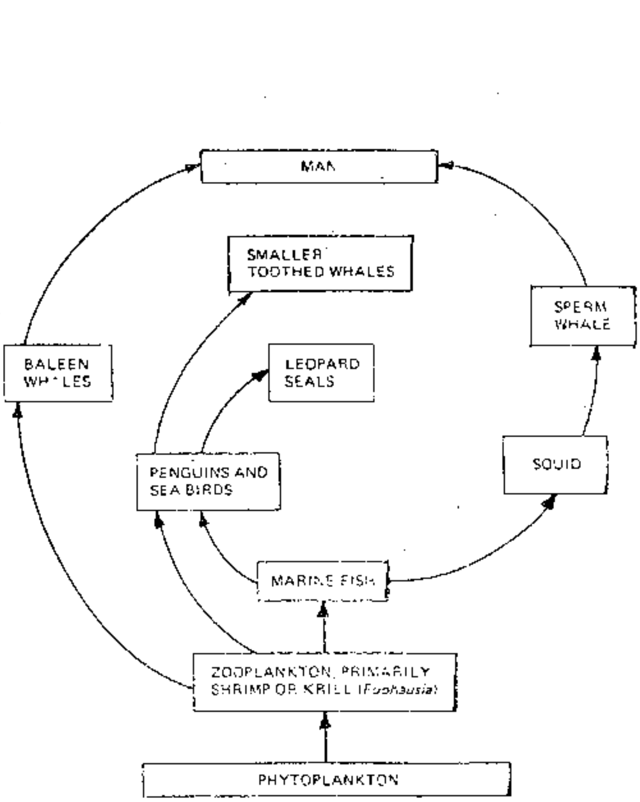

Fig. 4.5. A simplified food web for an antarctic aquatic ecosystem.

A food web which has been worked for small organisms of a stream community is shown in fig. 4.6. This diagram not only illustrates interlocking nature of food chains and three trophic levels but also brings out the fact that some organisms occupy an intermediate position between three major trophic levels. Thus the net spinning caddis feeds on both plant and animal material and is therefore intermediate between primary and secondary consumer levels.

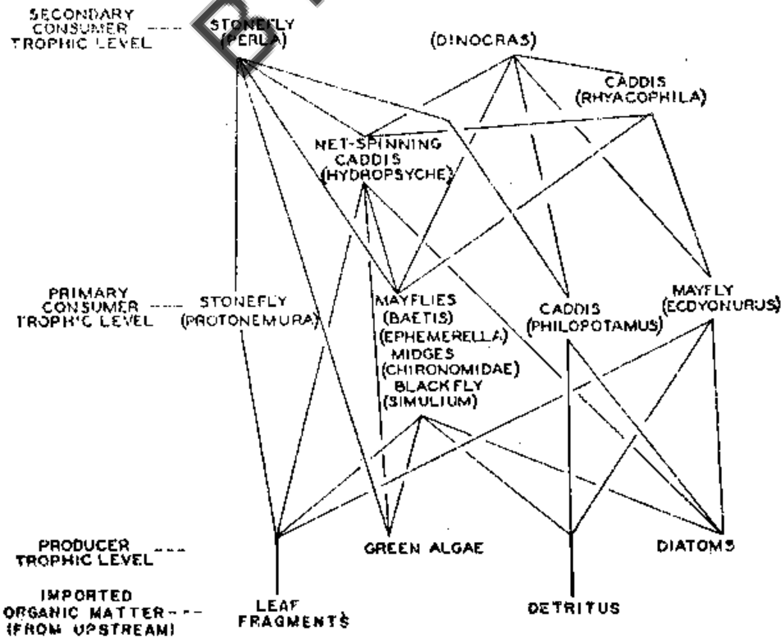

Fig. 4.6. ~~10~~. A portion of a food web in a small stream community in South Wales. The diagram illustrates: (1) the interlocking of food chains to form the food web, (2) three trophic levels, (3) the fact that organisms, such as *Hydropsyche*, may occupy an intermediate position between major trophic levels, and (4) an "open" system in which part of the basic food is "imported" from outside the stream. (Redrawn from Jones, 1949.)

Check Your Progress - 6 & 7

6. What is meant by food web?

7. What are the main primary producers in the arctic terrestrial ecosystem?

Note: a) Write the answers in the space given below.

b) Compare your answers with those given at the end of this unit.

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4.5. SUMMARY

The green plants produce food material from simple nutrients and these are called producers. The animals depend on plants for food and these are called consumers. The consumers are classified as primary consumers, secondary consumers, tertiary consumers and quaternary consumers. The chain of events where the living substance is converted from one from to the other is called food chain. Some organisms eat the producers as well as carnivores and these are called omnivores. Naturally the food chains never operate in isolated sequences. Several food chains are operating together and intersecting with each other to form web like structure called food web.

There are two types of food chains that occur in nature. They are grazing food chain and detritus food chain. The grazing food chain starts with living green plants, goes to grazing herbivores and onto carnivores. Most of the ecosystems in nature follow this type of food chain. The grasses - rabbit - fox sequence in terrestrial ecosystem and phytoplankton - zooplankton -fish sequence in aquatic ecosystem are the examples of grazing food chain. Detritus ford chain goes from dead organic matter into microorganisms and then to organisms feeding on detritus and their predators. These ecosystems depend chiefly on organic matter. The example for detritus food chain are mangrove leaves - fungi & batcteria - crabs, copepods etc. - minnows & small game fish - large game fish.

Food web is nothing but the interlocking pattern of several food chains. The complexity of any food web in an ecosystem depends upon the diversity of organisms in the system. Accordingly it would depend upon two main points viz., length of the food chain and alternatives at different points of consumers in the chain. In the arctic and antarctic regions the ecologic relationships are relatively simple and amenable to study. In the arctic terrestrial ecosystem, the primary producer is represented mainly by lichens, a symbiotic combination of algae and fungi. In the antarctic seas, there is also a simple trophic structure in which all primary productivity depends upon phytoplankton.

4.6. CHECK YOUR PROGRESS: MODEL ANSWERS

1. Green plants utilize the radiant energy of sun and produce the food material during photosynthesis. These green plants occupy the first trophic level in the food chain and these are called primary producers. These plants are consumed by plant eaters (herbivores) which constitute the second trophic level and these are called primary consumers.

2. Omnivores are the organisms which eat the producers and carnivores at their lower level in the food chain.

3. There are two types of food chains in nature. They are grazing food chain and detritus food chain.

4. Grazing food chain starts with living green plants goes to grazing herbivores and onto carnivores

5. Detritus food chain goes from dead orgnic matter into micro - organisms and then to detritivores and their predators.

6. Under natural conditions the food chains never operate as isolated sequences. They are inter connected with each other and form some sort of interlocking pattern called food web.

7. The lichens are the main primary producers in the arctic terrestrial ecosystem.

4.7. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write a detailed account on different types of food chains.
2. What is a food web? Write briefly about food web with examples.

II. Answer the following questions in about 10 lines each.

1. Write briefly about grazing food chain.
2. Briefly write on detritus food chain.
3. Write briefly about Arctic terrestrial food web.
4. Briefly write on Antarctic aquatic food web.

Dr. M. Ramachandraiah

UNIT - 5 : ENERGY RECYCLING BY MICROORGANISMS

Contents

5.1. OBJECTIVES

After going through this unit you will be able to :

* list out different nutritional types of bacteria,
* list out and describe various carbon fixation pathways,
* list out and describe various types of fermentations,
* describe the methods of degradation of fats, fatty acids, proteins, nitrogenous compounds, sulphur containing compounds, phosphorus compounds etc.,
* describe the method of formation of methane and its oxidation,
* describe the method of utilisation of carbon monoxide,
* describe the method of degradation of phenols,
* define and describe the formation of humus and decomposition of it.

5.2. INTRODUCTION

For growth all organisms require 30-40 elements for synthesis of cellular constituents and also an energy generating system consisting of essentially of an electron donor and electron acceptor. Under aerobic conditions oxygen will be the terminal electron acceptor, but under anaerboic conditions a variety of compounds are capable of replacing oxygen. Microorganisms recycle the energy in nature from one compound to the other and the balance is mostly maintained continuously.

Differences in the source of energy, i.e., electron source, are used to distinguish between various groups of microorganisms. Autotrophs are able to grow using either the energy liberated by the oxidation of certain inorganic compounds (chemosynthetic autotrophs) or the energy from light (photosynthetic autotrophs). Both can utilise inorganic sources of carbon and nitrogen. Heterotrophs use organic compounds as energy and carbon sources and in many instances the same compound serves both the purposes.

Fungi, most protozoa and many bacteria are heterotrophs. The nutritional requirements vary enormously according to the synthetic ability of the genus, species or even the particular strain. Many fungi can grow and sporulate satisfactorily with a sugar, simple inorganic or simple organic nitrogen source and mineral elements. The obligate parasites of plants such as rusts and smuts could not be cultured. The green algal flagellates in a suitable nutrient medium may loose their chlorophyll and change from photosynthetic autotrophs to heterotrophs. Other algae are also capable of heterotrophic growth in dark conditions but the range of substrates used is very much restricted.

The bacteria which are omnipresent are nutritionally the most versatile organisms ranging from photosynthetic to chemo-synthetic autotrophs. The bacteria are the most commonly occurring organisms and recycle the energy utilising all types of organic and inorganic material present around including the dead micro and macro-organisms. The recycling of energy by microorganisms utilising different resources are dealt in detail in this unit.

5.3. NUTRITIONAL TYPES OF BACTERIA

Based on the sources of carbon, the bacteria are classified as autotrophs and heterotrophs. Autotrophs which are also called lithotrophs are the organisms whose sole source of carbon is CO_2. They also require water and inorganic salts for growth. Different sources of energy is used to fix CO_2 and form various organic compounds. Autotrophs include both photosynthetic autotrophs and chemosynthetic organisms. The photosynthetic autotrophs (photo-lithotrophs) utilise energy from light and chemosynthetic autotrophs (chemolithotrophs) derive their energy from oxidation of inorganic material like iron, sulpur, ammonia and nitrite.

Heterotrophs which are also called organotrophs can not grow with CO_2 as a sole source of carbon and carbon should be supplied in organic form. The photosynthetic and chemosynthetic forms are also included in heterotrophs and they are called phtosynthetic heterotrophs (photoorganotrophs) which utilise light enegy and chemosynthetic heterotrophs which obtain energy from oxidation - reduction reactions.

5.4. CARBON FIXATION PATHWAYS

Three categories of carbon fixation pathways are recognised in autotrophic microbes. They are ribulose bisphosphate pathway, ribulose monophosphate pathway and serine pathway.

The organisms which are conventionally considered as autotrophs fix carbon dioxide present in the atmosphere through ribulose bisphosphate pathway or Calvin-Benson pathway.

$$6CO_2 + 18ATP + 12NADH_2 \dashrightarrow \text{Fructose 6 phosphate} + 18ADP + 12NAD + 18pi$$

The second type of pathway, the ribulose monophosphate pathway which is first detected in methane oxidisers by Anthony (1975) is also observed in pseudomonads, hyphomicrobia, yeasts etc. The essential features of this pathway is the oxidation of C_1 compounds to formaldehyde which serves as the prime carbon source for biosynthesis of other compounds.

The serine pathway has some common feature of ribulose monophosphate pathway in that the formaldehyde formed in oxidation of C_1 compounds is the primary source of carbon for biosynthesis. The serine pathway group includes methane and methanol oxidisers. All the three pathways are represented in fig. 5.1.

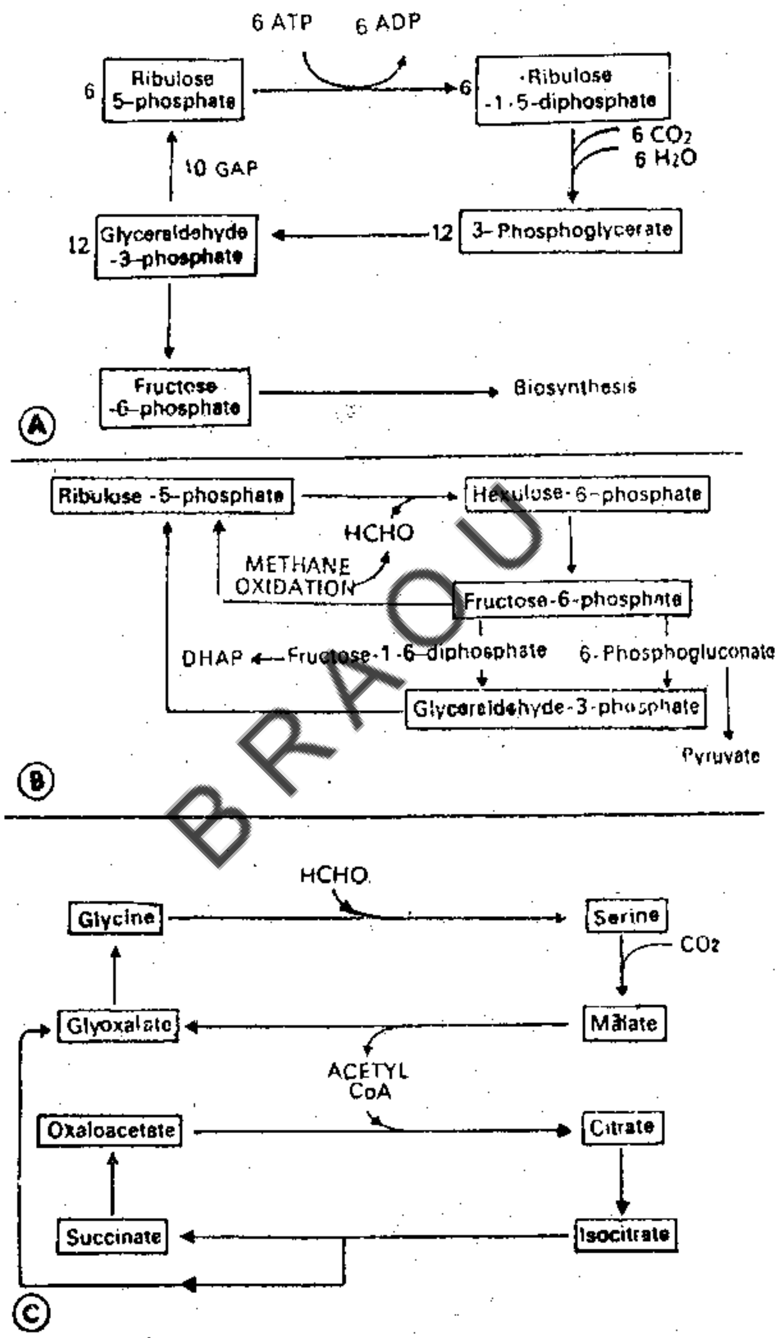

Fig. 5.1. Carbon fixation pathways.

The chemotrophs and hetertrophs play a vital role in the conversion of various inorganic and organic compounds.

5.5. DEGRADATION OF CARBON COMPOUNDS

The main types of carbon compounds added to the soil and aquatic system are plant and animal remains which contain high molecular weight carbon compounds. A very small portion of the total account for the soluble molecules. In the plant remains the high molecular weight compouds are cellulose, hemicellulose, lignin and starch in addition to smaller quantities of fats, waxes, oils, proteins and nucleic acids. In dead microorganisms and animals a similar range of high molecular weight compounds exists in addition to glycogen. In invertebrates and fungi the polymer, cutin occurs widely and in bacteria a chemically similar aminopolysaccharide is found. The other polymeric compounds account for a substantial part of the total carbon in these organisms. Hexoses such as glucose, fructose and mannose are taken up into the cell by means of specific permeases and are phosphorylated directly in the cell during transport with conversion into fructose-6-phospahte or glucose-6-phosphate. Disaccharides such as saccharose, lactose, maltose and cellobise are taken up and cleaved into monosaccharides (hoxoses) in the presence of disaccharide spliting enzymes viz., invertase, β -galactodase, maltase, cellobiase. Pentose are assimilated by few organisms. Pentoses like wood sugar (xylose) is converted into hexoses and part of them by transformation via transketolase system. Polysacharides such as starch, glycogen, cellulose, inulin and other glycons are not taken up by bacteria as such by the cell but are cleaved outside the cells by the secreted exoenzymes. The polysaccharides are degraded outside the cell to disaccharides or monosaccharides. Both these products will be taken up and subiected to further transformation by the cells.

Check Your Progress-1

Write three examples each for polysaccharides, disaccharides and monosaccharides.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

On the surfaces of the soil and also in the aquatic system, the residues are attacked not only by bacteria and fungi but also by animals which play a role in the dacay process. The examples are springtails, bark lice and earings. They also increase the surface area of the residues available to the microflora. Various types of worms present in the soils eat the partially decomposed material and transport into the soil proper. Further decay occurs in the guts of these animals as a result of action of the microflora in the guts.

Degradation of Monosaccharides: Glucose is not only the quantitatively predominant product of photosynthesis of microorganisms but also degradation product of high molecular weight carbohydrates. The degradation of glucose to pyruvate is the back bone of cell metabolism. It beigns with two phosphorylation reactions and the cleavage of fructose bisphosphate, then runs through an oxidation and two phosphorylation reactions ending with pyruvate. This pathway is known as glycolysis or Embden-Meyerhof pathway. Many prokaryotes use hexoses by a different pathway, Entner-doudoroff pathway. Becuse of its characteristic intermediate, it is also known as 2-keto-3-deoxy-6-phosphogluconate pathway. In both these pathways, the end product is pyruvic acid.

The glycolytic pathway which is represented in Fig.5.2. is an enzymatically controlled series of chemical reactions that beigns with a six carbon glucose molecule and result in the formation of pyruvic acid molecules. During the break down of glucose by oxidation-reduction reaction, energy is released for the formation of 4 ATP molecules. Because of the utilisation of 2 moles of ATP, one in the conversion of glucose to glucose-6-phosphate and another in the conversion of fructose-6-phosphate to fructose-1,6- bisphosphate, the net result is only 2 molecules of ATP. In addition to this, the hydrogen atoms removed from the orgaic molecules are transferred to the hydrogen carrying molecule, NAD^+ which may either carry the potential energy of the electrons to the electron transport system or to other organic reactions where energy is required.

Glucose
1 ↓
Glucose -6- phosphate
2 ↓
Fructose - 6 - phosphate
3 ↓
Fructose - 1,6-diphosphate
4 ↓ 5 ↓
3-phosphoglyceraldehyde ⇄ Dihydroxy acetone phosphate
6 ↓
1,3-diphopshoglyceric acid
7 ↓
3- phosphoglyceric acid
8 ↓
2- phosphoglyceric acid
9 ↓
phosphoenol pyruvate
10 ↓
pyruvic acid

Fig .5.2. Degradation of one molecule of glucose to 2 molecules of pyruvic acid by glycolysis. 2. Hexokinase. 3. Phosphohexoisomerase. 4. Phosphofructokinase. 5. Aldolase. 6. Triose phosphate isomerase. 7. Phosphoglyceraldehyde dehydrogenase. 8. Phosphoglycerokinase. 9. Phosphoglyceromutase. 10. Pyruvic kinase.

In Entner-Doudoroff pathway glucose degradation (Fig. 2.9b) which is the route used more frequently in bacteria for the degradation of hexoses (monosaccharides) and gluconate, 2 molecules of pyruvic acid is formed from 1 molecule of glucose or gluconate. In this pathway also energy is released for the formation of 4 molecules of ATP and only one ATP molecule is utilised in the coversion of glucose to glucose-6-phosphate. The net result is 3 ATP molecules. The hydrogen atoms removed from the organic molecules in this pathway also are transferred to the hyrogen carrying molecules NAD(P) and NAD.

Pyruvic acid formed in both these pathways is further oxidised during different reactions in Krebs cycle (citric acid cycle or tricarboxylic acid cycle) and Electron transport. The cycle begins after pyruvic acid (Fig.5.3.) has been oxidised to CO_2 and $NADH_2$ and Acetyl CoA. The two carbon acetyl molecule is chemically combined with Coenzyme-A and then moved into the cycle. This cycle results in the complete oxidation of the organic molecule to CO_2 and Hydrogen. The organic sugar molecule does not exist in any organic form after completion of the Krebs cycle and two ATPs are generated by substrate level phosphorylation (during the coversion of α-ketoglutaric acid to succinic acid) in addition to the reduction of NAD^+ and FAD^+ with hydrogen. These are later transferred to the Electron transport system.

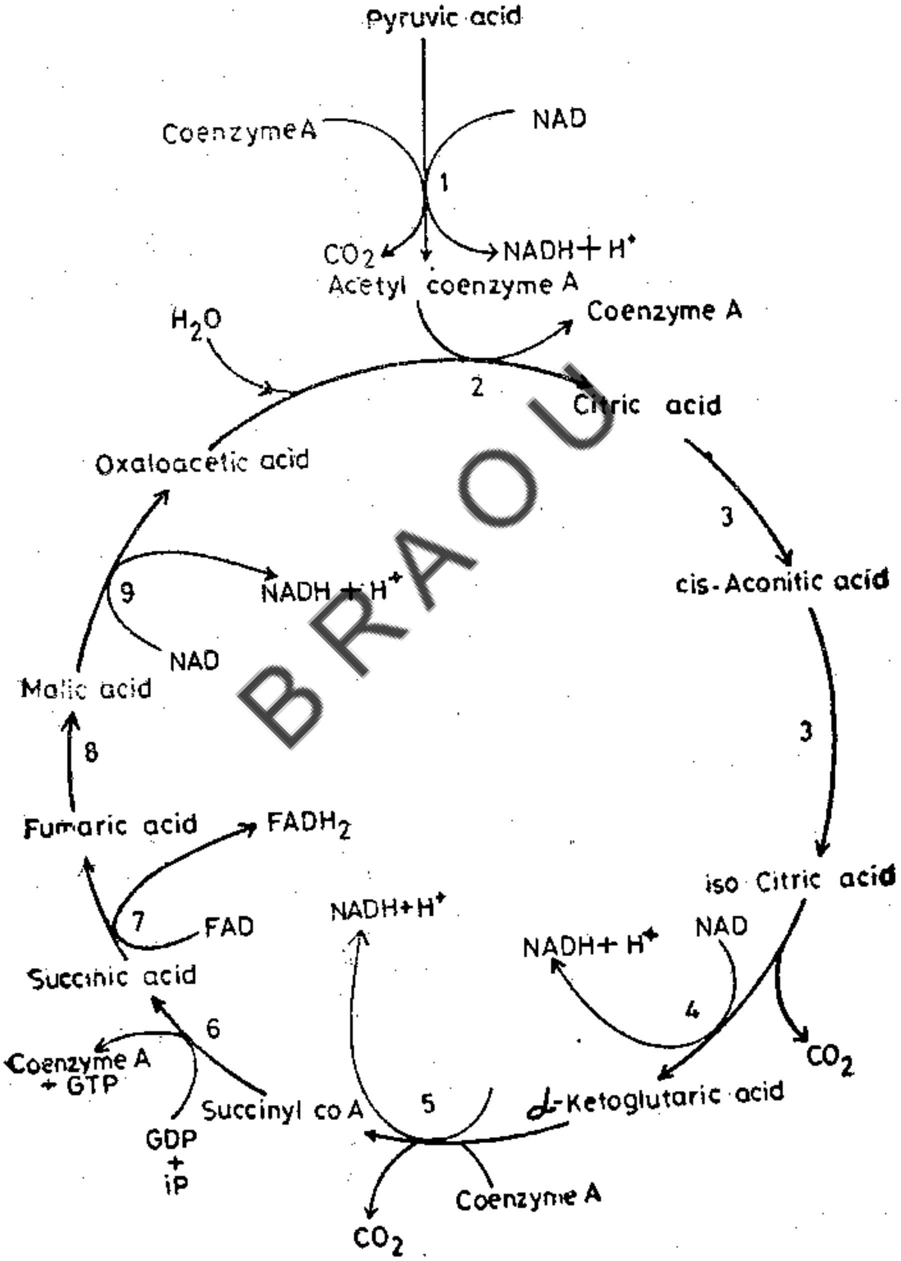

Fig.5.3 Krebs cycle or TCA cycle. 1. Pyruvic acid dehydrogenase and decarboxylase with TPP as coenzyme 2.Condensing enzyme 3.Aconitase 4.Isocitric acid dehydrogenase & decarboxylase 5α-Ketoglutaric dehydrogenase & decarbnoxylase 6.Succinyl kinase 7.Succinic dehydrogenase 8.Fumarase 9.Malic dehydrogenase.

The electron transport system which is also known as cytochrome system is a series of oxidation reactions (Fig.5.4). The movement of electrons down this biochemical wire establishes a kind of electron current that derives the H^+ protons to atmospheric oxygen. ATP is produced by oxidative phosphorylation during the flow of electrons through this system. The electrons entering this system from $NADH_2$ result in the synthesis of 3 ATPs and from $FADH_2$ the result is 2ATPs.

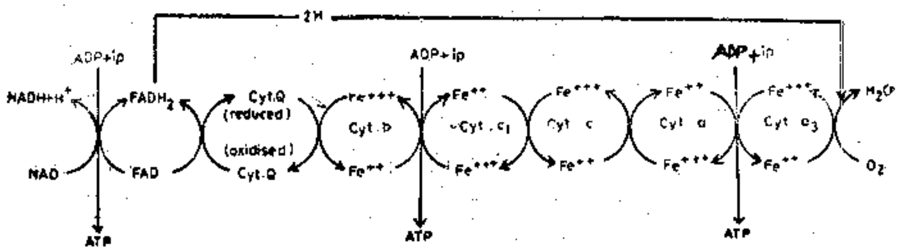

Fig. 5.4. Electron transport system. A schematic representation of the respiratory chain (There is a doubt about the participation of Cyt.Q in the electron transport)

During the degradation of the glucose molecule through glycolysis, Krebs cycle & electron transport system two ATP molecules are utilised in some reactions and 40 ATPs are produced (four from glycolysis, two from Krebs cycle and 34 from electron transport system) under aerobic conditions. The net profit to the cell is 38 ATPs. If the oxygen is not available (anaerobic respiration) Krebs cycle and electron transport system are closed down leaving the glycolotic pathway as a ready source of energy.

Fermentation: The term fermentation which is literally a chemical change followed by effervescence is loosely applied to several processes carried by some micro-organisms such as bacteria, yeasts and certain fungi. Under anaerobic conditions various types of fermentation products are formed by various groups of fermentation bacteria or micro-oganisms utilising various types of carbohydrates.

Alcohol Fermentation: Ethyl alcohol (Ethanol) is the fermentation product with many fermentation yeasts and few bacteria. The ethanol forming bacteria and yeasts are used in the industrial production of Alcohol. Pyruvic acid produced in glycolysis is converted into alcohol and carbon-dioxide in two steps. In the first step pyruvic acid is decarboxylated into acetaldehyde and carbon dioxide in the presence of an enzyme pyruvic acid decarboxylase. In the second step acetaldehyde is reduced to ethyl alcohol by the reducing agent $NADH+H^+$. This reaction is catalysed by the enzyme alcohol dehydrogenase.

Lactic Acid Fermentation: The lactic acid bacteria obtain their metabolic energy solely through fermentation but thev are aerotolerant, i.e., they grow even in the presence of air. The lactic acid bacteria grow very well on milk, whey and plant juices where many growth factors and intermediate products are available. They are capable of cleaving milk sugar (lactose) by phosphorylation with the help of β -galactosidase into glucose and galactose and also capable of assimilating both of them. Homofermentative lactic acid bacteria convert the sugars into the lactic acid. In this process acetic acid and/or ethanol also appear in addition to lactate. The fields of application of lactic acid bacteria are manifold. They are used for the souring of milk and milk products, manufacture of cheese, bread, preparation of raw sausage, manufacture of lactic acid etc.

Propionic Acid Fermentation: Propionic acid is the product of fermentation of carbohydrates and lactic acid by propionibacteria. These bacteria are microaerotolerant and under strictly anaerobic conditions ferment acetic acid to propionic acid and succinic acid but in the presence of oxygen they carry out limited respiration and secrete acetic acid as well as propionic acid.

Formic Acid Fermentation: Formic acid together with other organic acids such as acetoacetate, succinate and lactate and alcohols (butanediol, ethanol and glycerol) are the fermentation products in the fermentation which is characteristic of members of enterobacteriaceae and for luminescent bacteria, some bacilli and few other forms.

Butyric Acid - Butanol Fermentation: Butyric, butanol, acetone, propan-2-ol and alcohols are the products of spore forming anaerobic organisms (clostridia). Among the clostridia there are several extremely thermophilic species and the temperature optimum lies between 60 and 75° C. The clostridia can ferment a wide range of naturally occurring polysaccharides such as starch, glycogen, cellulose, hemicellulose and pectins and also nucleic acids, proteins and pyrimidines

Homoacetate Fermentation : The homoacetate fermenters *(Clostridium formicoaceticum, C. thermoaceticum)* which are present usually in sewage convert hexoses into acetate. The acetate is utilised by methane forming bacteria to generate methane.

They produce more than 2 molecules of acetate (almost 3) per mole of hexose. The reason for this is that they are capable of using carbon dioxide as hydrogen acceptor and of transferring the fermentation hydrogen to carbondioxide to form acetate.

The acetic acid forming bacteria *(Acetobacter, Gluconobacter)* are characterised by the fact that they oxidise sugar and alcohol only incompletely even when oxygen is supplied in excess. For their growth they use the hydrogen derived during the reactions as a source of energy and transfer it via the electron transport chain to oxygen.

5.6. DEGRADATION OF FATS & FATTY ACIDS BY MIROORGANISMS

The fats are digested into glycerol and fatty acids before undergoing oxidation. The glycerol is converted into phosphoglyceraldehyde and then proceeds through the respiratory pathway. The fatty acid molecules are broken down into two carbon fragments which are converted into acetyl. This is then proceeds through the respiration pathways as shown in Fig.5.5

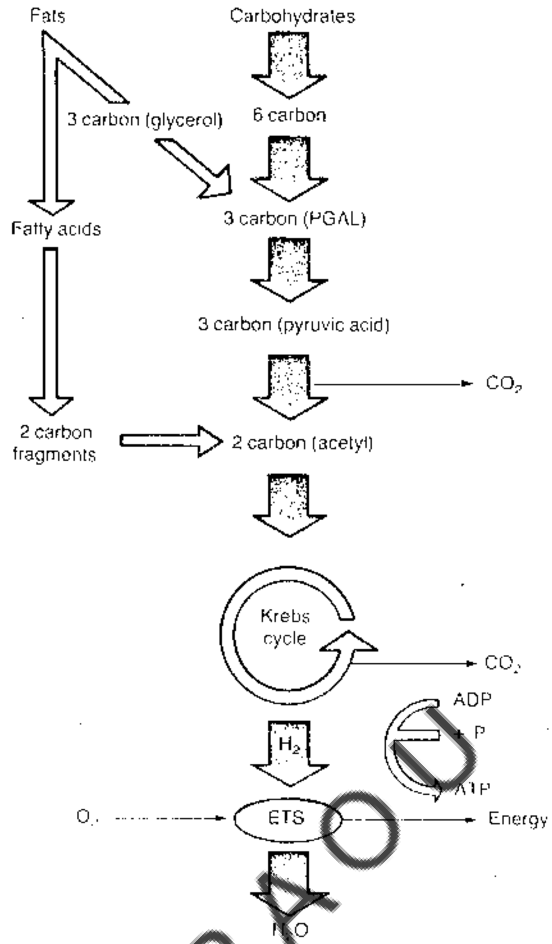

Fig.5.7. Degradation of fats & fatty acids.

Check Your Progress-2

How are fats and fatty acids digested ?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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5.7. DEGRADATION OF PROTEINS

The proteins are digested into aminoacids before they can undergo oxidation. The aminoacids are converted into Ketoacids which enter the respiration paths as pyruvic acid or one of the ketoacids of kerbs cycle as shown in Fig.5.6.

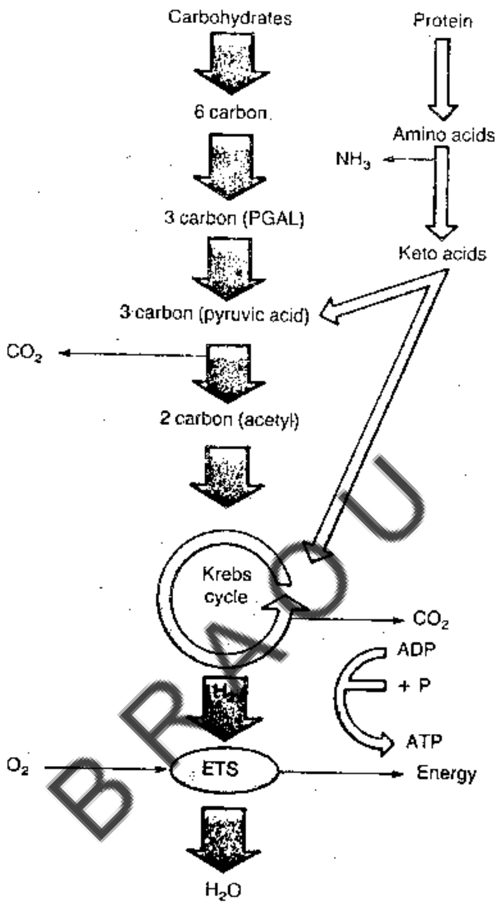

Fig. 5.6. Degradation of proteins.

5.8. NITROGEN SOURCES & DEGRADATION OF NITROGENOUS COMPOUNDS

Because of its role in proteins and nucleic acids, nitrogen is one of the most important structural elements of all living organisms. The nitrogen content of the atmospheric air is 78-80%. Although nitrogen is available in abundance, animals and most of the plants are unable to fix atmospheric nitrogen. The activity of some of the microorganisms in a series of processes results in nitrogen being available to plants in an assimilable form.

Symbiotic Nitrogen Fixation : A relatively large group of plants (the legumes) are capable of fixing atmospheric nitrogen through a symbiotic association with soil bacteria of the genus *Rhizobium*. Neither of them above is able to fix nitrogen. The actual site of nitrogen fixation is in the nodules formed on the roots of the legumes as a result of the penetration of the bacterium into their roots. Species of *Rhizobium* are highly host specific to particular species of leguminous plants. A reddish pigment develops in the nodules of the leguminous plants which is very much similar to the haemoglobin of red blood cells of mammals. It is called leghaemoglobin which means the haemoglobin of legumes. About 300 species of nonleguminous Dicotyledonous plants are also known to fix nitrogen symbiotically. They include the species of *Casuarina, Alnus (alder), Myrica etc.*

Nonsymbiotic Nitrogen Fixation : A wide range of aerobic and anaerobic bacteria are capable of non-symbiotic nitrogen fixation. This includes the aerobes, *Azotobacter, Beijerinckia, Azotomonas, Pseudomonas,* and *Nocardia,* the facultative anaerobes, *Klebsiella, Bacillus olymyxa and Rhodospirillum* and the anaerobic *Clostridium pasteurianum, Desulphovibrio, Methanobacterium, Chromatium and Chlorobium.* Although *Azotobacter* is an active nitrogen fixer *in vitro,* the efficiency of its nitrogen fixation is low. It fixes only 5-20 mg of nitrogen per gram of sugar oxidised. Thus, to fix 5-20 pounds of nitrogen per acre, these organisms require and entirely utilise 1000 pounds of carbohydrates.

Check Your Progress - 3 & 4

3. What is meant by symbiotic nitrogen fixation?
4. What is Non-symbiotic nitrogen fixation?

Note: a) Write the answers in the space given below.

b) Compare your answers with those given at the end of this unit.

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Biochemistry of Nitrogen Fixation in Nodules : Ferredoxin which is an electron carrier provides the reducing power for nitrogen reduction in anaerobic bacteria such as *Clostridium.* In aerobic bacteria *(Azotobacter)* the reducing power is the respiratory electron transport itselt. In root nodules of legumes, the reductant appears to be the coenzyme NADH. Nitrogen fixation is an energy consuming reaction. To convert one molecule of nitrogen to 2 moleculels of Ammonia 6 electrons and 12 ATP are required. A pair of electrons transferred to the respiratory chain would yield 3 ATP molecules. Thus each ammonium molecule synthesized would require about 10 molecules of ATP.

Besides this process, the growth of root and bacteria require energy. Taking all these aspects into consideration it is estimated that about 25 molecules of ATP are required for the reduction of one nitrogen molecule. Studies on *Clostridium,* an anaerobic bacterium, revealed that the required ATP molecules are derived by the oxidation of pyruvate and the electrons are transferred to ferredoxin. The electrons from Ferredoxin are then added to nitrogen reducing enzyme nitrogenase and then to nitrogen, finally producing Ammonia as shown in Fig.5.7.

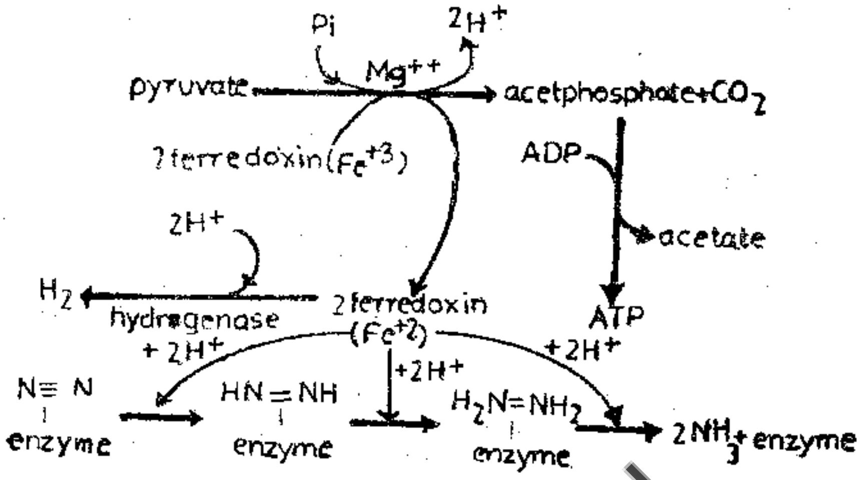

Fig.5.7. Sequence of electron transfer during nitrogen fixation.

Nitrification : Some Autotrophic and many heterotrophic marine bacteria can use ammonia or ammonium salts to synthesize the cell substances. But this is not generally accessible and must be converted to nitrate in a process called nitrification. The oxidation of Ammonia to nitrite are exothermic reactions (energy emanating) and is achieved chiefly by organisms of only two autotrophic genera, *Nitrosomonas* and *Nitrobacter.* There are numerous examples of *in vitro* demonstrations of nitrification by heterotrophic bacteria and fungi but the significance of the activity of these organisms is very small in natural conditions when compared with the autotrophic process. Ammonium nitrogen is the inorganic form of nitrogen and it occurs as ammonium ion (NH_4^+) or ammonia (NH_3). They are interconvertible $NH_3^+ H_2O \rightleftarrows NH_4^+ + OH$. The first step in this process is the oxidation of Ammonia to nitrite and it is mediated by *Nitrosomonas,* a gram negative rod with polar flagella.

$$2NH_3 + 3\,O_2 \longrightarrow 2\,NO_2^- + 2\,H_2O + 2\,H^+$$

$$2\,NH_4 + 3O_2 \longrightarrow 2\,NO_2^- + 2\,H_2O + 4\,H^+$$

The intermediate steps in this process are not yet confirmed. The nitrites formed by these organisms are toxic to plants as well as to the organisms forming it. Fortunately, *Nitrobacter* has the same characteristics as *Nitrosomonas* and converts nitrite to nitrate which is also energy releasing process.

$$2\,NO_2^- + O_2 \longrightarrow 2\,NO_3^- + \text{energy}$$

The nitrification process is very important to the soil fertility because of the fact that nitrate ions are preferable to ammonium for the nutrition of higher plants.

Denitrification is the name given to the process of nitrate reduction in which dinitrogen oxide or nitrous oxide (N_2O) and nitrogen (N_2) are formed.

$$NO_3 \longrightarrow NO_2 \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$$

Numerous bacteria are capable of producing energy with denitrification. They are all bacteria which are incapable of growing in the absence of oxygen and nitrate. Obligate anaerobes are not known among the denitrifiers. The denitrifiers are the only organisms that can convert bound nitrogen to molecular. They are responsible for the loss of nitrogen by the soils.

The bacteria belonging to the second group, mainly Enterobacteriaceae reduce nitrogen under anaerobic conditions. Here the reduction of nitrate to nitrite is regarded as an electron transport process and the reduction of nitrite to ammonium is linked to fermentation process. Nitrite acts as an external electron acceptor. The total process is also known as nitrate ammonification.

$$NO_3 \longrightarrow NO_2 \longrightarrow HNO \longrightarrow NH_2\,OH \longrightarrow NH_3$$

5.9. DEGRADATION OF SULPHUR CONTAINING COMPOUNDS

The microorganisms are versatile and can utilise most of the sulpur compounds for deriving energy and are instrumental in making sulphur available to higher plants. Most of the sulphur is combined in organic compounds (amino acids and sulphate esters present in sulphated polysaccharides), inorganic sulphate, sulphide and other reduced compounds.

Release of sulphur from organic compounds : Most of the proteins degraded by microorganisms produce sulphur containing aminoacids such as cystine, cysteine etc. These sulphur containing aminoacids when present in well aerated conditions, sulphate is formed by a route not involving hydrogen sulphide. In waterlogged anaerobic conditions hydrogen sulphide is the major compound and it plays a vital role in the pollution of waters. The production of H_2S from cysteine is shown below.

$$\begin{array}{l} CH\,SH \\ CHNH_2 \\ COOH \end{array} + H_2O \xrightarrow[\text{desulfurase}]{\text{Cysteine}} \begin{array}{l} CH_3 \\ C{=}O \\ COOH \end{array} + H_2S + NH_3$$

Cysteine — Pyruvic acid

The ammonia and pyrvic acid produced in this reaction are used for the synthesis of cell substances or production of energy. The hydrogen sulphide may be oxidised by filamentous colourless sulphur bacteria such as *Beggiatoa* under fully aerobic conditions possibly at the surface.

$$2\,H_2S + O_2 \longrightarrow 2S + 2H_2O$$

The hydrogen sulphide produced also acts as an electron donor for carbon dioxide reduction in photosynthetic bacteria.

$$CO_2 + 2H_2S \xrightarrow{\text{light}} (CH_2O) + 2S + H_2O$$

Photosynthetic bacteria which oxidise hydrogen sulphide to elemental sulphur belong to the families chlorobiaceae *(Chlorobium sp.)* and Chromatiaccae *(Chromatium sp.)*. The elemental sulphur is oxidised to sulphate by chemolithotrophic bacteria belonging to the genus *Thiobacillus*. The most important species is *Thiobacillus thioxidians* which oxidises sulphur and thiosulphates to sulphuric acid under aerobic conditions.

$$2S + 3O_2 + 2H_2O \longrightarrow 2H_2\,SO_4 \qquad \text{(Sulphuric acid)}$$

The sulphate formed is most suitable form of sulphur for all higher plants. On the other hand, *Thiobacillus denitrificans* oxidises sulphur with the reduction of nitrate to derive the energy necessary. This is an important factor in the loss of soil fertility in certain anaerobic soils.

$$5\,S + 6\,HN_2O \longrightarrow 5\,H_2\,SO_4 + 3N_2$$

Sulphate Reduction : The sulphate present in the soils is assimilated by microorganisms and higher plants and it is incorporated into proteins. The organisms chiefly responsible for reducing sulphate are members of the genus *Desulphovibrio*. These organisms are wide spread in nature and occur in a wide range of environmental conditions. They are found growing both heterotrophically using carbohydrates, organic acids and alcohols as electron donors and also autotrophically as molecular hydrogen as the electron donor for deriving energy. Under anaerobic conditions, microorganisms are responsible for the generation of hydrogen sulphide. The sulphate reducing organisms are economically important and they cause corrosion to underground iron pipes by the removal and use of Hydrogen as an electron donor which forms a protective covering around the pipes under anaerobic conditions.

5.10. TRANSFORMATIONS INVOLVING PHOSPHORUS

Phosphorus is needed by microorganisms for the synthesis of nucleic acids and to a lesser extent phospholipids and organic phosphate compounds. The organic residues containing phosphorus present in aquatic and terrestrial environment are degraded by heterotrophic microflora, which convert them into inorganic phosphate while deriving their energy, making it available for highr plants. Most of the phosphate in aquatic system is bound to cations such as Aluminium, Calcium, Iron and magnesium and the Compounds are insoluble and precipitate out. The insoluble inorganic phosphate is made available to plants as a result of the liberation of organic acids by microorganisms which dissolve insoluble inorganic phosphate compounds in the soil.

5.11. OTHER TRANSFORMATIONS

The microorganisms require several other elements in smaller amounts for growth and obtain them from environment. The fungal flora appears to be less sensitive to Manganese and iron.

availability than the bacteria. *Bacillus* and *Arthrobacter* have a particularly high requirement for iron. The Manganese oxidising bacteria occur commonly in the upper layers of heavy soil and are more widely distributed in sandy soild. Certain heterotrophic bacteria such as *Pseudomonas, Corynebacterium, Flavobacterium* pedonirobium can oxidise manganese for deriving necessary energy.

Some heterotrophic bacteria may cause deposition of iron from organic complexes by using the organic compounds as the energy source and it is possible that iron deposited in this way may play a part in the formation of iron pans. Certain other heterotrophic bacteria under anaerobic conditions, can reduce Ferric to ferrous iron. Where sulphide ions occur, that is precipitated as ferrous sulphide.

5.12. METHANE FORMATION AND OXIDATION

In completely water logged anaerobic soils, *Clostridium* species may convert organic matter into carbon dioxide and hydrogen which are in turn converted by certain anaerobic bacteria to Methane (CH_4). Only a few bacteria such as *Methanobacterium, Methanococcus, Mathanosarcina* are capable of Methane production. Although, they are morphologically dissimilar, they are included in the family Methanobacteriaceae. All the members of Methanobacteriaceae gain their energy from the oxidation of Hydrogen gas and the reduction of CO_2 according to the following reaction.

$$4\,H_2 + CO_2 \longrightarrow CH_4 + 2H_2O + \text{energy}$$

Under the action of Methane oxidising bacteria, methane is first oxidised to Methanol by Methane oxygenase and this is then dehydrogenated. The hydrogen liberated in the oxidation of Methanol to carbon dioxide is used as a source of energy for methane and methanol oxidation organisms.

Check Your Progress - 5

How does the organic matter converted into Methane?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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5.13. UTILISATION OF CARBON MONOXIDE

Carboxydobacteria use carbon monoxide available in synthesis gas and blast furnace waste gas for the generation of energy. The carbon monoxide (CO) is oxidised to carbondioxide by carbon monoxide oxidase and the reducing equivalents arising are used for the aerobic generatior of energy.

5.14. DEGRADATION OF PHENOLS

In nature phenols are available in plenty. They are also used by microorganisms for deriving energy for their growth. The phenols are first oxidised by a monooxygenase to pyrocatechol.

Pyrocatechol is then cleaved by a dioxygenase to an aliphatic dicarboxylic acid (cis-cis-muconic acid) which is finally converted into known metabolites, Acetyl CoA and succinate which will be included in the krebs cycle for deriving necessary energy.

5.15. FORMATION AND DECOMPOSITION OF HUMUS IN SOIL

Most of the carbon present in the organic residues is converted into simple sugars and then oxidised to CO_2 and energy but some is incorporated in microbial tissues which themselves will eventually be decomposed. The remainder is incorporated into humus which is the dark coloured amorphous organic material which is very very important for soil fertility. The process whereby it is formed is not fully understood but the soil animals are indispensable in the process since the soils where there is no soil fauna, humus is not found. The chemistry of it is also obscure. It is not a single compound but it is essentially polyphenolic in nature containing some aminoacids and aminosugars. The quantity of humus in a mature soil varies little from year to year provided it is not depleted as a result of cultural practices. Humus is relatively resistant to degradation either because it is intrinsically stable or because it is adsorbed to clay particles. Whatever may be the reason, only a small fraction of the total humus is broken down in any one year. The humus degradation is mainly achieved by autochthonous flora.

5.16. CONCLUSION

The microorganisms such as algae and photosynthetic bacteria produce several organic compounds and energy with the help of carbon dioxide, H_2O and light. The other microorganisms such as heterotrophic bacteria, fungi, protozoans play a vital role in the degradation of several organic and inorganic compounds which are added to the soil and aquatic medium by the dead higher and lower organisms to derive their energy and the energy is converted from one to the other continuously. Some microoganisms degrade them under aerobic conditions (in the presence of oxygen) and some degrade them in the absence of oxygen (anaerobic conditions).

5.17. SUMMARY

The microorganisms recycle the energy in nature from one compound to the other and the balance is mostly maintained. Various groups of microorganisms are distinguished due to the differences in thier source of energy. Autotrophs can grow using the energy liberated by the oxidation of certain inorganic compounds (chemosynthetic autotrophs) or the energy from sunlight (Photosynthetic autotrophs). Heterotrophs use organic compounds as energy and carbon source. Fungi, most protozoa and many bacteria are heterotrophs. The bacteria which are omnipresent are nutritionally the most versatile organisms ranging from photosynthetic to chemosynthetic autotrophs. The bacteria are the most commonly occuring organisms utilizing all types of organic and inorganic materials present around including dead micro-or macro-organisms.

In autotrophic microbes three types of carbon fixation pathways are recognised. They are Ribulose bis-phosphate pathway, Ribulose monophosphate pathway and serine pathway.

The main type of carbon compounds added to the soil and aquatic system are plant and animal remains which contain high molecular crbon compounds. A very small protion account for the soluble molecules. In the plant remains high molecular weight compounds are cellulose, hemicellulose, lignin, starch in addition to smallar quantities of fats, waxes, oils, proteins and nucleic acids. In dead microorganisms and animals a similar range of high molecular weight compounds exist in addition to glycogen.

Glucose is the predominant product of photosynthesis of microorganisms but also degradation product of high molecular weight carbohydrates. The glucose is converted into carbondioxide and water to derive their energy in aerobic respiration. Under anaerobic conditions various types of fermentation products are formed by various groups of microorganism. Different types of fermentations are alcohol fermentation, lactic acid fermentation, propionic acid fermentation, formic acid fermentation, Butyric acid-Butanol fermentation, homoacetate fermentation etc.

The fats are digested into fatty acids and glycerol. The glycerol is converted into phosphoglyceraldehyde and then enters into respiratory pathway. The fatty acids are converted into two carbon fragments which are converted into acetyl and this enters into the respiratory pathway. The proteins are broken down into amino acids which are later converted into keto acids to enter into krebs cycle.

Nitrogen which is abundently available in atmospheric air (78-80%) can not be utilised by most of the plants and animals. The atmospheric nitrogen is fixed in two different ways *viz*, symbiotic and non-symbiotic means. *Rhizobium*, a bacterium is the one which fixes atmospheric nitrogen by associating itself symbiotically with most of the leguminous and other plants. The aerobic bacteria such as *Azotobacter, Beijerinckia, Pseudomonas* etc., the facultative anaerobes such as *Klebsiella, Bacillus* etc and anaerobic bacteria such as *Clostridium, Desulphovibrio, Chlorobium* etc are capable of fixing atmospheric nitrogen non-symbiotically.

The microorganisms are versatile and can utilise most of the sulphur compounds for deriving energy and are instrumental in making sulphur available to higher plants. The sulphate present in the soils is assimilated by microorganisms and higher plants and incorporated into proteins.

The organic residues containing phosphorus present in aquatic and terrestrial environment are degraded by heterotrohic microflora while deriving their energy and making it available to higher plants. In completely water logged anaerobic soils, *Clostridium* species convert organic matter into carbondioxide and hydrogen which are in turn converted into methane by anaerobic bacteria such a *Methanobacterium, Methanococcus* etc. Certain microorganisms are able to utilise carbon monoxide, phenols and able to decompose humus in the soil.

5.18. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The examples for monosaccharides are glucose, galactose and fructose and the examples for disaccharides are saccharose, lactose and maltose where as starch, glycogen and cellulose are the examples for polysaccharides.

2. The fats are digested into glycerol and fatty acids before undergoing oxidation and the proteins are digested into amino acids.

3. The higher plants cannot fix atmospheric nitrogen on their own. But when the species of *Rhizobium* (bacterium) are in association with the roots of higher plants by producing root nodules, they can fix atmospheric nitrogen. This is called symbiotic nitrogen fixation.

4. Certain aerobic and anaerobic bacteria such as *Azotobacter, Beijerinckia, Klebsiella, Clostridium* etc are able to fix atmospheric nitrogen and this is called symbiotic nitrogen fixation.

5. In anaerobic soils, the organic matter is converted into carbondioxide and hydrogen by species of *Clostridium* and they are in turn converted into methane by other bacteria such as *Methanobacterium, Methanococcus, Methanosarcina* etc.

5.19. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write briefly about nutritional types of Bacteria and the three carbon fixation pathways of them.
2. Write an account on the degradation of carbon compounds by microorganisms.
3. What is ment by fermentation? Write briefly about different types of fermentations.
4. Write briefly about nitrogen fixation.
5. Write an account on the degradation of sulphur and phosphorus compounds.

II. Answer the following questions in about 10 lines each.

1. Write briefly about nutritional types of bacteria.
2. What is fermentation? Write briefly about alcohol fermentation.
3. Write briefly about lactic acid fermentation.
4. Briefly write on propionic acid and formic acid fermentations.
5. Write briefly about homoacetate fermentation.
6. Write a brief note on the degradation of proteins, fats and fatty acids.
7. Briefly write on symbiotic nitrogen fixation.
8. What are the differences between symbiotic and non-symbiotic nitrogen fixations?
9. Write briefly on the transformations involving phosphorus.
10. How is methane formed and how is it oxidised?
11. Write briefly about the formation and decomposition of humus in the soil.

Dr. M. Ramachandraiah

UNIT - 6 : ECOLOGICAL PYRAMIDS

Contents

6.1. OBJECTIVES

After going through this unit you will be able to :

* write an account of pyramid of numbers,
* describe the pyramid of biomass
* list out the different types of pyramids of energy.

6.2. INTRODUCTION

Every ecosystem has a more or less definite trophic structure, consisting of few to several levels. Trophic structure is the interaction of food chain phenomena in an ecosystem. It is measured as standing crop per unit area or as energy fixed per unit area per unit time. There is a definite relationship between different organisms with respect to energy, number and biomass. Trophic structure and function of an ecosystem can be depicted graphically by means of pyramids in which green plants, the primary producers form the base, whereas successive trophic levels form the tiers which make up the apex. These are the ecological pyramids. Charles Elton first proposed the idea of representing these trophic structures graphically by means of pyramids. The graphic representations of the interrelationships between successive food levels in a food chain are called Ecological Pyramids.

6.3. ECOLOGICAL PYRAMIDS - A GENERAL ACCOUNT

The familar concepts of food chain, food web, niche and ecological pyramids became particularly prominent in ecology from the work of a researcher from Oxford University, some seventy years ago. This young scientist, Charles Elton published a text book Animal Ecology in 1927 which contained his observations of food chain. A food chain is a chain of eating and being eaten; that connects large, carnivorous animals to their ultimate plant food. Elton did not talk of 'energetics' in discussing these phenomena, instead he talked of food nutrients. His observations, led directly to models of energy flow in ecology. Elton's most important observations were made on the tundra at Bear Island, near Spitzbergen. Elton discussed the transfer of food from animal to animal as the Food Cycle. He did this because he observed that indestructible solid matter was passed from animal to animal; particularly combined nitrogen.

Workers since Elton's time have been more inclined to stress the transfer of food calories through food chains and webs. The movement of calories is, of course, unidirectional since energy is degraded in the process, according to the second law of thermodynamics. Nutrients are cycled in an ecosystem but energy flows through it.

The ease with which animals could be seen on the tundra brought home another fundamental fact, that animals high on food chains were both larger and rarer than animals lower down. This result Elton called the Pyramid of Numbers sometimes referred to as the Eltonian Pyramid. Each layer on the pyramid represents the kind of animals living at parallel levels as food chains, all herbivores on one level, all primary carnivores on the next level, all secondary carnivores on the next level and so on. These levels are now called Trophic Levels.

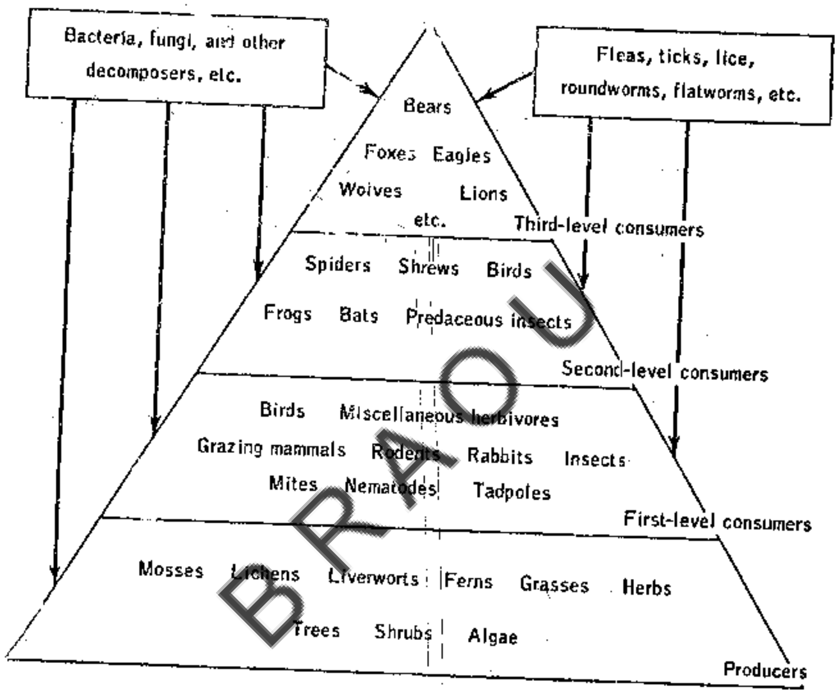

Fig.6.1. Biotic Pyramid.

Thus a food chain in an ecosystem consists of several food levels or trophic levels extending from the primary producers to the top carnivores. The first trophic level is known as the producer level, since it is here that energy is transformed and useful energy - rich chemicals are produced which support the rest of the pyramid. Of course, they do not really produce energy, but only transform into usable form of energy which comes to the earth from the sun.

The higher levels are the consumers (fig.6.1.). Herbivores are the first level consumers, predators are second level consumers etc. More or less outside the pyramid, but important to it, are the decomposers (fungi of various kinds help in decay of various parts of plants).

The biotic pyramid actually rests on a base of soil, water, air and sunlight and it is the job of decomposers to recycle the elements present in the bodies of organisms and restore them to the bottom level of the system.

Check Your Progress - 1

Define an ecological pyramid? Who was the pioneer worker in this field?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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6.4. ECOLOGICAL PYRAMIDS - THEIR TYPES

The ecological pyramids can be drawn according to total number of organisms, total biomass or total energy flow at each trophic level. These diagrams tend to be roughly pyramidal in shape with broad bases and narrow peaks. The ecological pyramids are of three types.

1. Pyramid of numbers - This diagram is drawn on the basis of number of individuals in each trophic level.
2. Pyramid of biomass - This figure shows the total amount of living weight of members at different trophic levels, in the food chain.
3. Pyramid of energy - This is a pyramid drawn on the basis of rate of energy flow and/ or productivity at successive trophic levels.

The pyramid of numbers and biomass may be upright or inverted depending upon the nature of food chain in the particular ecosystem. The pyramids of energy are always upright. However the pyramid of numbers is not very accurate nor the proper method of studying the trophic structure since it can change due to many factors which are not considered while plotting the graph.

6.5. PYRAMID OF NUMBERS

Charles Elton observed that animals high on food chains were both larger and rarer than animals lower down. This result Elton called the Pyramid of Numbers sometimes referred to as the Eltonian Pyramid.

The ecological pyramid of numbers is based on the number of individuals in the various trophic levels per unit area. It indicates population density and the relationship between producers, herbivores and carnivores at successive trophic levels in terms of their number.

Each layer on the pyramid represents kind of animals living at parallel levels on food chain; all herbivores on one level, all primary carnivores on the next level and so on. These levels are now called trophic levels (after the Greek word for nursing). The number of individuals in each trophic level is less than the preceding one due to differences in the rate of population growth and predation of larger ones on the smaller organisms. In the pyramid of numbers there is an increase in the size of the body of organisms with a corresponding decrease in their number, as we progress from the base to the tip of the pyramid.

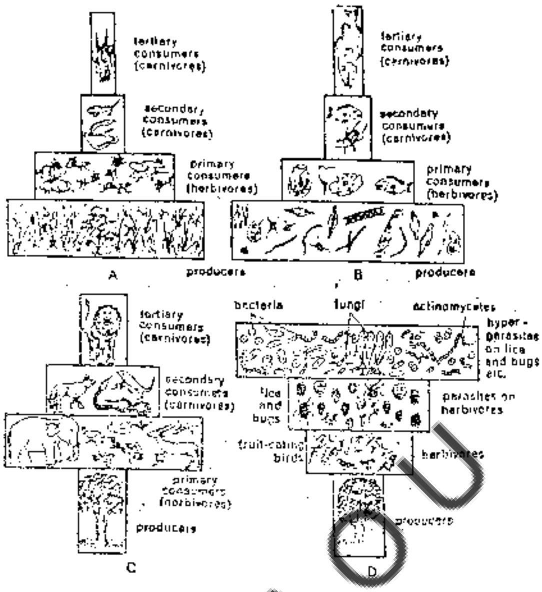

Fig 6.2 : Pyramids of numbers in different ecosystems. A-grassland, B. Pond, C. Forest, D. Tree.

It seems that there is a pyramid of numbers associated with many of the earth's habitats. The pyramids of numbers in three different kinds of ecosystems are discussed below. In a grass land (fig.6.2A) the producers which are mainly grasses are always maximum in number. This number then shows a decrease towards the apex as the primary consumers (herbivores) like rabbits, mice etc are less in number than the grasses; the secondary consumers are fewer than the primary consumers. Finally the tertiary consumers like hawks and other birds are least in number. The pyramid is upright.

The pyramid of numbers in the pond ecosystem is also upright (Fig6.2B). The producers are mainly the phytoplanktons comprising of algae, bacteria etc; the second trophic level formed of herbivores such as small fish, rotifers etc are less than the producers; the secondary consumers (carnivores) such as fish, water beetles etc. are less in number than the herbivores. Finally the tertiary consumers represented by the bigger fish are least in number. Elton (1927) described the possibilities for water saying "In a small pond, the numbers of protozoa may run into millions, those of *Daphnia* and *Cyclops* into hundreds of thousands, while there will be far fewer beetle larvae and only a very few small fish"

In a forest ecosystem (fig.6.2C) the pyramid of numbers is rather different in shape. The producers are huge trees and the herbivores comprising of birds, elephants, deer etc are greater in number than the producers. Then there is a gradual decrease in the number of successive carnivores thereby making the pyramid upright again (Fig.6.3) shows a pyramid of numbers of arthropods on a tropical forest floor, a result probably typical of most terrestrial sites.

The pyramid of numbers may also be inverted as in a parasitic food chain (fig.6.2D) and this is due to the fact that a single plant may support the growth of many herbivores. Each herbivore in turn may provide nutrition to several parasites which support many hyperparasites. Thus from the producer towards consumers there is a reverse trend, that is the number of organisms gradually show an increase making the pyramid inverted in shape. Why are there pyramids at all and where are they found? To Elton, one aspect seemed to have a clear explanation and this was the separateness of the trophic levels. According to Elton, animals came in size fractions that were remarkably distinct. He found a quantum jump in size between an insect and a bird, between a water flea (*Daphnia*) and a midge larva (*Chaoborus*) and between a midge larva and a fish. Elton explained this with his Principle of Food size saying that animals tended to be of a size that let them thrust their prey into their mouths whole. There is an advantage in an animal being big, so that it can easily catch and eat its prey to keep itself alive. So there must be an optimum size for any animal, a size determined by the size and agility of its food with clear exceptions. This explanation seems to have widespread validity wherever the pyramid structure shows up clearly. Animal size goes up by quantum jumps along the food chains of a pyramid of numbers. This is due to successive needs to handle larger prey. To reflect the change of size between the trophic levels correctly, the pyramid of numbers is drawn with steps as in Fig.6.3.

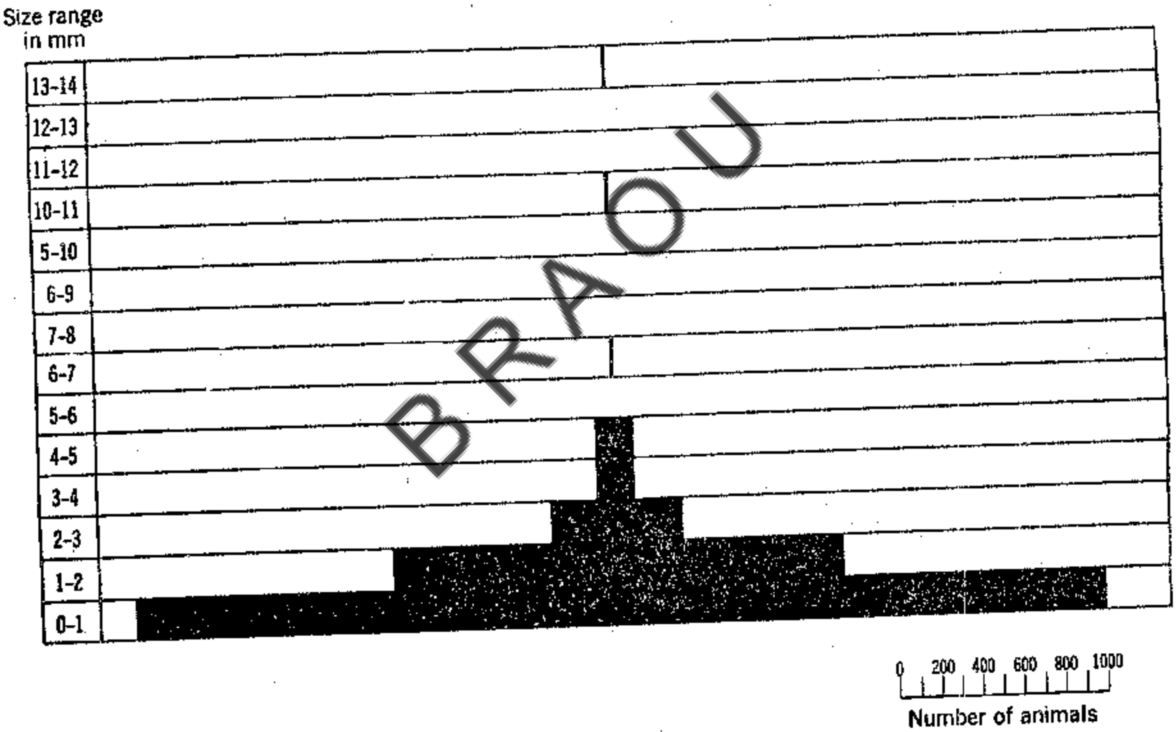

Fig. 6.3. Eltonian pyramid of numbers on the floor of a forest in panama.

Some pyramids of numbers are drawn with sloping sides, instead of stepped sides as in fig 6.4. Juday (1940), a limnologist, was the first to introduce the pyramid with sloping sides. Real counts of animals are likely to reveal steps of a pyramid. It was these steps, which led Elton to the importance of food size, itself the forerunner to the concept of energy flow.

The observation of food chains and pyramids by Elton, threw up an important question - "Why are big animals, particularly big carnivorous animals rare?" Elton in 1927 explained that small animals reproduced more quickly than large animals, but lived shorter lives. This rapid reproduction of small animals resulted in large numbers of individuals. Slowly reproducing large animals however, could not maintain such large populations. hence population size is a function of rate of reproduction. Elton's explanation can apply to a state of equilibrium - when a high rate of birth is balanced by a high rate of death. Thus Elton's explanation could not apply in most circumstances.

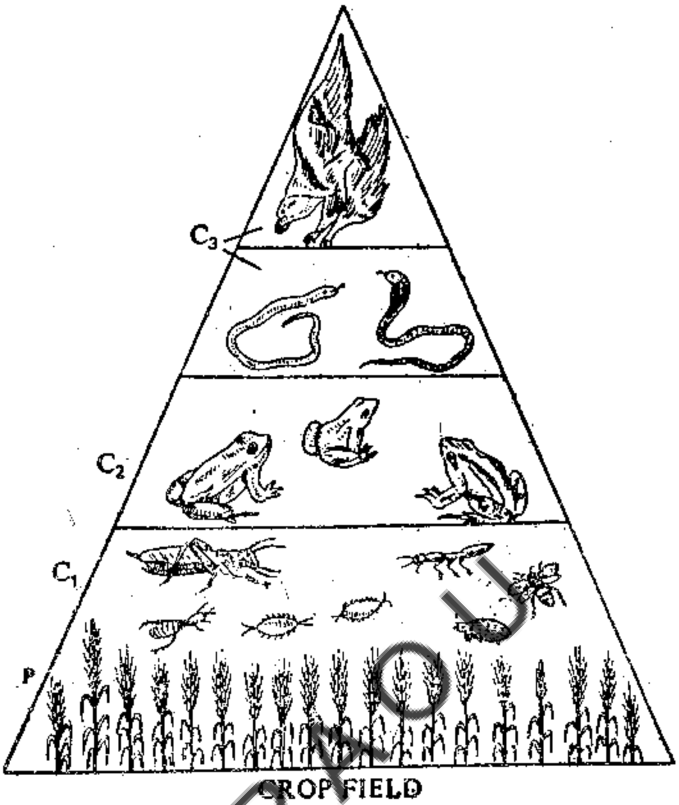

Fig.6.4. Upright Pyramid of numbers in a grassland

Elton's pyramids are now generally explained by the help of energetics. Small animals low on the pyramid are the food of large animals higher up. Energy enters the base of the pyramid as food calories. In maintaining life, energy is constantly being dissipated as heat. The usable food energy flux received by each successive trophic level is less than that below.

Living biomass is itself a store of energy. Its maintenance costs are a function of its mass. It follows that less biomass can be supported by the food energy received in each higher trophic level. Even if the animals at all the levels of the pyramid were of the same size, those high on food chains would of necessarily be less numerous than those below. "Since because of the principle of food size, those high on the chains tend to be large, the avilable energy for body - building and maintenance is sufficient for even few of them. This explanation for the pyramid of numbers has generally been applicable to all systems in euilibrium, where all populations are regulated.

Some obvious qualifications must be made to the assertion that the pyramid of numbers are every where - elephants which are very large animals are herbivores and they have no predators, moose are preyed upon by wolves, although they are larger. Parasites are smaller than their prey and so on. The pyramids of numbers do not give a true picture of the food chain as they are not very functional. They do not indicate the relative effects of the 'food chain' and 'size' factors of the organisms. They generally vary with different types of food chains in the same environment. Sometimes it becomes very difficult to represent the whole community on the same numerical scale as in the case of forest.

Check Your Progress -2

What is a pyramid of numbers? Explain with an example.

Note: (a) Write the answer in the space given below:

(b) Compare your answer with the one given at the end of this unit

6.6. PYRAMID OF BIOMASS

The pyramid of biomass is based on the living weight (fresh or dry weight) of members of different trophic levels, in the food chain. The biomass (total amount of living material) product at each trophic level when plotted in the form of an area gives this ecological pyramid. These pyramids are rather fundamental as they show quantitative ralationships of the standing crops. If the biomass of the individual producers is large, the biomass of the successive consumer levels will show a progressive decrease. The result is an upright pyramids. Such upright pyramid are seen in grassland and forest (see fig 6.5A & 6.5B).

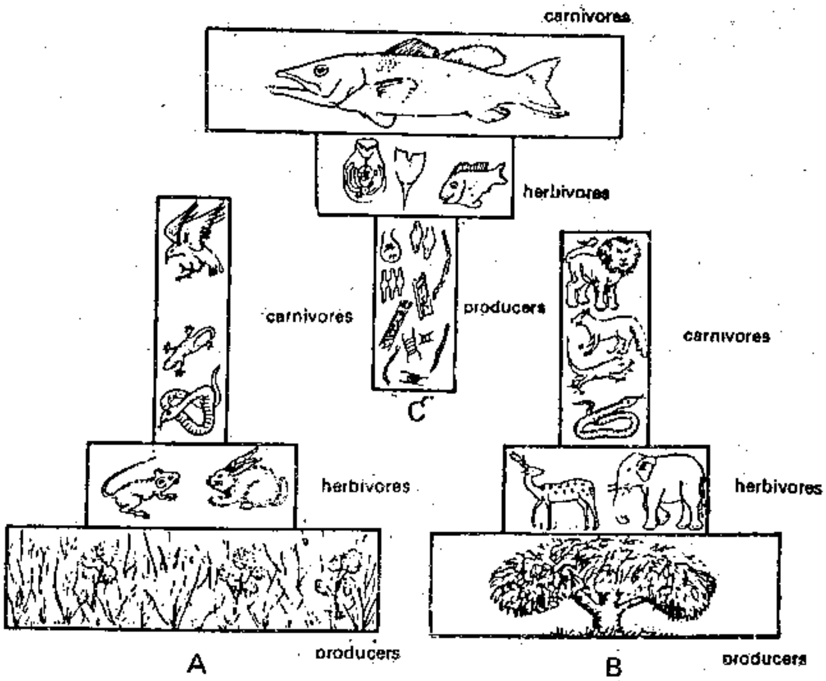

Fig.6.5. Pyramid of Biomass. A. Grassland. B. Forest.

In a forest ecosystem the first trophic level is occupied by trees and other plants. The second trophic level is taken up by herbivores such as insects, various mammals etc. This is followed by the secondary consumers such as mice, snakes etc following these are the tertiary consumers such as beavers; these make up the fourth trophic level. Assuming that in an area of forests, 5000 kg. of plant material is produced during a particular period. Then the biomass of primary, secondary and tertiary consumers will be about 900 kg of insects, 100 kg of mice & 1.5 kg of beavers (fig. 6.6.).

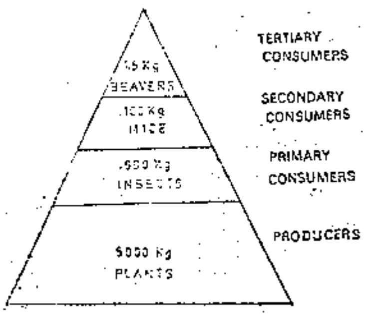

Fig. 6.6. Pyramid of Biomass represented by weights.

Another common example of the upright pyramid of biomass in the forest is the one comprising of trees, birds and insects. The biomass of the trees which form the base of the pyramid is the greatest. These are the producers on which live the birds. These birds eat the fruits of these trees; their biomass is less than that of the trees. Parasites like bugs and lice live on the birds. These form the third trophic level. Their biomass is less than the birds.

An upright pyramid of biomass is also obtained in an aquatic system. The base of the pyramid is formed of phytoplakton. This has the largest biomass. The second trophic level is occupied by zooplankton. This has less biomass than the preceeding trophic level. The third trophic level is represented by small fishes and molluscs. The biomass of this level is again less than the second trophic level. The apex is occupied by the fishes which has very reduced biomass.

However for a short period in some aquatic ecosystem such as pond, lake, ocean an inverted pyramid of biomass may be obtained. For example, in a lake the phytoplankton may grow in large number during summer. The zooplankton feed on them and grow in number. But in winter the growth of phytoplankton is less and is almost negligible in areas where the surface layer gets covered with ice. At this time the total biomass of zooplankton will be more than phytoplankton and the pyramid be an inverted biomass. The primary producers are microscopic algae characterised by short life cycle, rapid multiplication and little accumulation of organic matter. The size of consumers show progessive decrease. This pyramid however does not give us the correct picture of the trophic levels of the ecosystem for the entire period. It is therfore important to draw the pyramid after considering the total biomass for a long period such as one complete year.

Check Your Progress- 3

Describe an upright pyramid of biomass in an aquatic system.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit

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6.7. PYRAMID OF ENERGY

Of the three types of ecological pyramids, the pyramids of energy give the best picture of the overall nature of the ecosystem. The fundamental principle of ecology is that energy flows through the food chain in several steps till it reaches the top carnivores. The energy of the sun is trapped by the primary producers, the green plants. This trapped energy is converted into chemical energy, which in its potential form is stored as food in the green plants. From the producers energy flows through the various trophic levels like herbivores and carnivores till it reaches the top. The energy content progressively decreases in each succeeding trophic level in the food chain. This decrease is caused by a loss of large amount of energy in the form of heat and is known as thermal emission. This occurs regardless of the number or biomass of the trophic levels. As long as there are food chains, pyramids of energy flow must develop. The rate of total energy flow or productivity at succeeding trophic levels during a particular period, when plotted in the form of an area gives the pyramid of energy. In this pyramid the number and weight of organisms at any level depends on the rate at which food is being produced. In contrast with the pyramid of numbers and biomass which are pictures of standing situations (organisms present at any given moment), the pyramid of energy is dyanamic, a picture of movement of food mass through the food chain. It is always upright as in all of these cases there is always a gradual decrease in the energy content at successive trophic levels from the producers to the various consumers. This is in observance of the second law of thermodynamics.

The pyramid of energy is seen in a terrestrial ecosystem as well as in the aquatic ecosystem.

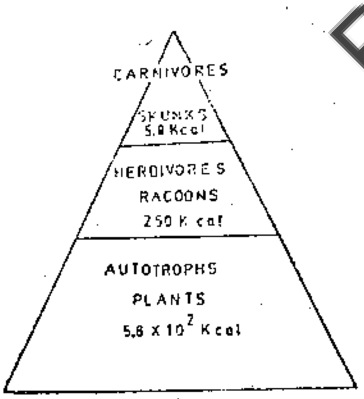

Fig. 6.7. Pyramid of energy (in units).

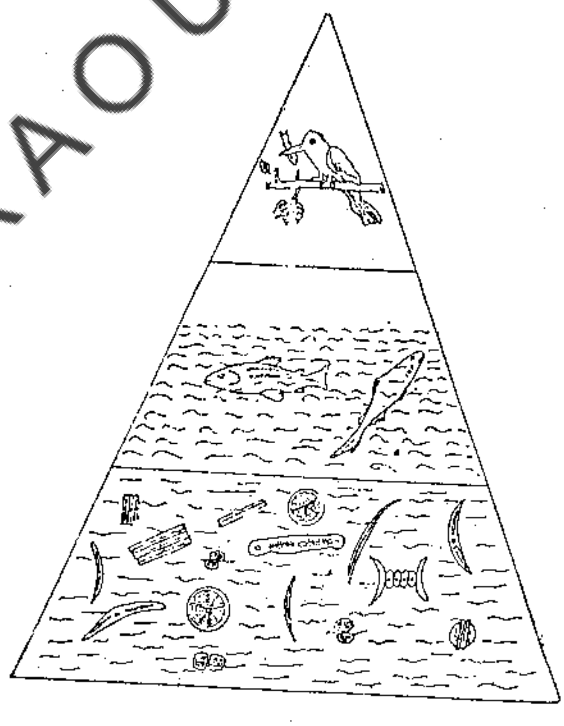

Fig. 6.8. Pyramid of energy in a pond.

In the terrestrial ecosystem the first trophic level is represented by plants-the autotrophs. They trap the largest amount of energy. This energy decreases in the second trophic level represented by the herbivores. The secondary consumers (carnivores) represent the third trophic level and they get much reduced energy . This energy can be measured in different units. Assuming that in a particular area of a forest the total energy trapped during a particular period is 5.8×10^2 KCal (kilo calories). The total amount of available energy at the next trophic level, in the herbivorous animal like raccoons will be only 250 K Cal and in the carnivorous skunks at third trophic level only 5.8 K Cal. (fig 6.7.).

The pyramid of energy is also observed in an aquatic ecosystem (fig 6.8.). Here the primary producers are the phytoplankton. These minute floating plants trap the solar energy. These plants are consumed by the zooplankton and small fishes which represent the primary consumers. The food energy is transferred from the first tropic level, the producers, to the second trophic level - the primary consumers. During this transfer a considerable amount of energy is lost as heat. Therefore the energy available to the second trophic level is less than that of the first trophic level. The secondary consumers the large fishes and fish-eating birds prey on the primary consumers for obtaining energy. During this step energy flows into the secondary consumers but a large amount of heat is lost again. Thus an upright pyramid of energy is obtained. The energy flow model is very general describing relative upper limits that may not always be reached. Many factors are involved in fixing population number and invidual size at any time or place, than just position on a food chain and the principle of food size.

In many systems the energy of plant biomass decomposed is far greater than the energy of biomass eaten by herbivores, so that the distribution and abundance of local life may depend heavily upon the process of decomposition. Even more distorting is the fact that food chain may be reduced to a single link when grazing herbivores feed directly on vegetation. Limits are set for the distribution and abundance of animals adapted to different kinds of food. Large carnivorous animals for instance always must be rare whereas small herbivorous animals can be abundant.

The energy flow model represented an important advance in the history of ecology some forty years ago. The workers who were to realize the importance of energetics in explaining this phenomenon were mainly those studying aquatic systems. Even Elton (1927) had noticed that his pyramid was nicely expressed in a pond where the herbivorous animals tended to be small. Important to the neat expression of pyramid in ponds was the fact that most plant biomass in this system did go to true herbivores and not to rot as in a forest or a prairie. Aquatic scientists who were active in community studies in the 1930's confirmed Elton's observation of pyramids (Juday 1940).

Check Your Progess-4

Write a short account of pyramid of energy?

Note: (a) Write the answer in the space give below.

(b) Compare your answer with the one given at the end of this unit.

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6.8. SUMMARY

Every ecosystem has a definite trophic structure. consisting of a few to sevaral trophic levels. There is a definite relationship between the different oganisms with respect to energy, number and biomass. This interrelationship between the various trophic levels can be depicted graphically by means of diagrams called ecological pyramids. Charless Elton first proposed the concept of ecological pyramids. An ecological pyramid is made up of many trophic levels. The first one forming the base of the pyramid is the producer level followed by the second trophic level represented by the herbivores. The third level is represented by the carnivores which may be primary carnivores, followed by secondary and tertiary carnivores making up the apex of the pyramid. Ecological pyramids may be drawn on the basis of (a) number of invididuals, (b) biomass, (c) rate of energy flow.

The pyramid of numbers and biomass may be upright or inverted depending upon the of food chain. The pyramids of energy are always upright.

6.9. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Ecological pyramids are the graphic representations of the interrelationships, between successive food levels in a food chain. The pioneer worker in the field of ecological pyramids was Charles Elton, a reseacher from Oxford University. He published his observations in a text book called Animal Ecology in 1927.

2. A pyramid of numbers is based on the number of individuals in the various trophic levels. Pond is an excellent example. The base of the pyramid is formed by diatoms and green algae. The second trophic level is represented by fish which are the consumers. These are less in number than those of the preceeding trophic level. The top carnivores like heron represent the tip of the pyramid. These are less in number than the consumers on which they feed.

3. In an aquatic system like pond or lake an upright pyramid of biomass is obtained. The base of the pyramid is made up of phytoplankton; this is the first trophic level with the largest biomass. This is followed by the second trophic level represented by the zooplankton. The third trophic level is represented by small fishes and molluscs, the fourth trophic level represented by large fishes, makes up the apex of the pyramid. With the progress from the base to the apex there is a gradual decrease in biomass, resulting in an upright pyramid.

4. The pyramid of energy is always upright. It is seen in a pond, grassland and a tree ecosystem. Energy flows through the food chain in the ecosystem in several steps till it reaches the top carnivores. At every step a large amount of energy is lost by radiation. The energy

content of the several trophic levels progressively decreases. Thus the primary producers have very large amount of energy while the top carnivores have very diminished energy.

6.10. MODEL EXZMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. How does energy flow through the ecosystem?
2. What is food chain? Explain the series of steps that are involved in the food chain?
3. What is an ecological pyramid? Explian the different types of ecological pyramids.

II. Answer the following questions in about 10 lines each.

1. Write briefly about a food chain.
2. Explian the pyramid of numbers.
3. Describe the pyramid of biomass.
4. Write about the pyramid of energy.

Dr. Saraswathi Rao

UNIT - 7 : ECOLOGICAL SUCCESSION

Contents

7.1. OBJECTIVES

After going through this unit you will be able to:

* explain the evolution of plant communities,
* describe plant succession,
* list out and describe the different stages in a hydrosere and xerosere.

7.2. INTRODUCTION

Disturbances of ecosystem seem to occur frequently as man misuses his technology and creates environmental problems. Ecosystems react to disturbances of various kinds, natural and man-made. A French naturalist George Buffon in 1742 noted that one vegetation type prepares the way for another type. One of the concepts in the theory of the process of recovery from distrubance, is called succession. In the early days of modern ecology E. Warming, in his text book "Oecology of Plants" published in 1895, developed the idea that vegetation change was universal. The concluding part of the book was devoted to succession. F.E. Clements, published his book "Plant Succession" in 1916. His work influenced the American ecologists on the topic of succession for over half a century. Ecologists including E.Odum, are now looking at certain aspects of the succession as a process by which the ecosystem develops, which means the emphasis is placed more on energy flow and mineral - cycling changes and less on species composition of communities.

Ecological succession is a biological process of evolution of biotic communities on bare areas. The biotic community of an area has a life history. It takes birth, develops and ultimately matures. In ecological successions plant species replace each other in sequences that seem to be roughly predictable. Succession may be looked upon as a process of total ecosystem development, so that a formal definition can be Ecological. Succession is the gradual change that occurs in an ecosystem of a given area of the earth's surface on which populations succeed each other.

7.3. EVOLUTION OF PLANT COMMUNITIES

Many agents, of course, can disturb an ecosystem. Any physical phenomenon that will destroy life directly or alter environmental conditions, so that the old community cannot tolerate the new conditions or allows new organisms to compete successfully with the old species, provides a situation in which succession may occur. Volcanic activity, earth quakes, floods, glaciers, severe erosion, land slides, drought, disastrous storms, may temporarily denude an area or cause the death of many of the inhabitants. In a similar way rising and sinking of land masses may create changes which are so subtle that we do not recognise them as successional. Although movements of land masses occur gradually they do produce conditions that are involved in succession. A disturbance of natural vegetation by cultivation, lumbering or forest fire is followed by vegetational changes in a definite pattern.

Plant communities have their origin, then develop and finally mature. The birth of plant community begins with invasion. In this process spores and seeds of plants are transported on to a bare area. Some of these propagules germinate depending on the right environmental conditions. These new arrivals from outside are called pioneers. These reproduce and multiply, thereby beginning the process of colonisation. This is the second stage in evolution, followed by the third stage Ecesis. In this stage the migrants adjust themselves to the new area. This process is essential in the development of plant communities.

The next step is this evolution is further propagation leading to aggregation of pioneers. The consequence of this step is competition for food, light and space among the plants. In this struggle only the strong survive and multiply. The plants interact on the habitat and modify the environment. This is known as reaction.

Thus the gradual process of evolution of plant community takes place. The environment becomes finally stable since it cannot be modified indefinitely. It is the climate that determines the type of final vegetation, which will be in equalibrium with the climate. This is called the climax community. The dominant species of the climax community are in total harmony with the environment so that the community is relatively stable so long as the climate and physiographic factors do not change.

Check Your Progress -1

1. What are the different stages of evolution of Plant communities?

Note: a) Write the answer in the space given below.

b) Compare your answer with the one given at the end of this unit.

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7.4. PLANT SUCCESSION

Plant succession is a process in which a series of different plant communities occupy an area in a developmental sequence till the climax stage is reached.

Succession consists of changes in the community that occur in an orderly sequence and in a predictable direction. Succession is the result of changes that the existing community brings about in the physical environment. Succession leads ultimately to the establishment of a relatively stable community which is almost in complete harmony with the prevailing conditions of the environment.

Succession is a biological process and not a physical one. It is controlled by the community and not by the physical environment. The latter only determines the pattern and direction of succession but does not cause it.

Often successions are accompanied by changes in habits leading to greater productivity. Succession ends with a climax community characteristic for the region or habitat type. This phenomenon can be explained by the co-existence of plants with different strategies and life histories. There seem to exist three main classes of plant strategies: ruderal, competitor and stress-tolerator. These general strategies are suited for invasion in sequence, first into unoccupied habitat, then to invasion against competition and finally to persistence in a community where competition is so strong that individuals suffer physical stress. Physical development of ecosystem is particularly noticeable in primary successions. The more permanent of complex communities and ecosystems develop only after a prolonged series of communities occupies a site, usually with an accompanying series of physical modifications of the habitat.

Types of Plant Succession: Concepts and Terms

Succession traditionally is divided into primary and secondary, autogenic and allogenic types. Primary successions colonize bare sites and lead to the first occupation of the habitat by the climax community. Examples are successions on sand dunes, volcanic mud-flows, glacial till, filled-in lakes and marshes. Secondary succession replace a climax community following a disturbance. Old-field successions are secondary successions, as are the successions that replace forest in gaps after hurricanes or fires.

Autogenic succession is succession directed from within the ecosystem itself. The term particularly refers to habitat changes brought about by the biota as and when soil is built and nutrients are collected. If these enrichments of soil promote the next community replacement then the succession is autogenic.

Allogenic succession is a succession driven by forces outside the ecosystem as when a progressive fall in a marshy water table due to stream down-cutting leads to a succession of plant communities suited to progressively drier habitats. The communities themselves may have had no influence on the critical habitat changes. The conceptual differences between autogenic and allogenic successions are significant. In the former, plants and animals are the genesis of change, in the latter, they merely respond to changing climate or geography.

All the communities which are formed and replaced until a climax community is reached are collectively termed a sere and any one community of the sere is a seral stage.

A primary-succession sere may for example commence with wind-blown sand and end with a climax community like grassland or forest. A secondary succession sere may start with a ploughed field and end up with a climax community like a forest. The origins of the two kinds of succession are different. Since autotrophs are very important in these successions they are called autotrophic succession. Successions has also been applied to changes in dead organic matter as it is reduced to simple organic compounds. Often many species of animals, fungi and bacteria invade the dead material and before it is reduced to organic compounds, several changes of communities have occurred. Examples include the successions involved in rotting of dead trees, reduction of animal dung, breakdown of sewage in streams, invasion and destruction of plant galls. In these cases, green plants are usually not involved. Thus these are called heterotrophic successions. The organisms in heterotrophic successions gradually use up the energy of the dead organic matter. There may be a series of different organisms which replace each other, but the end point is utilisation of all the energy and dissipation of the community.

Hydrosere is a successional sequence on wet land. Wetland successions in general are called Hydrarch Successions. In a like manner successions on dry sites like sand dunes are called Xerarch Successions. A sere beginning in saline water is Halosere and sere beginning in dry situation is Xerosere. There are two types of xeroseres a) Lithoseres-those beginning on bare rocks b) Psammoseres - those beginning on sand.

The communities of sere are called Seral Communities. The earliest seral community on a site is the Pioneer Community. The succession is said to end with the climax, which is the community with which a succession ends and in which species perpetuate themselves through reproduction. Since slow changes continue in a "climax" community even when the climate is constant, an alternative definition may be that the climax is a community similar to comparable environments that are free from physical disturbance and in which important species can persist for many generations. The composition of the climax community depends on the physical properties of the habitat type can be recognised by its characteristic dominant plants. But this typical result of a local succession or sere is often prevented by events like repeated fires or heavy grazing, leading to a quite different climax community. This community is called Proclimax (Grime, 1979). The species important to the proclimax will be quite different from those that would be important if the succession had been left to proceed without the impositions of the disturbance. In heavily grazed pastures, for instance, unpalatable grasses or forbs may be common or even dominant, though they might quickly disappear if the grazing pressure was removed. Perhaps the most extreme example of a proclimax is an agricultural field where repeated ploughing produces a community of opportunistic herbs. This listing of successional phenomena emphasizes plants. Parallel replacements may proceed among the animals and for the maintenance of a proclimax animal consumers can be decisive. But the more readily observed replacements are among the plants. Most studies of ecological succession, therefore concentrate on changes in plant populations.

Two sets of successional phenomena require explanation, the population replacements themselves and the parallel modifications of habitats that are particularly notable in some successions.

Check Your Progress-2

Name the two types of xeroscre?

Note: (a) Write the answer in the space given below

(b) Compare your answer with the one given at the end of this unit.

7.5. HYDROSERE

A hydrosere originates in a freshly formed lake or a pond. The hydrosere occurs in seven developmental stages culminating in the climax community. These stages are detailed below

a. **Pioneer Stage:** This stage is represented by phytoplankton which include unicellular and colonial forms of green algae near the water surface. There is no plant life in the bottom of the pond. The animals feeding on dead phytoplankton are *Amoeba, Paramecium* and *Vorticella* and sometimes blue-gill fish, sunfish and small caddis flies.

b. **Submerged Stage:** Represents that stage where the water is less than 10ft. deep. In this stage totally submerged plants occur along with free floating plants. These plants are *Hydrilla, Potamogeton, Vallisneria, Utricularia, Zanichellia,* submerged *Ranunculus* and many algae such as *Chara* fill the water as tangled vegetation. This vegetation modifies the habitat making it more suitable for new invaders.

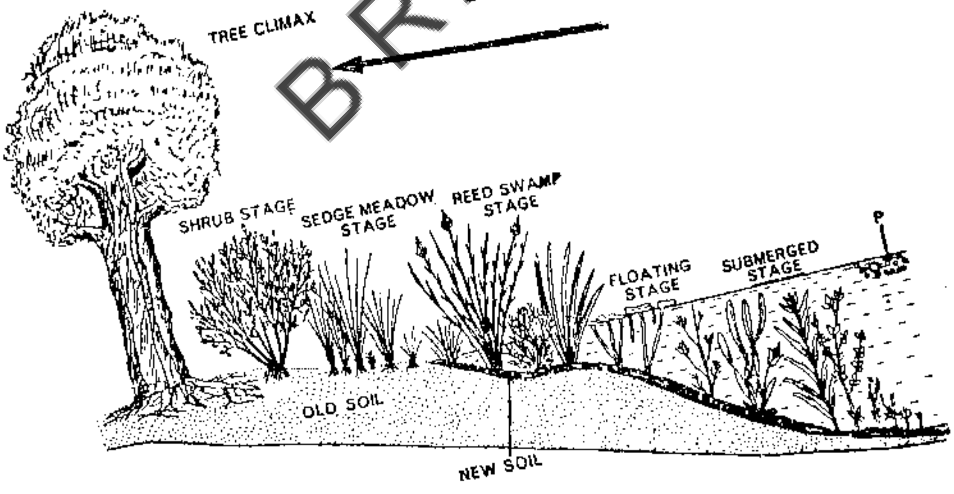

Fig. 7.1. Plant succession in an aquatic system.

c. **Floating Stage:** Water in the pond becomes shallow due to deposition of soil and humus. The water depth at this stage is 5 to 10ft. which favours rooted plants such as *Nymphaea* (water lillies) and *Marsilea* (the water fern). The plants which float are *Eicchornia* (water hyacinth), *Lemna* (duck-weeds), *Pistia, Wolfia* and *Ceratophyllum* (hornwort). These plants make conditions unfavourable for the submerged plants, which migrate to deeper water. The plants of the floating stage continue to deposit soil and humus on the lake bottom. This causes it to become too shallow for these plants, paving way for the next stage. The animal life of the floating stage include *Hydra* sp. snails, frogs, diving beetles, whirling beetles.

d. **Reed Swamp Stage:** The water depth is 2 to 3 ft. at this stage. This favours marsh plants like *Carex, Phragmites, Typha, Rumex, Eclipta, Sagittaria* and the like. These plants are rooted at the bottom and are partly submerged, with their shoots extending above water. These plants cut off light from the floating plants which find the habitat unfavourable and migrate into deeper water. The animal life consists of dragon flies, may files, water scorpion, annelid worms, fishes, blue heron, kingfisher and musk rats.

e. **Marsh Meadow Stage:** At this stage the water is just at the surface of the soil. The plants favouring this stage are species of *Polygonum, Campanula, Carex,Eleocharis* (spike rushes), sedges and tall grass. These plants together change the habitat by building up the soil, transpiring large amount of water and leaving behind dead reamins. This makes the area rather unsuitable for the plants of the reed swamp stage, but perfectly suitable for the next stage.

f. **Wood Land Stage:** In this stage water-loving shrubs and small trees like populus, salix and tree willows are prevalent. These plants act on the habitat and change it by vigorous transpiration, accumulating plant debris and catching wind-borne soil. Small plants which can tolerate the shade also grow among these shrubs and trees.

g. **Climax Forest:** In this stage more trees make their appearance. These are the shade-tolerant type. These will gradually replace the preceeding sun-loving trees. The type of climax vegetation will be determined by the climate. If the climate is moist a forest community will develop. In case it is dry, a grassland may develop.

In a hydrosere, the area which was once under deep water turns into a forest.

7.6. XEROSERE

Plant sucession in xerophytic conditions is called a xerosere. An excellent example of xeric habit is rocky habitat, where there is almost complete absence of water. Nutrients are also lacking while there is plenty of sun, wind and high temperature.

There are six developmental stages in a xerosere.

a) **Crustose -Lichen Stage:** The lichens of the crustose type are the first settlers on bare rocks. *Graphis, Licidia* and *Lechanora* are important plants of this stage. These plants can withstand extremely dehydrated conditions. They display slow growth and can absorb any rain which falls on them. Lichens secrete acids that slowly corrode and decompose the rock.

b) **Foliose-Lichen Stage:** This is the second stage in the xerosere and is represented by xeric foliose lichens such as *Physcia* and *Parmelia.* These are transported by means of spores or fragments. They occupy the depressions caused by crustose lichens, which die and decay, leaving humus on the rock. The growth of foliose lichen brings about further degradation of the rocky habitat and makes way for the growth of xerophytic mosses.

c) **Moss stage:** This stage is represented by mosses such as *Polytrichum* and *Grimmia*. These mosses can endure extreme dry conditions. Fruticose lichens such as *Cladonia* and *Usnea* accompany these mosses. The growth of these lichens and mosses affect the growth of lichens of the second stage adversely. Hence they gradually disappear.

d) **Herbaceous Stage:** The growth, death and decay of xerophytic mosses leads to increased soil formation with greater water-holding capacity. This favours the growth of herbs with short life cycles. These are followed by biennials and perennials. The roots of these plants cause further disintergration of rock. These plants help increase humidity. These conditions are now favourable for the shrubs to grow.

e) **Shrub stage:** Shrubs are generally of the xerophytic type. The roots of these plants cause further disintegration of rock resulting in more soil. This is enriched by humus formed by death and decay of herbs. The growth of shrub not only reduces evaporation from the soil but also increases humidity. The wind movement is also decreased. These conditions allow for the growth of trees.

f) **Climax Forest:** Climax forest is the final culmination of xerosere. The earliest types of trees are xeric in nature with stunted growth. These are followed by larger trees; under their increasing shade, mesophytic trees appear. Now a new herbaceous and shrubby vegetation suited to more humid environment with richer soil develops in the shade on the forest floor.

Check Your Progress-3

Describe a xerosere briefly.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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7.7. CAUSES OF SUCCESSION

Clements stressed on two factors to explain the cause of succession. These factors are reaction and competition. Reaction is the action of the organisms on the environment. This includes such action as chemical and physical reactions on rock to produce smaller particles, changing the pH and water-holding capacity of the soil as organic matter accumulates. Soil formation is one of the most important ways organisms react to produce succession. A significant aspect of soil formation is the development of soil fertility. Various species of legumes (many of them appearing early in succession) may harbour root nodules in which there are bacteria capable of fixing free nitrogen of the air, thereby making nitrogenous compounds available to plants The ability of pioneer or early stage succession plants to add such a vital plant nutrient tothe soil is significant.

Competition means that as the reactions of organisms change the environment, conditions are created which are favourable to other species. These species could now compete with earlier ones for specific nutrients in short supply and could eventually displace the very species which created such favourable conditions. Thus whole communities may gradually change, as early forms of species drop out and later forms take over.

Although reaction and competition are very logical explanations of the driving force of succession. they are difficult to prove and are in fact often only assumed. That is, succession is observed and compeititon is assumed as the cause, while in actuality there might be other factors involved. Some recent studies have shown that competition for scarce nutrients does in fact exist, at least in some cases. Inhibitory substances secreted by some plants might be an important causative factor in succession. Such secretions are known from some flowering plants and from several microbial organisms. Some vascular plants produce substances which inhibit nitrogen fixing and nitrification bacteria. This could give these plants an advantage over species requiring larger amounts of nitrogen than themselves. Another situation is that a species may produce a substance which is toxic to its own seedlings. Probably chemical inhibition, reaction, compeititon and possibly other factors are all involved in the driving force of succession.

7.8. SPEED OF SUCCESSION

The time taken for a sere to run its course is not exactly known. However, there have been studies on this aspect which give some idea. Studies on lava flows in Mexico have indicated that lichens, algae and mosses have grown within 3 years after an eruption, flowering plants within five years, while trees and shrubs have taken 14 years. However the total process of succession on lava flows is lengthy, taking centuries for soil production. Investigations in New Hampshire have revealed that surfaces of bare rocks remained largely uncovered by vegetation till after 72 years. Mosses and lichens did appear on one landslide which was 19 years old. In Glacier Bay, Alaska early explorers noted that a glacier started receeding in about 1800. In 1935 a forest approaching climax composition occupied the site with the oldest trees, 121 years old. Thus a rapid succession has occurred in this case with the establishment of climax tree seedlings soon after the recession of the glacier. One ecologist used the age of trees and stumps as calculated by tree rings, historical data, his own and other worker's observation on various stages of succession in the area, and the known maximum length of life of trees, in estimating the duration of the sere in Algonquin Park, Ontario. He concluded that there the climax stage could be reached in 1,100 years, barring interuptions. Thus climate, the condition of the substrate, the extent of disturbance, and other factors may alter the time it takes for succession to be completed.

7.9. SECONDARY SUCCESSION

Most of the ecosystems, are in some stage of secondary succession due to the prevalence of disturbances which do not eradicate all life. Secondary succession is similar to primary succession in several ways. The differences occur because of the organic matter, seeds, spores and roots which may already be present in the soil and the plants still growing on the disturbed ground. The first stages of development are usually more rapid than in primary succession. In the study of succession on land slides mentioned earlier although areas of bare rock were still mostly uncovered after 72 years, herbs, shrubs and trees became established within 9 years in areas where residual forest soil remained or collected between the rocks. After 72 years the herb layer was virtually similar to the surrounding forest, and the tree species composition was approaching the climax. Initial propagules may also make the path of secondary succession drastically different from primary succession in the same area. Egler uses the terms Initial Floral Composition (IFC) and relay floristics to describe two principles of old-field succession. IFC means that when an old field is abandoned most of the species that will eventually appear in the climax community are already present. However annual plants grow faster than perennials so they become conspicuous first. Similarly, perennial herbs grow faster than shrubs and shrubs faster than trees. So we have "a stage" when annuals are dominant followed by perennial, shrub and tree stages. The other principle of old-field succession, relay floristics assumes that annuals invade and prepare the way for perennials, which in turn prepare the way for the invasion of shrubs, while shrubs do the same for trees. In this scheme there are successive invasions as in primary succession.

One major consequence of IFC is the direction that succession takes, for example the species composition through the sere may be completely different for each site, since it will depend almost entirely on what seeds and propagules are in the soil at the time of abandonment. For example if no tree seed or propagules are there, invasion by trees may be precluded for a very long time, since the original vegetation may be too dense to allow germination or survival of tree seeds. Thus old-field succession may be considered less predictable than primarysuccession. Egler believes that in old field succession, IFC is more important because it is a more common situation than relay floristics, but both situations may occur. There are important practical consequences to these principles since if IFC is the major mode of occurence of an undesired species, in certain cases it could be removed with the expectation that it could not quickly invade on its own. This could have practical applications in roadside and powerline vegetation control and in forestry.

7.10 RETROGRESSIVE SUCCESSION

In general, plant succession implies a progress to a 'higher' type of community, sometimes a different sort of situation occurs. A stable community may deteriorate and a new stable community develops. Some ecologists have called this retrogressive succession; they aver that a true development to a new community has taken place. Other ecologists insist that the new community is merely established at the expense of the deterioration of the site and tend to overlook the development to the new community as a sere. An example of this process may be found in areas that have been burned frequently. One such area may be observed near New York. Here an area of sandy soil covers a wide belt some 30 kilometers long and 8 to 10 kilometers wide. Much of this land was once covered with a climax forest of white pine. The trees were cut with increasing population and parts of the sandy soil were formed. Fires broke out frequently, burning the little humus present and transforming the whole area into a sandy plain. White pine could not tolerate the fires, but another pine, pitch pine could withstand the fires and the poor soil. Today the pitch pines grow scattered about as in a savanna, and the main vegetation beneath them is a dense growth of shrubs, including bear oak, shrub oak and dwarf cherries. Most of these shrubs occur in small numbers elsewhere in this region. Here the bushes and dwarf trees are dominant, or at least codominant with the pitch pine, and they form a community distinct from any other in the nearby region. Indeed no seral stage of normal succession in this region resembles this vegetation type. Yet if the fires and other results of human activity were ended, the area's normal climax would eventually be reestablished. Such an area is referred to as a disclimax.

7.11 COMPLEXITY OF SUCCESSIONAL PATTERNS

The pattern of succession may be complicated in situations where there is a partial disturbance of a climax forest. It was found that in one area where yellow birch trees were lumbered, the seedlings of the remaining birch trees found it difficult to become established because of competition from rapidly invading black berry and raspberry bushes. The invasion of shrubs also caused the rapid loss of favourable conditions created during lumbering operations. Finally, sprouting by red maple trees was a further complication because of the rapid initial growth of its sprouts compared to the slow growth of the birch seedlings.

Sprouting is a growth characteristic of great significance in forest succession. Chestnut trees are still sending up sprouts, even though the stumps of the former mature trees have mostly rotted away.

7.12. CLIMAX THEORIES

Succession involves the idea of a gradual change of communities towards a stable state known as the climax. It has been noted by many ecologists that a climax community is not perfectly stable; it is merely more stable than a seral community. Climatic fluctuations are known to affect it. Generally, in a forest climax, the many young saplings will be of the same species as the mature trees. There will be a tendency towards regularity of species composition on sites having similar environmental conditions. Productivity would be in a steady state and soil will have more depth and organic matter.

Determination of what is a climax community may be made in part by a study of vegetation in the area which is considered to have been undisturbed. A major consideration in the definition of climax is what factor or factors determine the stability and composition of the climax. Differences of opinion in this matter are the basis of several theories regarding the climax.

Mono Climax: According to Clements there is only one true climax in a climatic region. There are usually several such climatic regions within a biome, each region having its distinct climax. Each climax is, the end point of succession over a large geographic area. Certain species will be dominant and thereby control the species composition of the climax. The vegetation will react upon the soil, producing uniformity of soil throughout the climatic region despite any differences in original parental rock or soil conditions. Various situations may prevent the attainment of favourable conditions and complete convergence to the climax. Terms such as subclimax, postclimax, preclimax and disclimax are used to describe the deviations from the climatically stabilized climax.

Polyclimax: The polyclimax theory believes that climate is any one of the several factors controlling the stability and structure of the climax. This allows many climaxes in a climatic region. Thus a stable community on most favourable soils would be a climatic climax, on less favourable soils, anedaphicclimax, on rugged topography (which would produce local climates), a physiographic climax, in places where there is a continual disturbances by fire, grazing or other causes, a disclimax and so forth.

7.13. SUMMARY

Ecological succession is the gradual change that occurs in an ecosystem of a given area of the earth's surface on which populations succeed each other. This is a biological process controlled by the biotic community. The physical environment only determines the pattern and direction of succession. Vegetational changes take place in a definite pattern after a disturbance of vegetation. Succession may be primary, secondary, autogenic or allogenic or even retrogressive. Primary succession may begin in a newly formed pond. This is called hydrosere. If the succession occurs on a bare soil or rock it is known as xerosere. Several factors may affect succession.

7.14. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The evolution of plant community takes place in several stages. They are migration, invasion, colonisation, interaction, and reaction. This process ends with the climax community which is in equilibrium with the prevailing climate.

2. The two types of xeroseres are: (a) lithoseres - those originating on bare rocks, (b) psammoseres - those originating on sand.

3. Xerosere is plant succession in xerophytic conditions. It takes place in six stages beginning with pioneer & crustose -Lichen stage, followed by Foliose-Lichen stage, Moss stage, Herbaceous, Shrub and finally Climax Forest.

7.15. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. What is ecological succession ? What are its three major aspects ?
2. What is climax community ? Describe the evolution of plant communitions.
3. What are the factors which determine the plants that will survive competition and become dominant in particular habitat ?

II. Answer the following question in about 10 lines each.

1. Define plant succession. What are the plant successions you know.
2. What are the differences between primary and secondary successions ?
3. Write short account of hydrosere.
4. Write a short account of xerosere.

Dr. Saraswathi Rao

BLOCK - 2
ENVIRONMENTAL POLLUTION

UNIT - 8 : AIR POLLUTION

Contents

8.1. OBJECTIVES

After going through this unit you will be able to:

* describe the atomspheric structure,
* define air pollution,
* list out various air pollutants and their sources,
* describe the effects of air pollution on life and material,
* explain the air quality standards,
* list out control methods for gaseous pollutants and particulate matter.

8.2. INTRODUCTION

Earth is the only planet in the universe known to sustain life. The five elements of life-supporting system - air, water, land, flora and fauna - are all essential to the survival and well-being of Man. During his early periods, Man lived as a hunter-gatherer who survived by killing wild animals from the nearby environment. Then the primitive hunter-gatherer improved gradually, developed tools and hunting weapons. The advanced hunter-gatherer had some impact on his environment only in using fire. Both early and advanced hunter-gatherer societies survived by learning to work with nature. They had two energy sources-the sunlight captured by plants and their muscular power. Nature had its free will and ruled the roost. Nature was feared, worshipped and awed. Then came the agricultural revolution. Man's onslaught on nature began with fire and smoke leading to air pollution.

The "Agricultural Revolution" began 10,000 to 12,000 years ago and this changed the relation between man and earth. The formation of agricultural communities led to more consumption of food, and wood for fuel and buildings. To meet these needs people cut-down vast areas of forests and ploughed up large areas of grasslands. The next major cultural change took place in mid 1700's, known as "Industrial Revolution" which changed our relationship with earth even more than agricultural construction for dwelling shifted the dependence on renewable resources to non-renewable fossil fuels-first coal,later oil and natural gas. These new fuels and machines led to industrialization and increased urbanization. Unabated use of cheap fossil fuels that support industrialization and motor transport is responsible for most of the world's air pollution triggering a chain of global and regional environmental problems. A report of WHO expert committee warns that the earth's atmosphere is finite, and its capacity to cleanse itself seems to be limited. Since no life can survive without air, and no healthy life is possible without good quality air, the preservation of the air quality is of utmost concern.

8.3. ATMOSPHERE

The atmosphere is a gaseous envelope of the earth. It is recognised as layered, and is divided into four layers based on temperature variations. It is convenient to delineate these layers in the reverse order. The lower portion of the atmosphere is the troposphere. It extends from the ground upto a height of 6-17 km depending on latitude and season of the year. It comprises of 80% mass of atmosphere. Here, air temperature, barometric pressure and air density decrease with altitude. The normal temperature decrease is about 0.6° C per 100 meters and this decrease in temperature with height is the lapse-rate. However, at night loss of heat by radiation cools the ground and this inturn cools the air lying nearest to the ground. Thus, instead of temperature decreasing with height, a 'temperature inversion' occurs up to a certain height, the top of inversion, above which the usual lapse rate is encountered. The portion above troposphere where constant temperature persists is known as the tropopause. The stable layer of air above tropopause and upto 50 km is called stratosphere. It is characterized by the increase in temperature with altitude. In this region ozone molecules absorb UV radiation from the sun and decompose into oxygen molecules and oxygen atoms which on combination release energy in the form of heat, causing the temperature to increase with altitude. The upper surface is called stratopause. In the mesosphere upto 85 km the temperature falls with increase in altitude reaching 70° C at the mesopause. Ozone concentration decreases rapidly with height and the decrease in temperature is due to decreased absorption of sloar radiation by ozone.

The thermosphere upto 200-500 km also known as ionosphere is characterized by a steady rise in temperature with altitude. The temperature increase is related to the absorption of ultra-violet radiation from sun by molecular oxygen and nitrogen.

Composition of Air: The air we breathe is a mixture of nitrogen, oxygen, argon, carbon dioxide and other trace elements. The composition of dry air at sea level is as follows.

Component	Volume (%)
Nitrogen	78.084
Oxygen	20.946
Argon	0.934
Carbondioxide	0.031
Neon	0.00182
Helium	0.00052
Krypton	0.00011
Xenon	0.0000087
Methane	0.000125

The water vapour is confined exclusively to troposphere by the process of condensation and precipitation. Ozone is largely found in the stratosphere. The movement of air across the earth's surface continually renews the air around us.

8.4. CLASSIFICATION OF AIR POLLUTION

The chemical composition of the atmosphere given above gets modified by the injection of particles, gases and volatile substances naturally or through anthropogenic activities. As long as a chemical is transported away or degraded rapidly compared with its rate of production there is no pollution problem, but when the reverse occurs the result will be **Air Pollution.**

The WHO defines air pollution as a "situation in which the outdoor atmosphere contains materials in concentrations which are harmful to people or their environment". The citizen's report of state of India's environment expressed that in the Indian context, the definition should also cover the health hazards arising from indoor burning of non-commercial fuels (wood, cowdung, agriculture wastes etc.) which contribute a lot of smoke and particulate matter at low ground level. The Air (Prevention & Control of Pollution) Act of 1981 defines air pollution as "the presence in the atmosphere of any solid, liquid or gaseous substance as may be or tend to be injurious to human beings or other living creatures or vegeration or property or environment"

Thus, air pollution is the accumulation of the substances in the air in concentrations to endanger human health or to produce other measured effects on living matter and other materials. Chemical pollutants can be considered as the compounds in the wrong place at the wrong time in the wrong concentrations.

Check Your Progress-1,2 & 3

1. What is atmosphere ?
2. What are the features of troposphere ?
3. Define air pollution ?

Note: (a) Write the answers in the space given below.

(b) Compare your answers with those given at the end of this unit.

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There are two main groups of pollutants-primary and secondary. Primary pollutants are those that are emitted directly into the air including particulates, sulfurdioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NOx) and hydrocarbons. Secondary pollutants are those produced through reaction among primary pollutants and normal atmospheric compounds. Ozone and sulfuric acid aerosols are secondary pollutants. The primary pollutants account for more than 90% of air pollution problems.

On the basis of chemical composition, various air pollutants are classfied as follows:

Major Classes	Sub-classes	Typical member of sub-clauses
Particulates	Solid	dust, smoke, fumes, flyash
	Liquid	mist, spray.
Gases (organic)	Hydrocarbons	Hexane, benzene, ethylene, methane, butane.
Gases (inorganic)	Oxides of carbon	CO; CO_2
	Oxides of sulfur	SO_2; SO_3
	Oxides of nitrogen	NO;NO_2;N_2O
	Other inorganics	H_2S; HF; NH_3

Major Sources of Air Pollution: Many industrial activities, and particularly energy generation, material production and vehicular traffic have brought significant increase in the atmospheric contamination, in addition to the pollutants released from natural sources. Natural sources are the wind blown dust, volcanoes, forest wild-fires, vegetation and seasalt spray. Anthropogenic sources include the processing of mineral resources at high temperature such as Coal, Oil and Natural Gas combustion in electric power station and industrial plants, roasting and smelting in ferrous foundries, refuse incineration and kiln operation in cement plants, as well as internal combustion engines.

In the following the general source of estimated air pollution is given following Mohan (1991)

Source	% SO_2	%NO_2	%CO	%Hydro-carbons	%Perti-culates
Transportation	0.7	4.2	46.5	8.5	0.7
Industry	6.3	1.4	1.4	2.8	4.2
Power generation	8.5	2.2	0.7	0.7	2.1
Space heating	2.1	0.7	1.4	0.7	0.7
Refuse burning	0.7	0.7	0.7	0.7	0.7

The situation in Bombay as given in Scavenger, April 1980 of SOCLEEN is as follows:

Source	% SO_2	%NO_2	%CO	%Hydro-carbons	%Perti-culates
Domestic	0.8	3.6	2.0	2.4	`20.0
Commercial& Institutional	0.6	1.1	-	-	2.8
Industrial	68.8	36.4	29.0	51.4 1	5.0
Power generation	18.0	30.6	0.5	-	30.0
Transport	11.8	28.0	68.5	46.2	32.0

It appears that transport (automobile) industry and thermal power generation sources are the most important in the matter of air pollution.

Check Your Progress-4

Mention different types of air pollutants.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

8.5. SOURCES & EFFECTS OF VARIOUS AIR POLLUTANTS

8.5.1. Aerosols

Any solid or liquid matter dispersing through the air is an aerosol. Fine liquid particles are mists and solid particles are dusts or smoke; a high concentration of water droplets are fogs; smoke and fog together constitute smog. Natural sources are dust storms, volcanic eruptions, photochemical gas reactions, viable particles such as viruses, bacteria, fungi, spores, pollen from continental areas, and sea spray. Anthropogenic sources are combustion secondary products of photochemical and atmospheric reactions and industrial emissions.

Effects: Aerosols when present in high concentrations reflect or absorb the incoming solar radiation causing fluctuations in atmospheric temperature. Some of the atmospheric aerosols like hydrocarbons, Pb, As, H_2SO_4 have a damaging effect on human health because of their chemical nature. They penetrate through lungs causing irritation to internal membrane and transport absorbed toxic gases and vapours deeper into the lungs rather fastly. There has been an increasing concern about the biological aerosols like the bacteria, fungi, viruses and pollen grains since they are the cause of human, plant and animal diseases. The importance of human disease transmission by these biological aerosols is in part a function of urbanisation; it is here that airborne transmission of human disease is especially common. The human environment of crowded cities was a contributing factor in the plague epidemic of 1348. Pollen grains and fungal spores are responsible for human allergies, bacteria and viruses for human infectious diseases, fungal spores for human infectious diseases and allergies. As the air pollution information is accumulating, it is becoming evident that chemical pollutants and the biological aerosols interact with each other resulting in synergistic effects making human suffering more pathetic.

Check Your Progress-5

What are the major sources of air pollution?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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8.5.2. Carbon dioxide

Atmospheric CO_2 is a relatively small carbon pool, but has been measurably affected by anthropogenic CO_2 release. It seems that atmospheric CO_2 levels have been steadily rising at 1 ppm (part per million) per year - from 311 ppm in 1957 to 350 ppm now. The reasons often cited for such a rise of CO_2 are the burning of fossil fuels, and deforestation, the farmer causing about 75% of current CO_2 emission, and the latter about 20%. Presently, the atmospheric concentration of CO_2 is 350 ppm by volume. If there is a 4% increase in the consumption of fossil fuels annually, the atmospheric CO_2 is estimated to reach 400 ppm by the end of 2000 A.D.

There is also an equal concern for the consumption of oxygen during fossil fuel burning. K.C. Sahu (1994) of the Indian Institute of Technology, Bombay, states that the oxygen reservoir of the atmosphere (21% by volume) was not built up by photosynthesis - respiration cycle. The real source of oxygen is the organic matter buried in geological time; for each bit of organic matter buried, a corresponding quantity of oxygen has been released and stored in the atmosphere. By burning the fossil fuel we are removing oxygen from the present reserve of atmosphere. Sahu estimates that every three tonnes of carbon when burnt consumes eight tonnes of oxygen.

Effects: Continuous increase in the concentration of CO_2 affects the energy balance of the atmosphere by creating a "Greenhouse Effect". CO_2 is transparent to visible radiation and does not interfere with the incoming radiation which is in short waves. Solar radiation striking the earth is irradiated back as longer wavelength infrared radiation. CO_2 absorbs strongly in the infrared radiation. The insulating CO_2 blanket would thus retain most of this radiation and bring about a warming trend in the climate, hence the present day concern for global warming due to CO_2 increase.

An increased warming of the earth will result in the receding of glaciers, disappearing of polar ice caps, and the raise of ocean levels. It is estimated that if all the ice on earth should melt, 200 feet of water would be added to the surface of all oceans; then coastal cities would be inundated. The basis for these predictions is not absolute. Current climatic models project that the earth's average atmospheric temperature will rise 1.5° C to 5.5° C by 2040 AD if we keep pumping CO_2 and other greenhouse gases (CH_4; CFCs) into the atmosphere at the present rate. Because of many uncertainities in these global climate models, their developers believe their projections are accurate within a factor of two. This means that projected global warming during the next century could be as low as 0.7° C or as high as 11° C. There is about a 50% chance either way.

We may note that a serious reduction in CO_2 levels would be just as damaging as the increase, with surface temperature falling dramatically. During the last ice age, the CO_2 concentration was around 180 ppm. A total absence of CO_2 would likely leave the planet earth a ball of ice, or at best frozen tundra.

8.5.3. Carbon monoxide

Carbon monoxide is the product of incomplete combustion of carbon and its compounds. Human activities contribute 250 million metric tonnes of CO annually. Natural source of CO also exists, the most impportant source being the oxidation of methane. Atmospheric methane is produced by anaerobic decomposition of organic matter. CO is also produced in the ocean surface layer perhaps through biological oxidation by marine organisms. Some authors hold the view that automobile exhaust is by far the most important source. Misra (1990) citing the recent work stated that the CO produced from combustion contributes about 10% while the atmospheric reactions and emissions from oceans constitute the rest 90%. Of the different types of vehicles, two and three - wheelers (with two-stroke engines) are real culprits; they emit nine times more CO than cars. Both gasoline driven, and diesel driven vehicles exit CO, the former outwitting the later, and among the various pollutants in vehicular exhausts CO exceeds qualitatively. Nearly 70% of the vehicles in India in 1991 are two and three-wheelers, the related figures in various metropolitan cities being 42% in Calcutta as well as Bombay, 61% in Visakhapatnam (1994), 71% in Delhi, 73% in Madras, 80% in Bangalore and 85% in Hyderabad. By 2000 AD the two and three-wheelers are likely to constitute 80% and most of these will ply in the urban areas.

Effects: Carbon monoxide (CO) is a highly poisonous gas and it is generally classified as asphyxiant because of its strong combination with haemoglobin in the blood. CO competes with oxygen to combine with haemoglobin to form the carboxyhaemoglobin. CO wins the competition since it has 200 times more affinity for haemoglobin than O_2. The formation of carboxy haemoglobin impairs the transport of O_2 from lungs to other tissues. Headache, nausea, vomiting, visual disturbance, mental confusion, muscular noncoordination, rapid pulse, rapid and irregular respiration, distorted judgement, drowsiness, unconsciousness are some of the symptoms seen during acute toxicity due to high CO concentration in the blood. CO pollution is a serious problem in the urban areas and traffic police are particularly vulnerable; they are advised to have oxygen supplies.

8.5.4. Airborne Lead

The automobile exhausts are the major source of lead in the air. Tetraethyl lead and ethylene dibromide are added to gasoline to improve its efficiency as a fuel by reducing knocking. Finally, lead bromide comes out as a gas through exhaust pipes. Apart from automobile exhausts (80%), the other sources of airborne lead are metal smelters, battery producing plants, coal and oil burners. It is gratifying to note that Indian Government has taken a decision to produce in a phased programme the lead free gasoline. It has already introduced the same in the metro-politan cities of the country.

Effects : Lead is a highly toxic and cumulative poison. When airborne lead is inhaled it is trapped in the lungs and absorbed into the blood stream. Then the lead forms a mobile pool and is circulated throughout the body. Though some of this lead is present in body tissues and organs including liver and kidney, it is mostly attached to haemoglobin molecules. Lead accumulation leads to anaemia and, cirrhosis of liver. It affects nervous system and intelligence in young children.

8.5.5. Oxides of Sulfur

The oxides of sulfur, SO_2 and SO_3 are serious pollutants. The life-time of SO_2 is short lasting for 3-7 days. It is oxidised to SO_3 under the influence of sunlight, hence SO_2 is called primary and SO_3 secondary pollutants. In the presence of moisture SO_3 becomes H_2SO_4 or a sulphate salt. The major natural source is volcanic eruptions. Also the H_2S produced biologically on land in coastal areas and where organic waste is getting decomposed becomes a source of SO_2 when it is oxidised non-biologically by atomic and molecular oxygen and ozone. The anthropogenic sources are also important, particularly fuel combustion, oil combustion and refining, copper, lead and zinc smelting. The thermal power plants are important source of SO_2. In India they are entirely coal fired. Although the Indian coal has a low sulfur content, less than 1% the scale of coal use - the Singrauli plant alone needs 29,000 tons a day - offset the advantage of low sulfur content. According to one estimate SO_2 emissions from coal combustion in India had increased from 0.6 million tonnes in 1964 to 1.10 million tonnes in 1979. A super thermal plant using even normal or low sulphur coal will exit 100 tonnes of SO_2 a day. It is estimated that by 2000 AD, the power stations in India will consume 195 million tonnes of coal a year, then one can imagine the quantum of SO_2 emissions. Oceans are an important sink of SO_2. Plant uptake of SO_2 is almost completely through the leaf pores. Soil with increased number of micro-organisms absorb SO_2.

Effects : SO_2 destroys leaf tissues causing discolouration, necrosis etc. Alfa-alfa, barley, cotton and wheat are sensitive while potato, onion, corn and maple are resistant. The inhalation of SO_2 can cause short-term respiratory irritation, bronchial constriction and impaired breathing function may also result. The health effects due to SO_2 inhalation and conversion of SO_2 to H_2SO_4 in the lungs are aggravation of respiratory diseases including asthma, chronic bronchitis, reduced lung function, irritation to eyes and respiratory tract and death. The London Smog of 5-8 December, 1952 which took 3500-4000 human lives had a high concentration of SO_2 and particulate matter.

H_2SO_4 is highly corrosive, and cause 'stone cancer'. It speeds up the deterioration of building materials like carbonate stones. The more soluble $CaSO_4$ is formed and is readily washedout. Marble is particularly vulnerable to H_2SO_4. The danger to Taj mahal of Agra has been anticipated from the gigantic oil refinery at Mathura city 40 km from Taj Mahal. The rate of corrosion of iron is increased by as small as 50% in the presence of 0.1 ppm of SO_2 and particulate matter producing ferrous sulphate. H_2SO_4 also dissolves the protective corrosion layers made up of Zn, Cu, Al, etc. producing sulphates which are washed away. Acid hydrolysis of leather protein in leather goods and cellulose in paper are also known.

8.5.6. Oxides of Nitrogen (NOx)

A number of oxides of nitrogen exists, but the most common forms are Nitric Oxide (NO), Nitrogen dioxide (NO_2), Nitrous oxide (N_2O), the former two being the most important in air pollution. These gases are the important components in nitrogen cycle. Any imbalance in the concentration of NOx causes disruption in nitrogen cycle, which affects the ecological balance.

Nitric oxide is formed under high temperature combustion process :

$$N_2 + O \longrightarrow NO + N$$

$$N + O_2 \longrightarrow NO + O$$

$$(N_2 + O_2 \longrightarrow 2NO$$

The NO is oxidised in the atmosphere to NO_2 :

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

Natural bacterial action discharges about 5 X 10^8 tonnes of NOx mainly in the form of N_2O and often NO every year all over the world, whereas man-made sources annually release 5 X 10^7 tonnes of NOx. The principal sources of NOx in atmosphere are combustion of coal, motor vehicles and industrial processes. The predominant sources of NO are oxidation of NH_3 and high temperature combustion processes.

Bacterial denitrification in soils results mostly in the release of N_2O. The concentration of N_2O remains reasonably constant up to the tropopause and then decreases with altitude because of photodissociation reaction. The levels of nitric oxide and nitrogen dioxide in urban areas depend on traffic density and weather conditions. The NO_2 produced absorbs strongly in the UV region, dissociating to NO and atomic oxygen and subsequently ozone. Nitric oxide with ozone form nitrogen dioxide.

Effects : These oxides of nitrogen are converted to nitric acid (HNO_3) that returns to the earth. These are important in the formation of 'Photochemical Smog' which is more serious than the reactants. The effects of NO_2 on man range from unpleasant odour to serious lung congestion to death, depending on the concentration of NO_2 and the duration of exposure. Long term exposure to 0.06 ppm of NO_2 is related to an increase in acute respiratory diseases in humans. Clearly NO_2 levels in polluted urban atmospheres would result in adverse health effects.

8.5.7. Chlorofluorocarbons (CFCs)

The Ozone layer in the stratosphere filters out about 99% of the incoming harmful ultraviolet (UV) rays and protects us from increased sunburn, skin cancer, eye cancer, eye cataracts. Thus our good health and that of many other species depends on having enough "good" ozone in the stratosphere. But human activities are causing a depletion of this stratospheric ozone layer. Some pollutants enter the stratosphere and remain there for long periods and interact with ozone, and deplete the same. The pollutants responsible for this depletion are the Chlorofluorocarbons (CFCs), Nitrogen oxides and Hydrocarbons. CFCs are widely used as coolants in air conditioners and refrigerators and as propellants in aerosol spray cans, and in clearing solvents. Other widely used ozone destroying chemicals are the halones (bromine containing compounds), carbon tetrachloride (used as a solvent) and methyl chloroform (used as a cleaning solvent). The CFCs are highly unreactive and stay intact in the atmosphere for several years and slowly rise through the atmosphere until they reach stratosphere. Under the influence of high energy UV radiation from the sun there, they break-down and release chlorine atoms which speed up the breakdown of ozone into oxygen molecule (O_2) and oxygen atom (O). The oxides of nitrogen from nitrogen fertilizers also contribute to the reduction of ozone. It is estimated that unless the emissions of these chemicals are out drastically, average levels of ozone in the stratosphere could drop from 10% to 25% by 2050 A.D. or sooner. It is surprising to note that up to 50% of the ozone in the upper stratosphere over the antarctic is destroyed each September and October resulting in antarctic ozone hole. This is caused by the presence of large spinning vortices wherein clouds of tiny ice crystals form. The surface of these crystals absorb CFCs and greatly increases the rate of ozone destruction.

Currently there are attempts to reduce or totally avoid the use of CFCs. Substitutes are being discovered such as hydrofluorocarbons (HFCs) that contain no chlorine or bromine atoms and hydrochlorofluorocarbons (HCFCs) that contain fewer atoms of chlorine. Although HFCs are considered as "environmental friendly", these new chemicals eventually will also have to be banned to half ozone depletion. The 'Montreal Protocol' is a step to reduce the production of widely used and most damaging CFCs. By 1990, 49 countries have signed this historic treaty. The signatories to the above Protocol pledged to cut down the use of CFCs in a phased manner. India has started phasing out ozone depleting substances (ODS). It has created a special "Ozone cell" in the Ministry of Environment & Forests to launch a ODS phasing out compaign. It is encouraging to note that United Nations announced September 16, 1995 as the "World Ozone Day" to encourage people to reduce the use of Halone (used in fire engines) and CFCs responsible for depletion of the ozone layer.

Check Your Progress - 6

What is the threat to stratospheric ozone layer?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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8.5.8. Photochemical Smog

The word 'Smog' is coined by combining smoke and fog which characterize the most disastrous pollution episodes the world had witnessed. Under a stable temperature inversion, adequate sunlight, enclosed topography and certain chemical inputs, there is the formation of photochemical smog. This is more common in modern cities with sunny, warm, dry climates and lots of motor vehicles. The oxides of nitrogen and hydrocarbons in automobile exhaust combine in the presence of sunlight to produce new and more toxic substances known as "photochemical smong"

The components of the potochemical smog are largrly ozone, nitric acid, peroxy-acetyl nitrates (PANs) and aldehydes (formaldehyde) (Fig.8.2.). The formation of the oxidants, particularly ozone when 0.15ppm for more than an hour in atmosphere indicates the photochemical smog formation. SO_2, H_2SO_4 are also important pollutant usually found in potochemical smog. PBXn is produced in photochemical smog when olefins and NOx are present in air; it is 100 times more powerful than that of PAN.

Cities in the world with the serious photochemical smog problem includes Los Angeles, Denver, Salt Lake City, Sydney and Mexico. In India situation in Bombay, Calcutta, Delhi, Madras, Bangalore, Ahmedabad, Kanpur, Visakhaptnam, Hyderabad seems to be alarming, as the chief sources of air pollutants in these cities are industries and automobiles.

Effects : Smog decreases the visibility and is irritating to the respiratory system. Photochemical smog produces eye irritation and lacrimation and causes severe damage to many types of vegetation. Acute effects include increased mortality rate especially among persons suffering from respiratory and coronary ailments. Ozone increases respiration of leaves, killing the plants by depleting its food, while PAN blocks the 'Hill Reaction' in photosynthesis, thus killing the plants by shutting down food production.

8.5.9. Acid Rain

Acid rain is defined as one in the pH of less than 5.6. Industries, automobiles and power plants hurled millions of tonnes of nitrogen oxides and sulfur dioxide into the air. These emissions of

SOx and NOx are transported by winds and form secondary pollutants containing solutions of sulphuric acid, sulphate and nitrate salts. These chemicals are deposited on the earth in 'wet form' as acid rain or snow and in 'dry form' as gases, fog, dew, or solid particles. The combination of dry and wet depositions of acids and acid forming compounds onto the earth's surface is known to be acid deposition, commonly called acid rain.

In industrialised nations, acid rain is already a serious problem and according to some experts, acid rain is a boundless threat to the environment with far reaching consequenees. The pH values throughout Indian subcontinent are generally alkaline. This is attributed to the soil originated basic ions forming a major portion of atmospheric aerosols, and thus the ionic balance is in favour of basicity of rain water. However, acid deposition is emerging as a problem. Total SO_2 emissions in the country increased from 1.38 tonnes in 1966 to 3.2 million tonnes in 1979. According to the Air Monitoring Section of BARC, the average pH value of acid rain at Calcutta is 5.8; Hyderabad 5.73; Madras 5.85; Delhi 6.21; Bombay 4.8. The situation may become more serious with the increase in thermal power plants.

Effects : If the pH falls below 5.1, the rain is more harmful.

- Damages statues, buildings, metals and car finishers :
- Kills fish, aquatic plants and micro-organisms in lakes and streams.
- Weakens or kills trees, especially conifers at high elevations by leaching calcium, potassium and other plant nutrients from soil.
- Damages tree roots and kills many kinds of fishes releasing ions of aluminium, lead, mercury and cadmium from soil and bottom sediments.
- Weakens trees and makes them more susceptible to attacks by diseases, insects, drought, and fungi and mosses that thrive under acidic conditions.
- Affects the growth of crops such as tomatoes, soyabeans, carrots, and cotton.
- Causes leaching of toxic metals such as copper and lead from city and home water pipes into drinking water.
- Causes and aggravates many human respiratory diseases and leads to premature death.

Check Your Progress - 7

What is your understanding of acid rain?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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8.6. MINOR POLLUTANT GASES

The gases like Ammonia, H_2S, halogens and hydrocarbons are present in minor quantities, only in that they are of less of a problem but may occur in local high concentration as a result of accidents.

8.6.1. Ammonia

Ammonia is released into the atmosphere as a result of bacterial activity. Around 4 x 10^6 tons/yr are released from anthropogenic sources like coal, combustion and industrial processes using Ammonia. Ozone in the air oxidizes NH_3 to a number of materials, such as N_2, N_2, NH_4, NO_3. The water vapour attains the liquid state on the Ammonium sulfate particles thereby exerting an effect on visibility.

8.6.2. Hydrogen Sulphide

The anthropogenic sources of H_2S such as kraft pulp and paper mills, rayon production, coal gasification and oil refining accounts for approximately 3 x 10^6 tons/yr; in nature 98 x 10^6 tons/yr are produced by anaerobic decay of organic material by bacterial reduction of sulphates. H_2S is very toxic and is a hazard encountered when digging wells. Oxidation of H_2S in atmosphere contributes to SO_2 production which further affects the environment.

8.6.3. Halogens

Gaseous halogen pollutants include Fluorine, Chlorine, Bromine and Iodine, hydrogen halides and halogenated hydrocarbons and some pesticides and herbicides.

Anthropogenic fluorine sources are associated with aluminium superphosphate, steel, glass and ceramic production. Natural source is the sea water. Plants are sensitive to high concentration fluorine. Animals are indirectly affected when they eat plants as food, or drinking ground water where fluorides are abundant causing fluorosis.

Major natural source of chlorine is sea spray, from which HCl forms as a secondary product. Man-made source is the motor vehicle exhaust which contain lead halide aerosols upon decomposition produces chlorine atoms. Chlorine is very toxic and it has been used as poison in warfare. Chlorine causes partial closure of the leaf stomata.

Anthropogenic sources of Bromine & Iodine are combustion of petro and fossil fuels respectively. Damage due to Bromine is less and the radioactive isotope of Iodine I^{131} released as a result of nucler fission has a high radiological toxicity and accumulates in the thyroid.

8.6.4. Hydrocarbons

Natural sources, particularly trees, emit large quantities of hydrocarbons in the atmospohere. Methane is the major naturally occurring hydrocarbon emitted into the atmosphere. It is produced by anaerobic bacterial decomposition of organic matter as in swampy areas, paddy fields, land emission from geothermal areas, coal fields, natural gas and petroleum wells. Domesticated animals contribute by way of dung about 85 million tonnes of CH_4 and it has a mean residence time of about 3-7 years.

It has been estimated that anthropogenic sources contribute about 15% of the hydrocarbons emitted to the atmospohere each year. Automobiles are the major source in this respect: petroleum 55%, coal 3.3%, wood 2.2%, incinerators and refuse burning 28.3%, solvent evaporation 11.2%.

The majority of the harmful affects of hydrocarbon pollution are not due to the hydrocarbons themselves but the products of photochemical reactions, which give rise to 'Photochemical Smog'. At atmospheric concentration of 0.005 mg/kg ethylene can cause leaf damage to very sensitive plants.

8.7. INDOOR AIR POLLUTION

The walls provide an enclosed space which may allow indoor generated pollution levels to become quite high in a short time.

Indoor air pollution has a number of sources, like cooking, heating (fires, space heaters), use of aerosol spray cans, painting and cigaratte smoking. The pollutants of most concern in residential buildings are radon gas, formaldehyde and combustion products like nitrogen dioxide, carbon monoxide, CO_2. Other pollutants include ozone from photo-copying machines and other electrical equipments, benzene from solvent cleaners, styrene from carpets and plastic products and pesticides to kill insect.

Effects : Indoor radon increases the risk of lung cancer as alpha radiation affects lung tissues. Exposure to formaldehyde can burn eyes and irritate upper respiratory passages depending on environmental conditions such as temperature and humidity. High concentrations of formaldehyde often produce coughing, constriction in the chest and wheezing. Pesticide fumes used to kill pests and insects can cause sneezing, coughing and respiratory illness. Benzene and styrene are known as carcinogens even at moderate dosage.

Check Your Progress - 8

What are the sources of indoor air pollution?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

8.8. AIR QUALITY STANDARDS

In 1971 the Environmental Protection Agency in the United States prescribed air quality standards which are as follows :

Pollutant	Tolerance (ppm)	
CO	9	(not to be exceeded more than once/year for 8 hr period)
	35	(not to be exceeded more than once/year for 1 hr period)
SOx	0.5	
NOx	0.25	

The Central Pollution (Prevention & Control) Board, New Delhi, has fixed standards for ambient air quality for different area categories in India under the Air (Prevention & Control of Pollution) Act, 1981 beyond which ambient air can be considered polluted in a legal sense.

Area category	Suspended particulate matter ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	CO_3 ($\mu g/m^3$)	NOx ($\mu g.m^3$)
Industrial and mixed use	500	120	5000	120
Residential and Rural	200	80	2000	50
Sensitive areas (Tourist resorts, places with monuments, game sanctuaries, etc.)	100	30	1000	30

Check Your Progress - 9

Give the ambient air quality standards for SO_2 in India.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

8.9. AIR POLLUTION CONTROL TECHNOLOGY

Once Air Quality Standards have been adopted, two general approaches can be used to prevent levels from exceeding the threshold values. One is input control which prevents or reduces the severity of the problem. The other is output control, which treats the symptoms. Input methods are usually cheaper and easier in the long run than output methods. Major input methods are :

- recovery of the waste, for example SO_2 from stack gases.
- using energy more efficiently, for example 2-stage combustion resulting in the reduction of NOx.
- switching from coal to natural gas, which produces less pollution when burned.
- switching to renewable resources like sun, wind and flowing water, etc.
- identifying the source of pollution in a production process, eliminating it from that process, and finding a more environment friendly substitute.

Control of Gaseous Emissions from Stationary Sources

I. Sulphur Oxides

Input Control Methods

1. Burning of low sulphur coal, removal of sulfur from coal.
2. Converting coal to a gas or liquid fuel.
3. Removal of sulphur during combustion by fluidized-bed combustion of coal.
4. Removal of suphfur during combustion by limestone injection multiple burning

Output Control Methods

1. Using tall smoke-stacks.
2. Removal of pollutants after combustion by desulfurization or wet scrubbing.

II. Nitrogen oxides

Input control methods

1. Removal of nitrogen oxides during fluidized-bed combustion.
2. Removal of NOx during combustion by lime-stone injection multiple burning.
3. Reduction of NOx by decreasing peak flame temperatures.

Output control methods

1. Using tall smoke-stacks.
2. By using isocyanic acid the emitted NOx can be broken down into harmless nitrogen and water.

Control of Particulate Matter Emissions from Stationary Sources

Output control methods

1. Using tall smoke-stacks.
2. Removal of particulates from stack exhaust gases by using:

   (a) **Settling chambers :** These are the simplest devices for collecting dust particles greater than 100 μm. The size, density and shape of the particles and the density and viscosity of the gas are the most important parameters in the design of settling chambers.

(b) **Inertial separators :** In this method the separating force on the particles is achieved by a sudden change in direction of gas flow. Particles as small as 10 μm can be removed. When a dust particle is spinning in a circular path it is subjected to an outward force, as a result, the particles collect on the wall and fall on the bottom of the vessel.

(c) **Electrostatic precipitators :** The particle-laden gases are passed through high voltage discharge electrodes. The majority get charged and collected on grounded electrodes which are removed at regular intervals.

d) **Filters :** Collection efficiency is always very high and even for particles of 0.01 μm diameter. The fabric filter system consists of long tubular bags made of cotton, wool, teflon, fibre glass, fine stainless steel wire and various synthetic materials. The gas passes through a filter bag and the particles are collected on the inside by the filtering action of fabric. The dust retained on the bags is to be periodically shaken off.

e) **Wet scrubbers :** The collection process is dependent on collisions between the particles and liquid droplets in suspension in the flue gas. The collisions result from inertial, gravitational and electrostatic effects and diffusion pohenomenon.

Check Your Progress - 10

Mention some air pollution control equipment

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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8.10. CONTROL OF EMISSIONS FROM MOTOR VEHICLES

Input Control Methods

1) Relying more on mass transit, bicycles and walking.
2) Shifting to less-polluting automobile engines, like engines that run on hydrogen gas, or electric motors.
3) Shifting to less-polluting fuels.
4) Improving fuel efficiency.
5) Modifying the internal combustion engine to reduce emissions. Burning gasoline using a lean or more air-rich, mixture reduces carbon monoxide and hydrocarbon emission.

Outpout Control Methods

1) Using emission control devices.
2) Inspection of vehicles twice a year which encourage drivers not to tamper with emission control devices and to keep them in good working order.

In India the Air (Prevention and Control) Act 1981 was amended in 1987 to remove difficulties encountered during implementation, to confer more powers on the implementing agencies and to impose stringent penalties for violation of the provisions of the Act. The moror vehicles Act 1988 came into force from 1st July 1989, which compelled the owner to obtain a certificate of fitness for the vehicle for registration. Presently, every vehicle has to get its emissions monitored once in every six months and obtain certificate of pollution under control. This is practised in major cities.

8.11. AIR QUALITY MONITORING

The principal instrumental techniques for monitoring gaseous air pollutants, particulate matter and elements in air samples are as follows :

I. Gaseous Air Pollutants

Pollutants	Instrumental techniques
1. Carbonmonoxide, Hydrocarbons	IR spectrophotometry, gas chromatography.
2. Oxides of sulfur	Spectrophotometry, conductivity amperometry.
3. Oxides of nitrogen	Gas chromatogrraophy, IR spectro-pohotometry, spectrophotometry.
4. NH_3	Spectrophotometry, Potentiometry.
5. Polycyclic aromatic hydrocarbons Volatile pesticides	Gas chromatography

II. Particulate Matter

Pollutants	Instrumental techniques
1. Silicates Polycyclic aromatic hydrocarbons	Chromatography
2. Fluorides	Potentiometry
3. Sulphates	Electron spectroscopy

8.12. BHOPAL GAS TRAGEDY - A CASE STUDY

The Bhopal GasTragedy is often cited to show how fragile our industrial system. The tragedy was the world's worst industrial accident in human history. It took place on December 3rd 1984, just after mid-night. Nearly 40 tons of high toxic methyl isocyanate gas leaked into the ambient atmosphere from a storage tank in the Union Carbide pesticide plant located in Bhopal (Madhya Pradesh) which produced the carbamate insecticide, "Sevin" using Methyl Isocynate (MIC). Nearly 4,000 people were killed, and 3,00,000 were injured. The surviving people continued to suffer from a number of physical and psychosomatic disorders. Human beings were not the only victims of this tragedy, it took the toll of about 2,000 animals as well. MIC causes unbearable irritation and burning of eyes. When inhaled it reacts vigorously with fluids in lungs, resulting in the formation of methyl amine and carbon dioxide. As the two gases are heavier than air, they expel oxygen from lungs and choke the victim to death. About 2,800 people lost their jobs when the plant was permanently closed.

This calls for an effective management system incorporating identification and evaluation of hazards, reliability assessment and planning for emergencies.

8.13. WORLD'S MOST POLLUTED CITY

The air pollution capital of the world may be Cubatao, an hour's drive south of Sao Paulo, Brazil. This city of 100,000 people lies in a coastal valley that has frequent thermal inversions. Residents call the area "the valley of death". In this heavily industrialized city, scores of industries spew thousands of tons of pollutants a day into the frequently stagnant air. More babies are born deformed there than anywhere else in Latin America. Large number of people living there suffer from respiratory diseases. One resident says, "On some days if you go outside, you will vomit". The mayor refuses to live in the city.

8.14. SUMMARY

The atmosphere is one of our great resources. It consists of life saving gas, oxygen and also other gases like nitrogen, argon, CO_2, etc. Ozone layer in the stratosphere saves the biosphere from the high energy UV radiation by filtering it out. The earth's gaseous biogechemical cycles work fine as long as they are not disturbed. The problem is that human activities are disrupting these natural gaseous biogeochemical cycles and impacts are growing exponentially. To support a rapidly growing human population and to fuel unsustainable forms of economic growth, man is burning nature's fossil fuels and clearing forests. Due to the increased air pollutants like CO_2, NOx, SOx and others, major effects like ozone depletion, acid rains, global warming are threatening our very existence. And also these toxic gases damage vegetation, materials and human health. There is growing environmental concern leading to the prevention and control of air pollution by technology and legal terms.

8.15. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The atmosphere is a gaseous envelope of the earth. Based on temperature variation it is divided into troposphere, stratosphere, mesosphere and ionosphere.

2. Troposphere is the first layer which envelopes the living systems of the earth and the air in this layer is essential for the sustenance and perpetuation of all life on earth. Here the air temperature, barometric pressure and air density decreases with altitude.

3. Air pollution relates to the accumulation of substances in the air in concentrations to endanger human health or to produce other measured effects on living matter and other materials.

4. Air pollutants are either primary or secondary, the former being those emitted directly into the air and the latter produced through reaction among primary pollutants and normal atmospheric components.

5. The major sources are transportation, industry and power generation.

6. The stratospheric ozone layer filters out most of the incoming harmful ultraviolet radiation and protects the life on earth. The air pollutants specially chlorofluorocarbons destroy the ozone layer and the formation of ozone hole over the antarctic is serious concern.

7. The coal fired thermal power plants are an important source of SO_2 in the air. SO_2 is oxidised to SO_3 which in the presence of moisture becomes H_2SO_4 and this forms the acid rain.

8. The sources are cooling, smoking, using aerosol spray cans, painting and heating.

9. The standards are 120 μg/m³ for industrial and mixed use areas, 80 μg/m³ for residential and rural areas and 30 μg/m³ for sensitive areas.

10. These include settling chambers, inertial separators, electrostatic precipitators, filters, and wet scrubbers

8.16. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Describe the major layers of the atmosphere naming the important chemical species.
2. Define Air pollution. Name the natural and Anthropogenic sources of all air pollutants.
3. Describe the mechanisms that occur in Photochemical smog formation.
4. Write the effects of air pollution on Biosphere.
5. Write about some devices that are used to remove particulate matter.

II. Answer the following questions in about 10 lines each.

1. What is acid rain? Give a brief account of its effects on living organisms.
2. What are the effects of chlorofluorocarbons on ozone layer ?
3. Give a brief description of 'Green House Effect'.
4. Write a short account on 'minor pollutant gases'.
5. Describe briefly about aerosols and their effects.

Prof. A. Janaki Bai

UNIT - 9 : WATER POLLUTION

Contents

9.1. OBJECTIVES

After going through this unit, you will be able to:

* define pollution and list out the types of pollutants,
* describe various toxic effects caused by domestic and sewage wastes, industrial wastes, agricultural wastes, heavy metals and Radioactive wastes,
* explain this effect of water pollution on the health of human beings
* describe the control methods of water pollution and also the waste disposal method.

9.2. INTRODUCTION

Water is the most important and essential commodity necessary for life. Water is the universal solvent for a number of substances. It is an important ecological parameter and regulates the plant environment. The earth's surface is covered for more than 70% of its area by water in the form of sea, lakes and rivers.

According to UNEP (1987) 97% of the earth's water is in the oceans and only 3% on land. Of the fresh water component 77% is stored in the polar ice caps and in glaciers and a further 22% as ground water. Thus the available surface water in lakes and rivers comprises barely 1% of the total fresh water. UNEP estimates that on the global scale 73% of water use is for irrigation, 21% for industrial purposes and only 6% for public use. In the developed countries as much as 40% of usage is industrial while in developing countries the overwhelming bulk consumption is for irrigation.

In India 70% of total surface waters are polluted because many rivers during intermonsoon period are totally dry and their channels are filled with raw sewage in urban areas. It is present in the form of permanent water table below the land surface. The survival of man depends upon the wise utilization of finite fresh water resources for drinking, agriculture, aquaculture, industrial, recreational, transportation etc.

Royal Commission on Environmental Pollution (RCEP) defined pollution as "The introduction by man into the Environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structure or amenity or interference with legitimate uses of the environment". Pollution results in a modification of the water quality which is determined by natural physico-chemical and biological processes.

Man is over exploiting the natural resources for the economic needs which is resulting in ecodegradation, ecological imbalance and finally the environmental pollution. Pollution is an undesirable change in the physical, chemical and biological characteristics of air, water and land. They may affect human life, industrial progress, living conditions and cultural assets. Pollutants are residues of things or byproducts of man's actions. Pollution and pollutants increase with a rise in population. In developed countries the lakes and rivers are polluted by chemical and other industries where as in undeveloped nations it is due to dumping of sewage into different water bodies.

9.3. TYPES OF POLLUTANTS

Pollutants are classified into 1) Domestic and sewage wastes, 2) Industrial waste effluents, 3) Agricultural wastes, 4) Heavy metals and 5) Radioactive wastes.

9.3.1. Domestic and Sewage Wastes

Rivers and freshwater lakes serve as drinking water sources. They also serve as sinks for dumping of different types of pollutants. Man generally disposes most of the waste materials into the nearby aquatic environments such as rivers, lakes, ponds, wells, oceans etc that cause water pollution. This results in epidemics i.e., water-borne diseases like cholera, typhoid, gastero-enteritis etc. Household sewage, laundry detergents and organic matter add sulphates, pohosphates, nitrates and chlorides to the water. These favour the growth of algae which develop into water blooms that cause depletion of oxygen and produce toxic substances.

9.3.2. Industrial Wastes

Urbanisation and industralisation is polluting a number of aquatic habitats in most of the cities and other areas by letting out various types of effluents from a number of factories/industries. Paper mill factory, fertilizer factory, NTPC effluents, pharmaceutical, printing, textile, dye, electroplating industries let out effluents which are hazardous to human population because of their toxic nature. Some of these effluents which are let out on the ground may sink to the bottom layers of the soil and contaminate the ground water. Paper mill factory effluents are rich in lignin which is non-degradable or very slowly degradable. Fertilizer factory wasters enrich the habitat with nitrites, nitrates and sulphates. Pharmaceutical industries let out a mixture of chemicals, some of which are toxic. Certain industries let out heavy metals and contaminate the freshwater.

9.3.3. Agricultural Wastes

Pesticides, insecticides, fungicides and herbicides contain highly toxic chemicals and are finally washed into the rivers and streams from cultivated fields. Chemical fertilizers used at the time of crop cultivation also pollute the river and stream waters. The excessive use of insecticides, pesticides create pollution problem, specially the use of DDT, polychlorinated biphenyls etc. They become concentrated in successive stages of food chain i.e., Plants -> Herbivores -> Carnivores -> Man. Insecticides destroy a number of valuable aquatic food organisms and depress pohotosynthetic ability of phytoplankton. In human beings increasing concentration level of these compounds may cause cancer. Herbicides and Weedicides used for controlling weeds are also important water pollutants. Some of the herbicides such as 2,4-D interfere with photosynthesis and block food transport. These compounds are also capable of modifying the biodiversity and thus affect the functioning of the ecosystem. Indeed the insecticides and herbicides together constitute the powerful 'drugs' in the ecosystem.

9.3.4. Heavy metal pollution

Pesticide, fungicide, algicide, printing, textile, dye, tanning, battery manufacturing industries and metal finishing plants let out wastes containing heavy metals which create health hazardous conditions. Caustic soda and chlorine factory wastes are rich in mercury. It causes nervous disorders. Automobile fuel industries and vehicle exhausts release lead which accumulates in water. Several molluscs in streams are found to accumulate considerable amounts of copper and zinc. Similarly cadmium and cobalt also accumulate in rivers and streams and cause lethal effects.

9.3.5. Radioactive wastes

Some elements emit high energy radiations during their decay. Isotopes of those elements that emit such radiations are called radioactive isotopes or radionuclides. Wastes from nuclear power reactors add such isotopes to water reservoirs, rivers etc. These radioactive substances accumulate through contaminated food, water or air. They enter the food chain spreading to the concerned organisms. Cesium is known to accumulate in the body muscles, strontium in bones and iodine in thyroid gland. They cause, malformation of body at the time of birth.

Check Your Progress - 1

What are the different types of pollutants?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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9.4. GROUND WATER POLLUTION

Use of fertilizers and pesticides in agriculture, inappropriate disposal of both domestic and hazardous wastes and the failure of storage devices such as underground petroleum tanks as well as badly designed or located landfills can all lead to contamination of groundwater.

Around 100,000 chemical substances are in use in Europe today, They are listed as :

a) List I (Black List): Considered dangerous and must be eliminated.

b) List - II (Grey List): For these preventive action is required to reduce the potential to pollute.

The most common toxic inorganic substances affecting inland waters are the salts of heavy metals, copper, lead, nickel, zinc, chromium, soluble sulphides, ammonia and chlorine. Chemicals of serious concern in aquatic environment are insecticides, molluscicides, rodenticides, nematicides, algicides, herbicides and fungicides. High alkalinity can be highly damaging or lethal to fish life.

Check Your Progress - 2

What is the difference between black list and grey list ?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end. of this unit.

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9.5. POLLUTION IN URBAN INDIA

The environmental problems in urban areas are lack of proper sanitation, water supply, polluted water and refuse disposal because of urbanisation and industrialisation. Water pollution in urban areas is mainly due to sewage, sullage, solid wastes and industrial wastes. Large cities like Calcutta, Bombay, Delhi, Madras, Hyderabad etc. are facing these environmental problems very much. Waste water disposal is a problem in itself for urban communities.

All waste waters, domestic or industrial, ultimately get into riverine systems. Although sea is the ultimate sink, the rivers play the major role of transport. The river Ganges showed polluted stretches of water below Kanpur, Allahabad, Varanasi, Patna and Calcutta and city sewage is the major cause for pollution. The other major rivers in the country are also highly polluted in different stretches. Organic and biological pollution in inland and estuarine waters near the urban centres, industrial and port cities is mainly due to dumping of untreated or partially treated domestic wastes. All industrial estates are posing the problem of water pollution in India.

9.6. WATER POLLUTION AND HEALTH

Inadequate water supplies for drinking and other uses and inefficient, insufficient or nonexisting sanitation facilities are responsible for environmental health problems in India. According to WHO survey 90% of infant deaths could be avoided by safe protected water and sanitation. The Director General of WHO pointed that "The number of water taps per thousand persons will become a better indicator of health than the number of hospital beds".

The diseases caused due to lack of good water supply and sanitation can be classified under 5 categories.

a) Water-borne diseases such as typhoid, cholera, dysentry, gasteroenteritis and infectious hepatitis.

b) Water washed infection of the skin and eyes such as trachoma, scabies and conjunctivitis.

c) Water-based diseases like Schistosomiasis and guinea worm.

d) Diseases with water related insect vectors.

e) Infections that are primarily caused because of defective sanitation such as hookworm.

In India 70% of available water is polluted. The water supply systems in urban centres are facing the problem of contamination of water in the distribution system. Thus there are a number of surface and groundwater pollution problems in urban cities in India which require immediate attention.

Check Your Progress - 3

What are the diseases caused to human beings due to lack of good water supply?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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9.7. CONTROL MEASURES AND DISPOSAL METHODS

Sewage and domestic wastes are to be treated before they are let out into any nearby water body. Solid material is allowed to settle in tanks which can be digested. Sewage water may be diverted to the cultivated fields as it contains high nitrogen and phosphate. Sewage oxidation ponds and lagoons can be constructed and green algae like *Chlorella, Scenedesmus* etc. may be grown to remove the excess nutrients and also for the oxidation of organic matter.

All types of industrial waste effluents must be diluted first and then passed through "Effluent Treatment Plants" (ETP) to minimise the toxic effect of the effluents. Certain algae like *Stigeoclonium, Chlorella, Oscillatoria* and aquatic macrophytes e.g., *Eichhornia, Hydrilla, Pistia* may be grown in these wastes to remove/absorb the highly toxic substances (including heavy metals). Plants serve as detoxifying agents in water pollution. In an industrial estate a number of small industries can have a common ETP for the preliminary treatment of the waste. There should be an ecological balance between the dumping of wastes and the receiving environment (habitat). Under any circumstances these wastes should not be dumped in stagnant water bodies like lakes, ponds etc. The radioactive wastes are to be dumped in the deeper layers of the oceans or buried underground. Pesticides, fungicides, insecticides and others containing highly toxic substances have to be used judiciously and in very dilute concentration.

9.8. NEED FOR CLEAN TECHNOLOGY

It is to be borne in mind that to protect water we need to protect all environmental media because water is our most important mineral. If we pollute the soil by dumping all types of waste material we risk polluting water; if we apply chemicals to the soil they will leach out into groundwater and streams. If we have to achieve the goals of sustainability and biodiversity clean technology is only one component of the required strategy.

9.9. SUMMARY

Water is the most important and essential commodity necessary for life. It is an important ecological factor and its ecological significance is several fold. Pollution is an undesirable change in the pohysical, chemical and biological characteristics of an environment. Pollution results in a modification of the water quality which is determined by natural pohysico-chemical and biological processes. Pollutants can be classified into: 1. Domestic and sewage wastes. 2. Industrial wastes. 3. Agricultural wastes. 4. Radio active wastes and 5. Heavy metals. Water pollution in Urban areas is mainly due to sewage, solid wastes and industrial wastes. Industrial estates in India are posing the problem of water pollution. Inadequate water supply and inefficient sanitation facilities are responsible for environmental health problems. They cause a number of water - borne diseases, infant deaths etc. The dangerous substances which affect inland waters are listed. Water pollution control measures and disposal methods for different types of pollutants are discussed. To protect water we need to protect all environmental media and achieve the goals of sustainability and biodiversity clean technology is the only strategy.

9.10. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Different types of pollutants are (a) domestic and sewage wastes, (b) industrial wastes, (c) agricultural wastes, (d) heavy metals and (e) radioactive wastes.

2. Around one lakh chemical substances are in use in europe. These substances are listed as list I (Black List) and list II (Grey List). Most dangerous chemicals are listed in black list and those chemicals where preventive action can be taken to reduce the potential to pollute are listed in grey list.

3. Five categories of diseases are caused due to lack of good water supply. They are (a) Water-borne diseases such as Typhoid, Cholera etc., (b) Water washed infection of the skin and eyes such as trachoma, scabies etc, (c) Water based diseases like schistosomiasis and guinea worm, (d) Diseases with water related insect vectors, and (e) Infections caused because of defective sanitation such as hook worm.

9.11. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. What is meant by pollution? Mention the different types of pollution.
2. Discuss the effect of Industrial wastes on fresh water bodies and add a note on control measures.
3. Write an essay on water pollution in urban India.
4. Give an account of water pollution and health hazards.
5. Explain the water pollution control measures and disposal methods.

II. Answer the following questions in about 10 lines each.

1. Define water pollution.
2. Mention the sources of domestic and sewage wastes and their disposal methods.
3. Discuss the impact of Industrialization on aquatic environments.
4. Describe the Agricultural wastes which contaminate water.
5. Give an account of Radio-active waste pollution.
6. "There is need for clean technology". Substantiate this statement.

Prof. V. Venkateswarlu

UNIT - 10 : SOIL POLLUTION

Contents

10.1. OBJECTIVES

After going through this unit, you will be able to:

* explain the reasons for soil pollution,
* list out the important soil pollutants,
* explain the effect of soil pollution over ground water,
* describe the effects of various pollutants on the soil.

10.2. INTRODUCTION

Soils are formed over long period of time. Soil constitutes a biogeochemical shell around land and shallow waters. It affects the growth of organisms (especially plants) and is inturn influenced by the activities of the latter. It should be regarded as a living community of micro-organisms (algae, fungi, protozoa, metazoa etc.). Soil contains many inorganic and organic substances which are products of weathering and decay of organic matter. Microbes oxidize these substance to inorganic oxides but some organic compounds remain incompletely oxidized and add to pollution

Industrialisation, urbanisation and other human activities have a tremendous impact on soil and on this biosphere. Unplanned destruction of forests and litter has brought serious changes in land and water. It has caused considerable soil erosion.

Modern agricultural practices i.e., application of chemical fertilizers, spray of pesticides, fungicides, use of herbicides, weedicides are causing lot of damage to natural soils. Heavy doses of inorganic fertilizers are creating excessive acidity or alkalinity in the soil. The indiscriminate use of pesticides and fungicides are adversely affecting the soil by affecting the activities of soil microbes, flora and fauna. Many of once fertile soils have already been converted to agriculturally unfit alkaline or saline lands or marshlands. More than 25 million hectares of such barren lands are now distributed through out the World. The use of organic manure helps in preserving the quality of soils and their humus content. Soil Pollution is mainly caused by solid wastes and chemicals. The major pollutants can be classified as a) Solid wastes, b) Agricultural wastes and c) Industrial wastes.

10.3. SOLID WASTES

The major problem in large cities is the disposal of solid wastes including farm and animal manure, crop residues (agricultural wastes), fly ash, garbage, paper, cardboard, plastics, rubber, cloth, leather, construction rubbish, brick, sand, metal, glass from demolition of buildings dead animals, discarded old refrigerators, washing machines and autos. Huge quantities of these unwanted material bring about serious disposal problems.

The major amount of solid rubbish comes from households in the form of domestic wastes e.g., groceries, food scrap, vegetable remains, ash, wood, metal, plastics, ceramics, glass etc. All these form heaps of municipal refuse. Such places often become a dwelling for rats, flies, bacteria, mosquitoes and a large number of microorganisms having the potential of causing infectious diseases.

10.4. AGRICULTURAL WASTES

Modern agriculture is mainly responsible for polluting soil due to the non-judicious use of chemical fertilizers, pesticides, fungicides, herbicides and weedicides. Most of these will remain in soil for long periods without undergoing degradation and exert cumulative effect. These substances kill the living organisms present in the soil and with the continuous use, the soil microorganisms lose their capacity of nitrogen fixation. Thus they affect the nitrogen economy/balance of the soil.

10.5. INDUSTRIAL WASTES

Industries like pulp and paper mills, oil refineries and heating plants, iron and steel plants, plastic and rubber producing complexes, pharmaceutical industries are the main sources of soil pollution. Pulp and paper mills let out effluets which contain lot of lignin and this interferes with the life of terrestrial ecosystem. Pharmaceutical industries release a mixture of chemical substances which will disturb the soil texture due to disintegration of organic matter present in the soil. Finally this leads to ground water pollution. Some of the chemicals are poisonous and hazardous to life in soil.

Smelting and mining complexes pollute soils with heavy metals like cadmium, zinc, lead, copper, arsenic and nickel. These are phytotoxic even in small concentrations. The plants growing on such soils are unsafe for human and animal consumption. Many of the chemicals released into the air for e.g., radioactive minerals, sulphur and lead return to earth and pollute the soil.

Check Your Progress-1

What is the effect of wastes from pharmaceutical industries?

Note: (a) Wirte the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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10.6. CONTROL MEASURES AND DISPOSAL METHODS

Solid wastes can be disposed off by crude tipping or open dumping which is common in most of the Indian cities. More satisfactorily controlled tipping or the sanitary landfill is adopted in Delhi for solid waste disposal. In sanitary landfill, a layer of about 2 m of refuse is covered by atleast 23 cm of earth, ash or other inert material upto the level of the hole chosen. The surface can then be used for housing or sports fields. The wastes before filling, could be pulversed by machines so that the volume could be reduced and the life of the tip gets extended and some of the refuse will be quickly biodegraded. The sanitary landfill is regarded as a better remedy for large objects because it cause inexpensive biodegradation of such trash without causing much pollution, diseases etc. It is also desirable to fill low-lying watery areas and ditches by this stuff and the land thus reclaimed may be used for raising gardens, parks, playground or even apartment complexes. Domestic wastes have to be managed regularly by municipalities for proper disposal and economic recycling.

Animals refuse and agricultural wastes may be used as manure. They can also be used for biogas production. Sludge from biogas plants may serve as soil builder and fertilizer. Garbage dumps and sanitary landfills can be used for generating electricity by non-conventional energy source. The municipal solid wastes can be disposed by incinerator. It uses 300 tonnes of garbage per day for generating 3.75 MW of power.

Making biogas from garbage will also decrease soil pollution to an appreciable extent. In USA scientists are able to convert organic waste, such as rubbish, wood rags, cow manure into clean, high energy oil or gas. Most of the wastes can be recycled and put to use for daily benefits.

Use of chemical fertilizers may be reduced and supplemented with bio-fertilizers which are less expensive and harmless. The substances like pesticides, fungicides etc. have to be sprayed meticulously as they are highly toxic if used in excess.

The indusrtrial wastes contain a mixture of chemical substances both inorganic and organic and they should not be dumped on the soil either within the compound or let in in open channel. Firstly they have to be diluted and after subjecting them to preliminary treatment they should be diverted to any aquatic ecosystem. If the chemical effluents are not properly treated and dumped on the soil it will lead to ground water pollution. Protection and coservation of natural soils is highly desirable in the developing contries. In this context farmers have to be educated well in handling various substances in agriculture.

Check Your Progress-2

What is the use of animal refuse and agricultural wastes?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

10.7. SUMMARY

The soil is a natural environment and different types of soils are used for the cultivation of various crops and for the growth and development of biodiversity. Now a days the modern agricultural practices, industrialisation and urbanisation are having lot of impact on soil and affecting the life of the terrestrial ecosystem. These are mainly responsible for causing soil pollution. The soil pollution in turn leads to ground water pollution. The major pollutants like solid wastes, agricultural wastes and industrial wastes have to be disposed off in a scientific manner to maintain a better and healthy terrestrial ecosystem in urban areas and industrial complexes. The farmers should be trained scientifically using various substances in modern agriculture. It is highly desirable for everybody to protect and conserve the natural soils and for maintaining the ecological balance in the ecosphere.

10.8. CHECK YOUR PROGRESS : MODEL ANSWERS

1. A mixture of chemical substances released from pharmaetical industries disintegrate the organic matter present in the soil and disturb the soil texture.
2. Agricultural wastes and animal refuse can be used as manure. They can also be used for production of biogas.

10.9. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. What are solid wastes? What methods do you suggest for their disposal in urban areas ?
2. How are the modern agricultural practices affecting the soils?
3. Describe the different types of soil pollution.
4. What is the impact of industrial wastes on soil? How to cotrol it?
5. Explain the different control measures of soil pollution.

II. Answer the following questions in about 10 lines each.

1. Define soil pollution.
2. How can the solid wastes be utilized?
3. Mention the effect of soil pollutants on the nitrogen economy of soils.
4. What is the impact of soil pollutants on groundwater pollution ?
5. What are agriculture wastes and how do they caüse soil pollution?

Prof. V. Venkateswarlu

UNIT - 11 : APPLIED ECOLOGY

Contents

11.1. OBJECTIVES

After going through this unit you will be able to :

* define and describe renewable and non-renewable resources,
* describe and differentiate rabi and kharif crops in agriculture,
* list out different crops grown in our country,
* describe different methods of soil management,
* describe and differentiate pastures and grazing lands,
* describe the importance of forest ecosystem and developing waste lands,
* list out different types of wild life in our country,
* describe different methods of conservation of water.
* list out and describe different resources of energy and their recycling.

11.2. INTRODUCTION

All over the world environmental degradation is caused by excessive exploitation of natural resources. The knowledge gained from the previous units on the principles and application of plant ecology would enable us to make best use of our resources and to make them available continuously for future generation. Often man's activities result in modifying the environment

Excessive and unplanned exploitation of forest resources and energy resources during the last five decades contributed much to the present day environmental degradation. In developing countries, like India, the environmental problems are aggravated due to the poverty, growing populations and unhygeinic slums. Environmental deterioration contributes to pollution. Multiplying populations also contribute to environmental pollution. Rapid industrialization and modern agricultural practices, employing excessive chemical fertilizers and pesticides are also responsible for environmental degradation. As such, man has to equip himself with knowledge on ecology, which would help him to ensure continuous maximum supply of natural resources and agriculture production. Applied ecology throws light on management, forests, pastures, waste lands, pollution and renewable sources of energy etc. As such, applied ecology deals all aspects concerning the welfare of human society.

11.3. RESOURCES, THEIR CONSERVATION AND MANAGEMENT

Two kinds of resources can be easily recognised : Renewable resources like plants and animals. Water, although has no life cycle, can be recycled and as such is considered as renewable resource. Resources which cannot be regenerated or recycled once exhausted are classified as non-renewable. These include fossil fuels (petrol, coal) and mineral deposits. The soil formation takes thousands of years and hence can be considered as non-renewable.

There are many endangered plant and animal species. Although plants and animals are considered as renewable resources, some species became extinct and some are on their way, due to mismanagement.

Nutural resources can be inexhaustible (e.g., solar energy, atomic energy, wind power etc.) or exhaustible (coal, petrol etc.). Therefore, conservation and management of soils, soil water, forests, aquatic ecosystems and other types of ecosystems are important for future need of humanity.

Check Your Progress - 1

Define non-renewable resources?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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11.4. AGRICULTURE

Agriculture is one of the best examples of applied ecology, because the farmers, by continuous experimentation for many years, have identified the suitable soil type, season, quantity and frequency of irrigation, the amount and mode of fertilizers for obtaining the best yeild of a given crop. In India, farmers have been growing wheat, barley, gram, mustard and rape as **Rabi** crops for the last hundreds of years. On the other hand maize, tobacco, sesamum and cotton have been cultivated as **Kharif** crops. Cultivated plants are also subject to the same ecological laws as applied to forests or grasslands. As such a large number of varieties and races have been developed to suit different climates, soil and biotic factors and also to resist various pests and diseases.

In the days of primitive agriculture, suitable land was cultivated for many years with the same crop. At that time, farmers did not realise that if the field is cultivated with the same crop (e.g., wheat or cotton) for several years continuously, the soil gets gradually depleted of the mineral nutrients and becomes infertile. Then farmers used to move to new areas. Forests are cleared (shifting cultivation) for growing crop plants. Although, this practice gave good yields initially but later it gave place to soil erosion. Due to the nonavailability of abundent land, modern agro-techniques have emerged. Due to continuous cultivation of the same land for a long time, the natural fertility of the soil decreased, thousands of acres have become infertile, and water tables have gone down to levels, posing serious problem in dry periods.

About 142 million hectares are under cultivation (irrigated land 40 million ha; rainfed land 102 m. ha.) in our country. Of late, there has been improvement in crop productivity due to the practise of modern agrotechniques. For example, rice production has increased from 25 million tonnes (1954-55) to about 59 million tonnes by 1984-85. Concomitantly the yeild for hectare also increased from 820 kg to 1425 kg/ha. Wheat showed spectacular increase from 827 to 1873 kg/ha. Similarly, the production of pulses has also gone up from 11 million tonnes (1954-55) to 12 millions (1986-87). The main pulse crops of pigeon pea (protein content 22.3%), bengal gram, green gram, ground nut (also oil-seed crop) and peas. Recently, soyabean cultivation is becoming popular in view of its high protein content (43.2%).

Failure of monsoons in 1973 and 1974 created severe drought conditions. Bihar famine of 1967 was due to dry spells and for want of irrigation facilities. Therefore, where rainfall is inadequate or uncertain, irrgation of soil is necessary, minor irrigation or canal irrigation has to be extended. During the 2nd five year plan period provision has been made to bring 36.42 lakh hectares of land under minor irrigation; during the 3rd five year plan 60 lakh hectares were further brought under minor irrigation. Govt. of India and State Govts. helped in ground water exploration. Tube wells have been drilled in many states and farmers were supplied with pumpsets.

11.5. SOIL MANAGEMENT

Soil is the most important resource, as it takes many years to form a few inches of it (1cm top soil may take about 50 years). By conservation (con=together, servare=guard) and soil management we can ensure a continuous yeild of plants, animals and other materials by establishing a balanced cycle of harvest and renewal.

11.5.1. Soil Erosion

Deforestation is the root cause of soil erosion. This can be prevented by large-scale planting of trees and developing grass lands. Profusely distributed plant roots hold the soil together and prevents erosion due to floods, wind and land slides.

Check Your Progress - 2

What are the preventive measures taken for reducing soil erosion?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit

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11.5.2. Soil Fertility

The soil becomes sick and infertile due to (i) over exploitation (ii) water-logging and (iii) fertilizers and pesticides, which are not readily degradable. The following practices are recommended for improving the soil fertility.

(a) Rotation of crops with leguminous plants and vegetables, possessing nitrogen fixing capacity.

(b) Crop residue is allowed to remain in the field so that it decomposes and contributes to the organic matter and mineral content to the soil.

(c) Water logging to be prevented.

(d) By applying suitable chemicals or fertilisers, alkalinity and salinity of soil may be neutralised.

(e) Salt-resistant and drought resistant varieties are to be planted whereever necessary.

(f) Biodegradble pesticides and fertilizers to be employed.

Check Your Progress - 3

What are the causes of soil infertility?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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11.6. PASTURES AND GRAZING LANDS

Man's food includes vegetarian as well as non-vegetarian (herbivorous animals like sheep, goat, cow, pig, horses, rabbits etc.). Pastures or range lands provide grazing ground for cattle and other livestock. Range lands are dominated by a large number of grasses which form an important source of nutritional forage to cattle.

A large percentage of pastures or grass lands are found at the foot of mountains. In India, about 6.7 million hectares were under pastures during 1950-51 and the area increased to 14 million ha in 1962-63. Indian Agric. Res. Institute, New Delhi released a few high yeilding strains of fodder grasses (eg. Pusa giant Napier grass) Napier bajra hybird; another variety was produced by Punjab Agricultural University, Ludhiana, which is also high-yielding.

Stylosanthes is the preferred pasture legume and it grows so vigourously in certain pastures of Australia, that it is outgrowing the grasses. The maintenance and conservation of pastures is part of applied ecology. Some methods practiced in grazing land management are 1. Stock level policy, 2. Deferred grazing, 3. Fire and 4. Reseeding. In the stock level policy, it is managed that the problem of over grazing and starvation deaths are reduced to a minimum level. In deferred grazing, the pastures are usually marked into 3 segments and the cattle are allowed to feed in the first segment only for two years and they are moved to the 2nd segment in 3 rd and 4th years, and to the third segment in 5th and 6th years. The process is recycled and this allows the grasses to remain all through the year. Sometimes grass lands are burnt to destroy unwanted grasses so that better yielding ones may be planted later. In Reseeding good grasses some legumes are grown which also provides soil fertility.

11.7. FORESTS

Forests are considered to be the natural ecosystems where trees form the most dominant component of the ecosystem. In 1950-51, the total forest area in our country was 7.18 hectares; and in 1961-62, they are decreased to 6.95 lakh sq.km; and in later years the area is continuously decreasing. Latest satellite data reveals that India is losing 1.3 million hectares of forest every year. At the time of Independence, India has 22% of forest area (about 75 million hectares), whereas healthy national economy demands a total area of 33% under forests. The loss of forest area between 1951 and 1976, in India, due to river valley projects alone, is estimated around 4.80 lakh/ha with the result only 10% forest of the total land area has survived (Chand 1989).

Forests are the most important resources as they provide fodder, fibre, timber, fruits, herbals, medicines, habitat for wild life and many other raw materials required for forest based industries, like paper and pulp industries, beedi leaf, matches, ply wood etc. Indeed forest constitute 90% of the global biomass. Forest also regulate climatic conditions, thus giving protection to soil from wind and erosion. They also serve production function by capturing the solar energy and converting to plant biomass. Tropical forest vegetation is efficient in storing large amounts of mineral substances.

It is apt to recall the statement made by the famous environmentalist, Sri.Sunderlal Bahuguna; and it should be an eye opener for the future generation. According to him "Human kind is, today, poorer than what it was a few years ago, poorer not only in non-renewable resources, which are on the brink of extinction, but poorer in renewable resources like grass lands, forests, crop lands and oceans as well: resources that have become non-renewable due to their over exploitation. One third of the earth is desert; this is unethical because a single species i.e. human beings has no right to exploit other species to the extent that they are in danger of becoming extinct. A recent Kew Garden report has stated that by 2050 AD, as many as, 60,000 plant species will be extinct".

Our forest wealth is fast disappearing and in turn we are losing the precious bio-diversity. A significant part of the 15,000 plant species and about 75,000 varieties of the animal species found in India, is facing threat of extinction as a result of deforestation. In our country, about 70% of the house hold energy is in the form of fire wood, derived from natural resources. We are alrealdy facing short supply of fire wood and the villagers have to travel miles to collect the fire wood around their homes. In view of the above, Government of India has set up a Central Forestry Commission and has laid down a National Forest Policy for the speedy development of our forest wealth. The programme includes the development of the economic plantations, rehabilitation of degraded forests, forestry research and forest protection, improvement of forest communications.

Check Your Progress - 4

What are the important uses of forests?

Note: (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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Silviculture has become an important branch of forestry. Silviculture deals with the methods of forest regeneration, cultivation of trees and other forest management methods. The Himalayan forest areas of about 12.5 million sq.km is facing a major problem of deforestation, which in turn causes soil erosion. Number of forest based industries have come up causing air and water pollution: Paper Industries consume a lot of bomboo; It is not available in required quantities. Jhum cultivation (shifting) is another cause of deforestation.

Important timebr yeilding plants include *Tectona grandis* (teak), *Shorea robusta* (sal), *Dalbergia sissoo* (shishum), *Pinus spp., Cedrus deodara* (deodar), *Terminalia tomentosa, Boswellia serrata, Santalum album;* Beedi leaf comes from *Diospyros melanoxylon;* and many medicinal plants like *Rauwolfia serpentina, Cinchona, Terminalia arjuna* and many shrubs are present in the forest. Lac or sealing wax comes from insects living on forest trees. Bamboo, *Eucalyptus, Boswellia* are sources for paper industry.

The population explosion (both human and cattle) is the root cause of a deep economic and social crisis. Human population has grown from 361 million in 1951 to 668 million in 1981 and is expected to reach 1000 million mark by 2000 A.D. Cattle population, which was 237 million head in 1972, will be reaching to 438 million head by 2000 A.D. The gap between demand and supply is widening rapidly, creating a situation of storages of fuel, fodder and timber. The main reasons for the greater loss of forests are due to excessive felling of trees for fuel wood, exploitation of forests for profits and shifting cultivation practice. As such, there is an urgent need to develop and increase the forest area to the required 30% of the land area. According to the recent satellite studies, it is clear that only 19.5% of the total land is under forests in our country. However, the forests with minimum 40% density (known as closed forest) cover only 10%; 'open' forests stand at 8%; mangroove forest occupy 0.12% and coffee plantations of about 1.10% are also included.

From now, atleast 5 million hectares of waste land has to be brought under forest cover every year, if we have to change the worsening environment. The following important management practices have to be executed to over come the present day shortages.

a) Selective harvesting : There are some thick forests with closed canopy; as such seedling of dominant trees fail to get adequate light and aerial space to develop and remain dominant. In managing such forests, the trees are to be marked according to the time sequence and are to be harvested so that the desired dormant seedlings may fill the gap. Some of the harvested trees may also coppice (vegetatively from the base of the stem or the stump left after cutting the shoots). The new coppice branch can develop into a full fledged tree. Harvested trees of *Tectona, Eucalyptus, Leucaena* and a few other can coppice and there is no need of planting new seedlings.

b) Block cutting : In plantation forest, usually all the trees are of the same age. In such forests, the range is divided in 30-40 blocks. Trees in one block are harvested. The cleared land is planted with the seedlings of the same species. Then, the second block trees are harvested and the process is continued year after year, indefinitely because every year one or the other block is ready with mature trees.

c) Taungya system : A kind of agro-forest system has been involved to cut down the expenditure on growing forest trees. This is known as Taungya systems in India. Poor villagers are given cleared forest plots. In the first year, they are allowed to cultivate agricultural crops and to take the profits. In the next year, they have to prepare rows of beds for raising forest tree seedlings and they are allowed to cultivate agricultural crop only between these rows for 2 to 3 years and poor villagers get free land and all the harvest for 4-5 years. By 4th year, the seedlings of forest trees grow over a metre or little above, with firmly established roots. In the process, the forest department is getting free labour.

d) Social forestry : Realising the need for rebuilding the existing forest resources near the villages for rural housing needs, the government has launched massive programmes of social forestry throughout the country. Keeping in view of the most important aspects of production, idle land, labour and water resources for optimum production of fire woods, food, fodder, manure and timber. Under this scheme, areas like waste lands, railway lands, panchayat lands, roadsides, canal sides, uncultivable hilly slopes, riparian lands, wide buffer belts around dams and industrial premises and unused lands are being planted with fast growing trees, which are commercially valuable. These plants provide firewood for people, pulpwood for the paper industry, fodder for cattle and small timber for construction. They also act as wind breaks or shelter belts. It also helps in generating income of the people, providing full time employment. Social forestry involves the participation of people in large numbers. It helps in protection of natural forests as rural people get their requirements from social forestry plants.

Earlier, only one type of plant species is grown, but now growing more species of plants has proved better. *Leucaenea, Acacia, Prosopis, Sesbania, Casuarina, Eucalyptus, Tectona, Dalberga, Moringa and Azadiracta indica* are now being planted in social forestry. *Terminalia arjuna* and mulberry are also grown to raise tassar and silk cacoons. Fruit trees like mango, jackfruit, *Eugenia jambolana, Zizyphus* have also become important addition to the social forestry plants.

During the sixth plan period, the social forestry programmes received lot of funding from national and International agencies upto 1980, about 500 crores of rupees were spent on social forestry and consequently some green islands have appeared on hitherto barren lands. Centrally sponsored scheme for social forestry received Rs. 500 million, including fuel wood plantation; external assistance Rs.1600 million and state's scheme: Rs.1418 million (6th plan). In the externally aided projects, the world bank, Sweden, USA, Canada and the Canadian International Dev Agency have extended help. Under the 7th plan period (1985-90) a 'National Umbrella' project has been launched. For a massive social forestry programme Himachal Pradesh Govt. received a huge grant from Republic of Germany. Indeed, the achievement of social forestry programmes in sixth plan period was more than satisfactory with 3.47 million hectares of land, which for in excess of the target, was planted with trees. The target for 7th plan period is 10.5 million hectares. the goal of attaining 33% of land under forests could be achieved by mixing Fruit giving trees like coconut, mango, jack fruit, jamun, cashew in the social forestry programmes. In fact, such a practice is more economical than growing fruit trees in orchards.

11.8. WASTE LAND

The planning commission, under the leadership of Pandit Jawaharlal Nehru, had gathered report on the total wasteland in India in 1963; it was around 50.95 million hectares. The figure is going up constantly. Only during 1986, our government recognised the importance of developing of waste land and constituted the 'National Wasteland Development Board'. The board recommended massive afforestation programme for the reclamation of waste land, with the aim of planting 5 million hectares per annum. However, only 3.2 million hectares of waste lands were brought under plant cover in the first two year of 7th plan. On the other hand about 1.5 million hectares of forests are being denuded every year illegally. We have to take lesson from China and Japan. In China, after its liberation, increased its food products by successful implementation of waste land reclamation projects. Japan is able to preserve its natural forests by importing wood requirements. Approximately we are spending Rs.4,000 crores on fuel wood account, equivalent to 125 million tonnes of fuel wood. For afforestation of 5 million hectares every year, it is estimated that Rs.2,500 crores are required but it is not much if we consider the benefits through the environmental changes and the increased forest wealth. For developing waste lands in India, the best suited project seems to be agro-forestry as an integral part of social and farm forestry. It is also advisable to exploit blue green algae and mycorrhizal fungi in reclamation of degraded lands. The broad objectives of agro-forestry include the following :

a) to maximise the production of food, fuel, fodder, livestock and other forest products,

b) to utilise the farm resources properly,

c) reduction of pressure on protective and productive forests for meeting the local demand of fuel wood, fodder, building material, industrial timber etc. so that the existing forest can be spared for their protective and productive role,

d) to maintain the ecological balance,

e) and to check soil erosion, conserve soil moisture and increase soil fertility.

Land is a precious resource which is being degraded constantly by rain, wind, deforestation, erosion and various other factors. Land, if not conserved, becomes an important exhaustable resource. As such, land management is an important and essential aspect. Land must be identified based on the nature of soil, physico-chemical constituents, and then suitable agricultural practices should be encouraged.

The loss of forests causes even greater loss to many valuable forest plants and animals. There are many over exploited medicinal plants such as *Rauwolffia spp, Podophyllum spp* and *Aconitum spp* and are now considered as endangered species. There are many more plant species which are gravely endangared (eg. *Rafflesia sp., Diospyros hemiteles* (represented by one male plant in Mauritius), some Orchid species etc. Similarly there are species of animals which are gravely endangered e.g., Reptiles like Himalayan Newt or Salamander Marsh crocodile birds like the great Indian Bustard and Mammals like lion, panther, Tiger, golden cat and a few more.

11.9. WILD LIFE

In view of the threatened animal species, our government is taking necessary action to conserve the wild life by creating national parks and sanctuaries. Killing or capturing of any animal is prohibited in a sanctuary. Indian Board of Wild life has been established in 1952 and started awareness programmes to educate people. The important places conserving wild life are: i) one horned *Rhinoceres*, wild buffaloes (sancturies in Assam), ii) Kelameru bird sanctuary for pelicans and marine birds (in A.P.) iii) Gir forest in Gujarat for lions, Chital, Sambars and wild bears; iv) elephant, gaur, deer, sambar etc. (Periyar sanctarary in Kerala) Bittar Kanika National Park in Cuttak district helps in preserving mangroves and their associated fauna. There are many more distributed in other states of India. Our national animal is tiger, national bird is peacock and the national flower is lotus. For conserving the dwindling tiger population, project tiger was initiated in 1973 and the population went upto 4,000 and above.

11.10. WATER RESOURCES

Although 2/3 of the earth is covered with water, there is always scarcity of fresh water. As such, the management of water resources is very important. Therefore, serious attempts are now being made to conserve, retain and store surplus water so that water is available in times of need. Food waters should be controled and water tables must be maintained at proper levels. In view of the impending water shortage, many projects to conserve and store water have been taken up. The following are a few important projects: 1) Kosi project (Bihar) 2. Gandak project (Bihar) 3) Nargarjuna Sagar Dam (A.P.) 4) Tungabadra Project (A.P. & Karnataka) 7) Malaprabha project (Karnataka) 8) Bhakra Nangal Project (Punjab) 9) Hirakud Dam (Orissa) 10) Rajastan Canal Project (Rajastan) and so on.

For example, the Rajastan Canal project is boon to drought ridden Rajastan. It is expected to provide water for irrigating 11.6 lakh hectars in three districts. Bhakra Nangal Project is a joint venture of Punjab, Haryana and Rajastan. This happen to be the biggest valley projects, consisting of 226 m high dam at Bhakra, 29m high Nangal Dam, thousands of kilometers length of canals helping to irrigate 20 lakh hectares.

Water problem is an important problem. For example the sacred river Ganga is highly polluted. Former Prime Minister Rajiv Gandhi launched the Ganga Action plan to clear the polluted waters. Many Industries have been polluting the river. Under the direction of Supreme Court in 1983, a few industries responsible for pollution were prosecuted. Even electric crematoria were erected. The total estimate for the project is about 2000 crore rupees.

The sea water is salty, which is available abundantly. Sea water also needs to be managed because of its pollution. In Bhavanagar (Gujarat), fresh water is being obtained from sea water by desalination using solar energy for distillation. This is Cheap. Oceans are considered as non-renewable resources. In oceans natural oil and gas deposits are also found. Minerals (cobalt, copper, iron, manganese and nickel) are being exploited from sea bed. Menozyte (used in atomic energy production), gold and platinum deposits have been discovered from sea sands or sea bed.

Water resources, which are generally, renewable occur mainly as salt water (97.3%) and fresh water (2.7%). The fresh water occurs in frozen form (77.2%), as ground water (22.4%), in lakes and wetlands (0.35%) and in rivers and streams (0.01%) as given in World Resources (Basic Books, New York, 1986). A person needs about 2.7 litres per day. Even then, there is not enough supply of drinking water in villages. In some states, ground water availability is not adequate. As such, there is regular reoccurence of drought. However, our flowing rivers like Ganga, Godavari, Krishna, Cauvery, Mahanadi, Narmada and Brahmaputra serve 80% of our total population. Sharma (1987) observed that 92% of water is utilized for irrigation and 8% for domestic and industrial use. Only 1/4 of the available ground water potential is being used. There is urgent necessity to apply improved technology to increase water storage capacity and ground water utilization.

11.11. ENERGY RESOURCES

Petrol, natural gas and coal are considered as non-renewable energy resources. They cause environmental pollution, when they are burnt, also they are exploited so much they may not be available after a few decades. Therefore, alternate sources of energy has to play the major role.

All life on this planet is dependent on sun's energy. Plants are capable of capturing sun's energy during photosynthetic activity and produce food for all the other living organisms, including man. Petrol, coal and natural gas are all in reality come from Sun's energy. Vegetation from forests buried millions of years ago gets decomposed and is converted into petrol and coal under great pressure and temperature. Our new technology exploits the solar energy for cooking and generating electricity. Pohotovoltaic cells help in converting solar energy into electricity. Gradually solar cars may replace the cars, running with petrol power.

Wind energy and energy from tidal waves also contributes in generating electricity. Windmills are very common in Holland and are becoming popular now in India. You can see a few wind mills on Tirumala hills in Andhra Pradesh.

Biogas, utilising cow dung along with some plant substitutes is of immence use for cooking and also for generating electricity. There are a few villages, in India, particularly in Maharastra that do give their energy for cooking and electricity from the community Biogas generators. This is a kind of renewable energy source as millions of cattle give the needed cowdung and plants residue help as supplementaries (e.g., water hyacinth, Banana shoot system).

The most important renewable energy is the fuel wood and our villages need 130 million tonnes of fire wood. The demand may increase to 350 million tonnes by the end of the century. Forestry and social forestry help us to meet this demand.

Of late, we are also harnessing atomic energy for generating electricity (e.g., Trombay reactor, Bombay).

Recycling of Resources : Some resources are waste materials and can be recycled for later use. In fact, biogas is an example of efficient utilisation of cattle dung, garbage and aquatic weeds etc. The slurry produced in the process is used as valuable manure.

In USA, all waste paper, glass products and plastic materials have to be dumped separately, so that they can be recycled properly. Toilet paper can be made from waste paper.

In India, organic waste and crop residues are important resources available for recycling. Every year, about 2500 millions tonnes of organic waste is produced in our country and by proper utilisation some essential products like fodder, fuel, food and fertiliser could be recovered. We can also produce about 400 million tonnes of plant nutrients from the same organic waste. Although, developed countries like USA, UK, Germany and Japan are recyclying the waste very efficiently, we are lagging much behind.

Recently vermitechnology has come to rescue for efficient management of waste in our country. It helps in resource recovery and environmental protection. Nutrient cycling in soil is mainly due to the activity of soil microorganisms and fauna like earthworms. Reclamation of organic waste by biological degradation and decomposition is known as composting. The degradation of organic waste by earthworm consumption is known as vermi composting (Dash, 1993). Vermicomposting has a few advantages which are as follows :

1. Abatement of organic pollution by rapid reduction in the bulk density and elimination of foul odour.
2. Production of vermifertilizer (worm casts) and compost for application in agro ecosystems.
3. Production of vermiprotein or vermitin from waste and utilisation of this protein as feed for fish, poultry, pigs and domestic animals. The worm casts are also useful in mushroom cultivation and for growing vegetable and crops.

Worms like *Dichogaster bolaul, Drawidia willsi, Lampito mauritii* are good for our India conditions, while for temperate countries, *Eisenia foetida* is the best.

11.12. POLLUTION ECOLOGY

In previous chapters we have learnt about air, water, soil and noise pollution. Since, the causes are clearly understood, control of pollutants becomes easier. However, the nuclear waste has proved to be the most dangerous pollutant. It is mentioned in Times (October, 1988) that thousands of Americans may be afflicted with cancer due to the release of radio active particles into the air and due to the dumping of water into leaking pits.

11.13. POPULATION ECOLOGY

World Human population is estimated to reach 8 billion by 2000 A.D. The harmful effects of such huge population on the ecosystem are visible to us and therefore, voluntary family planning seems to be the best solution. Many developed countries maintain zero percent growth in population, while the developing countries doubling their population. For instance in India, population was 40 crores at the time of independence and it has already doubled. Such enormous population is responsible for excessive utilization of nature, poverty, disease and unemployment. The survival of making depends on us only; if we protect the nature, it will definitely helps to survive; and applied ecology helps in environmental protection and maintenance of natural balance.

11.14. SUMMARY

Over exploitation of natural resources is the cause of environmental degradation. Poverty, over growth of population rate of unhygienic slums in India are posing a threat to environment. Usage of excessive chemical fertilizers, modern agriculture practices and rapid industrialisation are also responsible to environmental pollution. Applied ecology emphasizes management of forests, pastures, waste lands renewable sources of energy etc that control pollution.

There are two kinds of resources based upon whether they can be regenerated or not. They are renewable resources and nonrenewable resources. Plants, animals and water are considered as renewable resources. Resources which can not be regenerated are considered as nonrenewable resources e.g., fossil fuels and mineral deposits.

Resources that occur in nature can be exhaustible or inexhaustible. Coal, Petrol etc are exhaustible natural resources and solar energy, atomic energy and wind power are inexhaustible. Management and conservation of exhaustible and inexhaustible is very much important for the welfare of the future generations.

Agriculture, management of soil, pastures, grazing lands, forests, waste land, wild life management, water resources, energy resources, pollution ecology and population ecology are the various aspects of applied ecology.

Agriculture forms the good example for applied ecology where the farmers experiment continuously regarding the suitability of soil, season, quality of irrigation and fertilizers for obtaining the best yield of a crop.

Formation of soil takes about thousands of years. Hence soil conservation and management are considered as renewable. Soil erosion can be prevented by planting trees and developing grass lands. By preventing soil erosion and enhancing soil fertility soil can be conserved in a proper way. Pastures and grazing lands provide grazing ground for cattle and other live stock. But only at the foot of mountains these are found in large numbers. Forests are the natural ecosystem and they provide fodder, timber, fibre, medicines etc. Forests regulate the climate conditions and protect the soil from wind and erosion. They also trap solar energy and convert into plant biomass. The important branch of forestry is silviculture which deals with forest regeneration, cultivation and other management methods of forest trees. Programmes of Social forestry have been launched by the Government to rebuild the existing forest trees near the villages for the needs of rural population. Proper utiliation of waste land is also a part of applied ecology. By growing plants in waste land ecological balance can be maintained. Conservation of wild life by creating sanctuaries and national parks is also very important step taken by the government.

Scarcity of fresh water always exist, though 2/3 of the earth is covered with water. Many attempts have been made for future need. Improved technology is very much necessary to enhance the water storage capacity and utilization of ground water, among the energy sources, petrol, natural gas and coal are nonrenewable energy resources, while solar energy, wind energy, tidal energy, biogas are renewable sources of energy. Recycling of the resources which occur as waste materials is another important task one should think about. Vermi technology is an efficient method of mangement of waste in our country. This is not only recovers the resources but also protects the environment. Pollution ecology and population ecology are some other aspects of applied ecology by which human society can be benefited.

11.15. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The resources such as plants, animals and water which can be recycled are called renewable resources.
2. Soil erosion can be prevented by large scale planting of trees and by developing grasslands.
3. Due to over exploitation, water logging and fertilizers and pesticides which are not readily degraded, soil becomes sick and infertile.
4. Forests are very useful and provide fodder, fibre, timber, fruits, herbals, medicines, any other raw materials required for forest based industries like paper and pulp industries, beedi leaf, matches, ply wood etc in addition to be a habitat for wild life.

11.15. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write an essay on agriculture and soil management.
2. Describe in detail about the forest management.
3. Write a brief essay on energy resources and their management.

II. Answer the following questions in about 10 lines each.

1. Write a note on soil erosion and soil fertility.
2. Give a brief note on waste lands.
3. Writer a short note on management of water sources.
4. What is vermi-technology?

Prof. Pannuri Rama Rao

BLOCK - 3

ENVIRONMENTAL PHYSIOLOGY

UNIT - 12 : BIOLOGICAL RESPONSES TO OSMOTIC CONDITION

Contents

12.1. OBJECTIVES

After going through this unit, you will be able to:

* describe salt and water regulation in Arthropods,
* list out and describe the adaptations of amphibians,
* describe the role of kidney, gut, cloaca & nasal salt gland,
* explain the mechanism of ion transport in the avian salt gland,
* describe the ionic regulation in terrestrial and aquatic animals.

12.2. INTRODUCTION

To show relationship between temperature and salt and water regulation (osomotic) a number of examples from desert animals may be mentioned as these organisms get adopted to extremes of temperature. Now let us consider both invertebrates and desert vertebrates. Though some organisms do not represent desert, they are studied with simulated conditions like desert.

12.3. SALT AND WATER BALANCE

12.3.1. Salt and Water Balance in Desert Arthropods

Much of research work was done on xeric insects and other arthropods as they live under conditions which as physiologically as stingent as those living in the desert environment. The physiological adaptations are similar in desert and xeric animals.

Problems of Desert Arthropods

1. Continual water loss as a result of transpiration through the general cuticular surface
2. Transpiration associated with respiratory exchanges.
3. Water loss in excreta.

The water loss is restricted by the possession of a highly impermeable cuticle which also reduce the respiratory loss of water. The cuticle is generally covered by a mono layer of wax. The water loss in these insects and other arthropods occurs because they have larger ratio of surface by volume.

12.3.2. Water Loss

In the case of insects the spiracles open into the sub-elytral space which effectively functions to reduce transpiration. Hence, the water loss is very less. This process is referred as "Thermal disorientation".

12.3.3. Regulation and Physiological Aadaptation for Water Loss in Insects and Some Arthropods

1. Usually the control of water loss is brought about by reduction of rate of amplitude of ventillary movements.

2. Presence of water proof wax layer in epicuticle causing thermal disorientation.

3. Recycling of the metabolic waste water by rectal absorption.

4. Water balance during flight: Many of these flying insects fly in higher cooler air to conserve water. In the high altitude area the Relative Humidity (RH) will be high, at the same time the temperature also would be less as compared to temperature at ground level. The pumping action of the thorax causes the water loss.

5. Uptake of water vapour from sun-saturated atmosphere: The Grasshopper *Chortophaga viridifasciata*, a true desert species and also cockroach *Araniraga* have ability to take water vapour from high RH ranges. This is a very interesting adaptation in the case of desert insects. The moulting of the animal has this ability of absorption of water. If the integument is damaged, the absorption capacity is lost. This clearly shows the moulting of the animal contributes to this capacity.

6. Role of Hemolymph, rectum and malphigian tubules in ionic regulation and solute reabsorption:

During acute dehydration conditions or dry conditions, one can see the alterations in the osmotic pressure of the hemolymph, volume of the hemolymph and also the tissue water content. In such situations the rectal reabsorption capacity, the secretion of salts or solutes by the malphigian tubules are controlled and are responsible for maintenance of the water balance and the osmotic balance in the animals. The insects feed on the fleshy leaves ingesting both water and salts. The excess salts ingested would be secreted by the malphigian tubules thereby maintaing the osmotic and water balance

12.4. AMPHIBIANS

Pelobatis syriacus, Solamandra couche, Bufo viridis, Bufo punctatus, Hyla rubella, Cyelorana platycephalus etc. are the examples for desert amphibians.

The amphibians show three important adaptations:

1. Behavioural adaptation to aviod extreme conditions
2. Tolerance-ability to withstand
3. Physiological
   a) Reducing the water loss and taking up of more water when available. The main organ involved is skin. Example: *Triturus* species.
   b) Storage in the urinary bladder and to reabsorb water during dehydration and aestivation. This adaptation is observed in the desert amphibians which show burrowing adaptations.
   c) The rate of functioning of kidney is reduced and the water loss through kidney is minimised.

Newts live several miles away from water resource and undergo aestivation in the underground burrows. They got very low rate of water loss. The *Triturus* species shows the highest degree of terrestrial adaptation among the amphibians.

Triturus takes higher amounts of water from the atmosphere after dehydration than that of Salamandra under same conditions.

Horomonal control of water uptake

Cloudsley Thomson (1973) reports that the extracts of neuro hypophysial gland and their hormones stimulate water absorption both *in vitro* and *in vivo*. They act on the skin and fecilitate water passage whereas on the kidney it has anti-diuretic effect and enhances water absorption. In general most of the amphibians are exposed to 200 cm/min to 4000 cm/min speed of dry air. This causes lot of dehydration and the animals adapt for this dry conditions.

12.5. REPTILES

12.5.1. Water and Salt Balance in Desert Lizards

There are a number of lizards which have a remarkable property of tolerating without water for longer periods. They take only diotary or metabolic water and survive. The following are a few desert lizards which show adaptations and regulations to desert conditions.

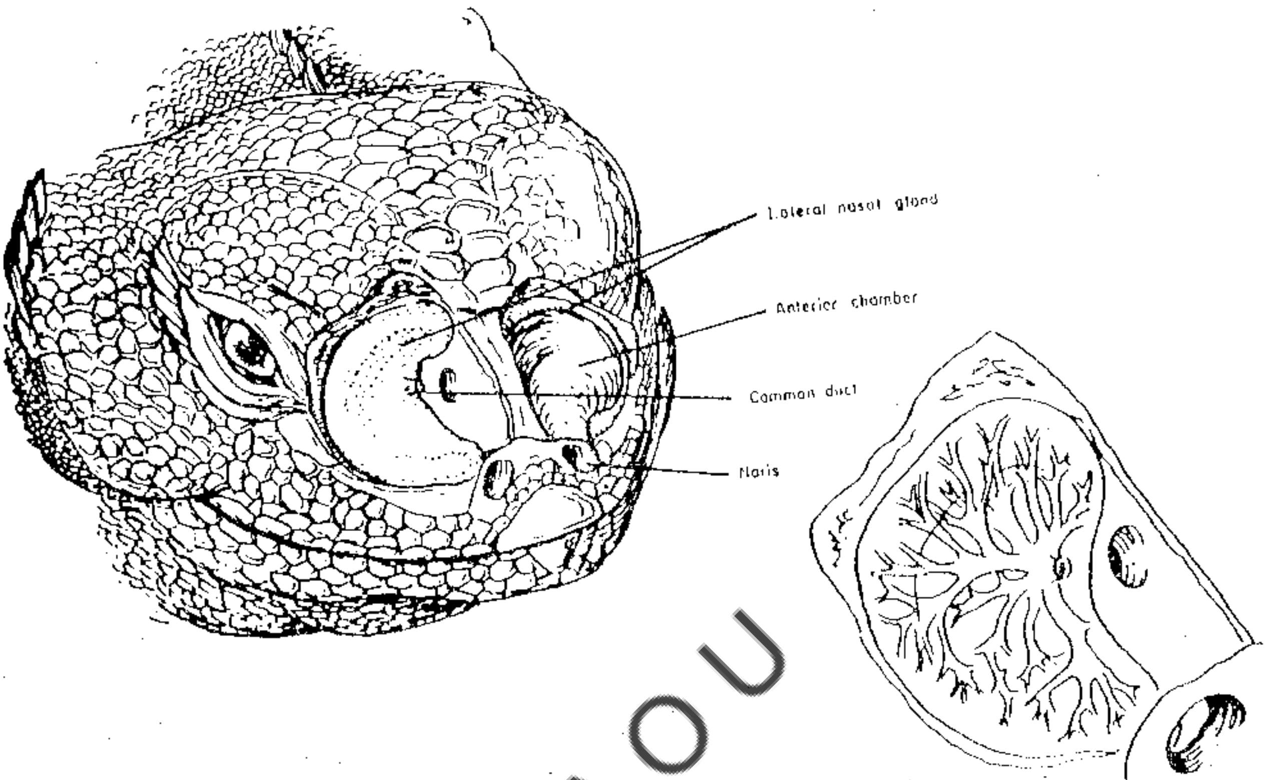

Fig. 12.1. Drawing of the head of *Dipsosaurus* showing the exposed nasal region and the nasal salt gland. The diagram at the right illustrates the gross morphology of the duct system of the gland (J.R. Templeton, unpubl.data).

Dipsosaurus dorsalis (Desert Iguana): Remains without water and takes only metabolic water. Nasal salt gland is present.

Sauromalus species (Chuck wallas) : Found on hot American desert and there is no access to water. Stores water in gular lymph sacs and uses extracellular water.

Amphibolurus ornates: Drinks only when water is available.

Phrynosoma m'calla: Never drinks in field.

Water Loss due to Temperature Extreme and Osmotic Balance:

The water is lost through the skin for most of the lizards, but the loss is less when compared to the non-desert lizards. The *Iguana* stays outside the burrow only for three hours, whereas for the rest of the time it stays in the burrow underground.

12.5.2. Role of Kidney in Excretion

The desert lizards have no loops of Henle in kidney whereas it is present in birds and mammals. Effective glomerular filtration and cloacal absorption of water is being present in desert lizards. Another important adaptation is that they secrete uric acid or urate instead of the urine. The salt absorption and tubular role in affecting electrolyte composition in desert lizards is still not clear.

12.5.3. Role of Gut and Cloaca

In desert lizards, a gradation in water content exists along the intestine towards cloaca. The water content was high in the cloacal region than in the rest of the intestinal portions. Another adaptation is the colloidal osmotic pressure of the plasma which provides sufficient force to absorb water from the urine and faeces in cloaca leaving the excreta with less water as moist pellets. The pellets consist of only 45% of water. The desert lizards have capacity to remove more of cations than anions. For example the desert Iguana can remove 4900 milli equivalents of potassium/litre of urine.

12.5.4. Role of Nasal Salt Gland

Some families of lizards like Iguana, *Sauromalus obescus, Ctenosaura pectinata* posses a nasal salt gland which secretes Na^+ and K^+ as sodium chloride, potassium chloride, Na_2CO_3 and K_2CO_3 with least loss of water. In normal conditions the blood cations should not exceed their physiological amounts. It exceeds when there is dehydration due to evaporation.

In such conditions these cations are usually excreted out along with urine in most of the non-desert animals. If these desert animals also excrete these cations along with water, like non-desert animals, it would cause excess dehydration and water imbalance but in the case of desert lizards they have developed a nasal salt gland which secretes these salts without much loss of water and excrete excess of potassium as mono potassium urate through the nasal gland. This compensates the cloaca and kidney function. This nasal salt gland is located bilaterally encased in a cartilage nourished by post natrial artery and innervated by ethmoidal nerve. Injection of high concentration of either NaCl of KCl intraperitoneally caused heavy secretion of salts through the nasal gland (Templeton, 1973)

12.5.5. Role of Hormones on Nasal Gland

Templeton (1972) showed that the nasal gland is stimulated by cholinergic drugs and inhibited by atropine. This suggests the autonomic control. It was also found that aldosterone has effect on the nasal salt gland secretion. When this hormone was injected there was excess of secretion of potassium whereas sodium was retained. Similarly vassopressin and arginine also act on the cloacal region of the lizards.

12.5.6. Hypernatrimia

The Australian lizard *Amphibolurus ornatus* in summer lives on ants rich in sodium chloride. Lacking sufficient water to remove the sodium they retain sodium along with water by expanding the extracellular fluid while drawing the intracellular fluid. When it rains, comes, rain water removes these ions.

12.6. AVES

There is considerable evidence indicating that the concentration gradient between the blood and the fluid secreted by the salt gland is established at the effective, luminal membrane barrier of the secretory cell.

i) The concentration gradient between the cell and the lumen is greater than between the blood and the cell.

ii) During secretion the duct of the gland becomes electropositive with respect to the blood by about +50 mv, presumable due to Na+ transport into the duct.

iii) Ouabain, a specific inhibitor of Na+ pumping and of the Na+ K+ ATPase, when administered into the duct, abolishes both secretion and the potential difference. Hence, the large quantities of Na+K+ ATPase present in salt glands must be effectively exposed to the lumen

12.7. MAMMALS

12.7.1. Water and Salt Balance in Desert Spiny-Mice

The desert mice *Acomys cahirinus* shows adaptation to desert conditions. The capillary vessels, cardiac capillaries and myocardial endothelia help in the maintenance of salt water balance. Injection of traces of Dextron and Evan's blue into the desert mice and also into a non-desert laboratory rat after dehydration, showed greater retention of Dextron and Evan's blue within the capillaries of Desert mice, whereas in the case of the non-desert mice the retention was very poor. This shows that the capillary wall pores are small and is under simulation by vasoconstrictor agents.

Water and Salt balance in desert camels (*Camelus dromedarius*)

Extensive work on the adaptive features of the camel was carried out by Schmidt Nielson and Maloiy (1974). The experiments to understand the physiological adaptations for desert conditions experiments like water balance, salt loading and measurement of glomerular filtration were carried out in a simulated climate chamber and was compared with a donkey. See below that Camel requires less water than a donkey at higher temperatures.

Temperature	Camel	Donkey
22°C	2 L/100 Kg wt./day	7.4 L/100 Kg wt./day
40°C	3.8 L/100 Kg wt./day	8.82 L/100 Kg wt./day

Glomerular filtration rate

The glomerular filtration rate is measured in terms of Inulin clearance test. In the camel that was subjected to dehydration 57% decrease in the urine flow and 30% decrease in the glomerular filtration rate was observed.

Under very high dehydration condition the camel was allowed to take sodium chloride salt solution. It is a remarkable observation that the camel can drink 3.5 to 5.5% of NaCl solution. They also observed under these conditions that the camel could excreate a highly concentrated urine. Another important observation was, the camel could survive more than 45 days if it is deprived of water and fed with hay only. The camel has got the capacity of reabsorbing 90 to 98% of water.

12.7.2. Hormonal Control

Under high dehydration the vassopressine increases the excretion of a concentrated urine whereas aldosterone stimulates the water absorption from the intestine. So in conclusion in the camel the following observations are made.

1. Excretion of a concentrated urine
2. Tolerance to dehydration
3. A low level of water expenditure
4. Tolerance to salt water drinking

12.8. GENERAL ASPECTS OF IONIC REGULATION IN AQUATIC ANIMALS

Problems of ionic adaptation come from two sources.

1. The overall concentration of total ions. 2) The concentration of individual ions. The concentrations of inorganic ions in the external environment range from zero, in the case of most terrestrial forms, to levels vastly exceeding those within the cells. These more or less sharp ionic gradients between the organism and its environment create the problems of maintenance of disequilibrium. The energy costs involved in keeping millions of ions per cell from attaining equilibrium with the external environment are high.

2. The second basic problem in ionic adaptation derives from the individual ionic composition of the cell and the external environment. Thus, the maintenance of ionic gradients involves a selective component. Not only must the cell be able to keep large numbers of ions from attaining equilibrium with the environment, but in addition it must possess regulatory systems with precise abilities to recognize different ions and to treat these ions differentially.

12.8.1. Adaptation in Freshwater Fishes

In freshwater fishes, the major problems of ion and osmoregulation are (1) maintaining ion concentrations in the blood at values at much higher than the outside fresh water, and (2) preventing an excess osmotic flow of water into the cells and tissues of the body. Gut and skin plays a negligible role in this problem thus the gills and kidneys are the major effector organs; solution of osmotic and ion problems involves the active uptake of Na^+ ions at the gill surface and the production of a dilute and copious urine at the kidney. Of these, the active uptake of Na^+ at the gills is qualitatively the more important process.

The gill transport system in freshwater-adapted fish displays two essential properties, that is (i) the salt pump is polarized in function so that the direction of net Na^+ movement is inwards, (ii) It must be a high-affinity system because the Na^+ concentrations in the outside fresh water can be very low (Fig.12.2.).

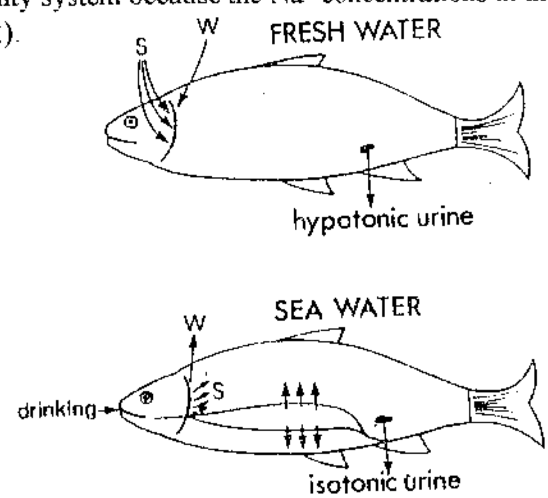

Fig. 12.2. Schematic representation of the role of various effector organs in the maintenance of salt (S) and water (W) balance in fresh water and sea water teleosts.

12.8.2. Adaptation in Marine Fishes

Upon encountering brackish water, an organism like the Salmon or the eel faced with quite different problems of ion regulation i.e. osmotic loss of water at the gills, the consequences of which are exaggerated by a continual "downhill" inflow of Na+ and other ions. Of the various effector organs potentially capable of responding to this new environmental challenge, the increased water intake at the gut balances the osmotic loss of water at the gill. This appears to be the only important contribution of the gut. The kidney are involved in the adaptive response by reducing the volume or urine eliminated and probably by increasing the Na+ output of the urine.

During salinity adaptation in fishes, important ultrastructural changes occur in the transport cells of the gill (the chloride cells) which shows a number of characteristics features. For example (i) Mitochondria with closely packed cristae are numerous and increase in abundance during salt adaptation; (ii) All transport cells have mechanisms for membrane amplification etc (Fig12.3.).

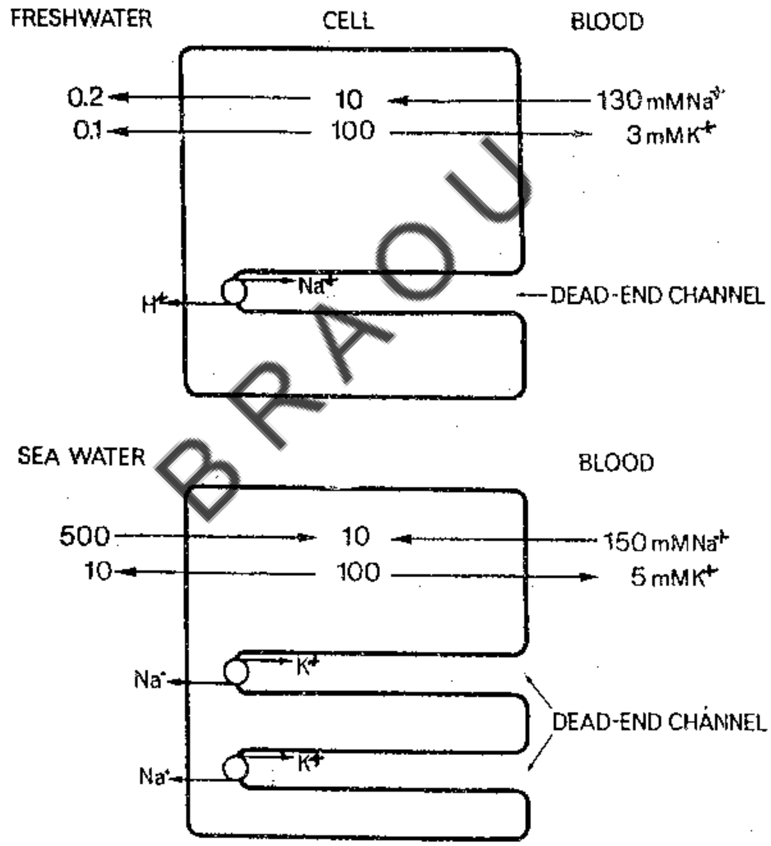

Fig. 12.3. Functional model of the chloride cell in the gills of freshwater and sea water adapted fishes. The model is to be looked upon strictly as a summary of the physiological and biochemical information that is available on the transport of monovalent cations. The anion "pump" which presumably accounts for Cl^- and HCO_3 movements is not shown.

In Brine shrimp cysts, when dehydration occurs they enter a cryptobiotic state where the energy metabolism is suspended. Rehydration reverses the condition. During dehydration polyhydroxyl solutes of animals offer cellular protection.

12.9. REGULATION IN PLANTS

A physiological background makes it quite evdient that water is an important ecological factor in the life of organisms. Water is universal solvent in which practically all the minerals, present in soil, may be dissolved. It is the medium of solutes, raw material in photosyntheis, and is essential for maintenance of turbidity of cells and sometimes plays an important role in fertilisation, pollination and dissemination. Water relations of plants bring about in them many physiological responses by affecting seed germination, water uptake, transpiration, photosynthesis and growth, respiration, translocation and some biochemical processes. Water shortage, in particular, which has been the main concern of human race, leads to many physiological effects in plants which in turn have many ecological effects as their counterparts. Droughts, thus has been a major physiological and ecological problem to be tackled by the scientific community of the world.

Adaptations of Land Plants - Water Balance Problems

Aquatic plants have hardly any problem of water, since such phenomena as transpiration, wilting etc., are generally not much pronounced or may be even absent but in land plants there is always a water-balance problem. Due to the limited amount of available water during the year, they are to evolve some characteristics that may check more loss of water from their exposed organs.

They have to maintain always some sort of balance between the loss and absorption of water. Due to these water-balance conditions, the structure of plants is greatly influenced. In land plants, which grow under unfavourable water conditions, there develop some characteristics, which are absent in plants growing under optimum moisture conditions. These characteristics are morphological as well as physiological. The former type includes the reduced size of shoot, elaborate root system, smaller blades with smaller stomata and smaller veinlets and more hairs on leaf surfaces, thicker cuticular layers and cell walls, well developed palisade tissue, poorly developed intercellular spaces and spongy parenchyma and xylem cells smaller and much lignified. The latter i.e. physiological ones include, a more rapid rate of transpiration as well as photosynthesis per unit area, higher osmotic pressure with an increase in protoplasmic permeability and decrease in its viscosity, greater resistance to wilting and early flowering and fruiting.

Some Important Adaptations in Hydrophytes

Morpholgical Adaptations

1. Excepting the emergent forms, root generally greatly reduce, even absent; if present, unbranched without root hairs.
2. Stem very much reduced, in some modified into rhizomes, thin and delicate.
3. Leaves thin, narrow, linear, some with long petioles and large lamina, covered with wax or hairs, in some dissected into segments.

Anatomical Adaptations

1. Aerenchyma extensive almost in all vegetative organs.
2. Cuticle generally absent.

3. Stomata either absent, or if present only at upper surface or even non-functional.
4. Mesophyll undifferentiated into palisade and spongy parenchyma.
5. Chlorophyll in addition to leaves also present in other parts of plant.
6. Epidermal cells thin-walled.
7. Lignified mechanical tissues lacking, conducting elements very few, non-lignified.

Physiological Adaptations

Habitats mostly deficient in oxygen content, thus having an ability to respire anaerobically or have low oxygen requirements. Special aerating organs are present.

Check Your Progress - 1 & 2

1. Mention four important points about water and salt balance in desert camels?
2. Write about the physiological adoptations in hydrophytes for ionic regulation?

Note : (a) Write the answers in the space given below.

(b) Compare your answers with those given at the end of this unit.

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12.10. SUMMARY

Animals and plants show osmotic regulation as responses to changes in water content in external and internal environment. Animals show both behavioural and physiological adaptations. Osmotic regulation is seen in both terrestrial as well as in aquatic animals. In desert arthropods water balance is maintained by various mechanisms like reduction in ventilatory rate, waxy layer on cuticle, body wasts recycling, adaptations in malphigian tubules and Haemolymph. Amphibians show adaptations in skin, urinary bladder and horomones also play a role. Reptiles show very interesting adaptations like nasal gland which secretes excess salts. Besides, a number of physiological adaptations are seen to minimise evaporative water loss. Aves also show mechanism for transport of ions with the help of avian salt gland. Mammals in desert show a number of physiological adaptations to minimise water loss and also maintain salt concentration in blood. The glomerular filteration in camel is unique and is different from non-desert animals. Salt and water balance is also regulated in aquatic animals also. Fishes show a wide range of adaptation for osmotic regulation. Plants show physiological adaptation for water balance in various extremes of ambient environment.

12.11. CHECK YOUR PROGRESS : MODEL ANSWERS

1 i) Excretion of a concented urine

ii) Tolerance to dehydration

iii) A low level of water expenditure

iv) Tolerance to salt water drinking

2 Hydrophytes are mostly deficient in oxygen content, thus having an ability to respire anaerobically or have low oxygen requirement. Special aerating organs are present.

12.12. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write an accout on salt and water regulation in desert reptiles
2. Describe salt water regulation in desert mammals.
3. Write an account on osmoregulation in fishes.
4. How do the salt and water regulation occurs in plants.

II. Answer the following questions in about 10 lines each.

1. How is water balance maintained in desert arthropods.
2. How is salt and water balance maintained in desert amphibians.
3. Write a brief account on avian salt gland.
4. Write a brief account on adaptations of hydrophytes.

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UNIT - 13 : TEMPERATURE AS ENVIRONMENTAL FACTOR

Contents

13.1. OBJECTIVES

After going through this unit, you will be able to:

* define homeothermy and poikilothermy,
* describe the behavioural aspects of thermo-regulation in desert animals, amphibians and reptiles,
* explain the role of adrenalin, and thyroid in thermo-regulation in mammals,
* describe the role of thermocutaneous receptors,
* define and describe thermal pollution

13.2. INTRODUCTION

The arid fifth of the earth provides habitats for a surprisingly wide range of animals. The hot and the cold deserts represent extremes to which originally aquatic animals have moved in radiation to dry land. Analysis of the structural, functional and behavioural aspects of this way out frings of physiology has proceeded steadily over the past decade. It is becoming clear that not only methods of rejecting heat at the surface but also of generating less heat internally have evolved for the desert. Intermittent food supplies and the concentration of salts in desert water have been met by fat storage and salt tolerance. Water independence and low rates of water turnover have evolved in desert animals, in association with low rates of energy metabolism. The evolution of the behavioural patterns for seeking shelter from the environmental forces has linked with the development of high resistance to electrolyte, osmotic or biochemical stress applied to cells during drought or dehydration. Adaptations are also seen in plants. Study of desert animals and animals which adapt to cold temperature can be taken as responses to temperature.

13.3. EFFECTS OF TEMPERATURE AND CLASSIFICATION OF ANIMALS

There are much variations in temperature and these variations affect plant distribution in various ways. It also affects animals. All animals are broadly classified into two groups.

1. Homeothermic or endothermic animals (warm-blooded)
2. Poikilothermic or ectothermic animals (Cold-blooded)

Some workers choose to categorise animals ability to maintain a relatively constant temperature. One group encompasses the **"homeotherms"**, orgnsims which, as their name implies, tend to maintain a constant or near-constant body temperature under most circumstances. Birds and mammals are the only organisms normally grouped under this heading. We will use the term "homeotherm" only in its most basic etymological sense. i.e., the term "homeotherm" will be used in reference to any organism which can hold its body temperature relatively constant, regardless of the phylogenetic status of that organism.

The second class of animals in this scheme are the **"Poikilotherms"**. These organisms have varying body temperatures and in addition, usually have only minimal capacities to regulate their body temperature physiologically.

Although majority of physiologists have used these two terms in the past, a departure from the traditions of the majority with meaningful terminology was given by *Hochachka and Somero* (1976) for thermal relationships. The terms **"ectotherm"** and **"endotherm"** terminologies denote the characteristic major source of body heat. This terminology has several advantages. Firstly, the two terms indicate clearly where the organisms obtains the greater share of its heat energy. Endotherms, as the name suggests, obtain their body heat largely from their own metabolic activities. Ectotherms obtain their heat from the environment i.e., they cannot maintain a body temperature much different from the ambient temperature owing merely to their own metabolic activity.

Check Your Progress - 1

1. Write the differences betwen Homeotherms or Endotherms and Poikilotherms or Ectotherms?

Note : (a) Write the answer in the space given below.

(b) Compare the answer with the one given at the end of this unit.

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13.4. THERMOREGULATION

13.4.1 Behavioural Aspects of Regulation

The behavioural adaptations to temperature observed among widely different groups of organisms may well be the most varied and successful to all types of temperature adaptations. There can be little doubt that the vast majority of motile organisms seek to avoid temperature extremes. This behavioural regulation takes many forms and occurs over a number of time courses. Many organisms migrate diurnally and seasonally to minimise the range of temperatures they must cope with. For example , intertidal fishes may seek deeper, cooler pools of water when the tide recedes and the temperature of the intertidal zone rises. Similarly, during the summer, many pelagic fishes migrate to deeper water where temperature are lower than those of shallow waters.

Other patterns of behavioural regulation of body temperature involve body orientation in the sunlight and the aggregation of individuals of effect group regulation of body temperatures. Insects and reptiles furnish us with especially good examples of thermal regulation via body orientation. These animals may bask in the sun during cool periods and seek shade especially during hot periods. Reptiles may also alter the shapes of their bodies to change the area of the light absorptive surface.

Aggregation phenomena, like other patterns of behavioural thermal regulations are phylogenetically diverse. Many species of birds huddle together during periods when the temperature is low and/or the wind is strong enough to create a singificant chill factor. An analogous behaviour pattern is observed with newborn mamalis; which often huddle closely together as a means of retaining metabolically generated heat. Behavioural thermal regulation thus involves both the aquaisition of heat from the environment and the control of heat dissipation to the environment. Thus many organisms have effective ways of regulating the flow of heat energy between their bodies and the environment, let us consider how the rates of heat production and flow within the organism can be controlled so as to isolate the organism's biochemistry from changes in ambient temperature.

13.4.2. Behavioural and Physiological Adaptations in Terrestrial Animals

The larger animals of the desert have relatively smaller surface area in proportion to their mass than the smaller animals. The smaller animals have bigger surface area than the mass of the body. The larger surface area in the small animals helps in the maintenance of the body temperature by heat exchange. Due to solar radiation, the transpiration rate and heat exchange will be higher in the case of smaller animals due to larger surface area than that of the bigger animals where the surface area is not sufficient enough for perfect heat exchange to maintain the body temperature. This has lead to the adaptation for metabolic regulation and is a substitute in larger animals.

In the smaller animals, the question of metabolic regulation would not arise because their larger surface area requires metabolic energy input. So their behavioural regulation is one of the substitutes to maintain their body temperatures. Colbert an authority on Reptiles hypothesis that the larger aminals like the extinct Dinosaurs might have adapted for Homeothermic regulation as their surface area is far less when compared to the mass of the body. A good example of a small animal maintaining efficient regulations is a lizard of Southern Peru namely *Lio laemus* which absorbs solar radiations and keeps its body temperature 30° above the ambient (environmental or surrounding) temperature of 0°C. Another example is that of a Permian Pericosaurus seems to absorb the solar radiation through the spines on its crest.

13.5. AMPHIBIANS

One of the best methods in judging the adaptability of desert amphibians to arid conditions is by determination of CTM value, which would mean the Critical Thermal Maximum. This CTM serves as an index of adaptability to the existence of a high temperature at which the activity gets disorganised but when temperature drops, the animal resumes normal activity. The CTM value is changeable depending upon the past thermal history of the animal. For example an amphibian from Sahara desert may be having a higher CTM value than that of amphibian from a semi arid zone. This can be demonstrated in a laboratory. For example the *Hyla* species which was acclimated at 10°C showed a CTM value of 35.8°C, whereas the same *Hyla* species which was acclimated at 30°C, the CTM was 40.4°C. Thus the CTM value depends upon the previous thermal history.

13.5.1 Skin as Main Organ for Temperature Regulation in Amphibians

Czopek (1955) showed that in frog 97 glands per millimeter square are present in the skin. Whereas Bufo (toad) showed 8 glands per millimeter square. The secretory activity of the gland showed an increase with temperature. These glands keep the animal always moist and also help in the gaseous exchange. It may be noted that 70% of respiration is done by skin which has skin capillaries in the range of 700 per mm square. This was observed in the case of Hyla arborea. There are also lymphatic sacs which store water to cool the body at high temperature. Taenaka (1963) observed that the epithelium basal cells show an increase in the space volume from 1.3 microns at 9°C to 2.7 microns at 22°C.

3.5.2. Role of Calcium

In a layer between capilary and reticular layers of corneum, a muco polysaccharide and also calcium depositions were observed in many of the desert amphibians. The calcium has the absorbing capacity of water. The skin also has water absorbing capacity from atmosphere. Added to this the permeability of the skin is also more in the case of a toad than that of a frog.

Bufo has greater permeability with 36.6 mg/hr/cm square than that of the frog's skin which showed water permeability of 16.5 mg/hr/cm square.

3.5.3. Urinary Bladder

The size and capacity of the urinary bladder is generally big in arid species than others. For example the Australian Leptodactylus bladder weighed 50% of the body weight. This urinary bladder is of great advantage to the amphibians during aestivation.

During aestivation there is low metabolic activity and there is a low and slow absorption of water through the bladder for the rest of the body. During aestivation the concentration of the nitrogen wastes, urea and other metabolic wastes goes up in the amphibian blood. The urinary bladder responds to neurohypophysal hormones for water regulations. Kidney also plays its role wherein the renal tubules absorb water. During dehydration the osmotic concentrations of the urine will be very high.

13.6. REPTILES

Sun Basking

Many desert animals exhibit arboreal orientation. That is, they climb up to trees and expose themselves to the sun and orient their body to the rays of the sun. Some animals flatten their body against the sun rays or raise on their toes. The desert reptiles under cold conditions orient right angles to the sun rays. In the case of tortoises they tilt their body against the rocks with ventral surface exposing to sun rays. The lizard Dipsosaurus orients its body perpendicular to the rays of the sun. Another interesting example is that of *Phrynosoma* which shows body orientation for thermal regulation.

Contact with Substratum

Dipsosaurus and other lizards dig the sand and expose its body to cool temperature. Under high temperatures these lizards move from one place to other while exposing its body to the cool sand burrows.

Cardio-vascular Adjustments

Phrynosoma emerges out of burrow by exposing its head only. The neck and the head region get heated. The internal jugular vein and the external carotid artery exchange the heat and also the rest of the body gets the warm blood through the external jugular vein by a special vascular adjustment.

13.7. MAMMALS

Thermoregulation in Australian Desert Kangaroos

There are two species of Kangaroos which are adapted to Australian desert lizards but still maintain better thermoregulation. Red Kangaroo lives in open plain of desert whereas the Euro lives in the rocky area and seeks caves for shade. Example: Euro (*Macropus robustus*)

Red Kangaroo (*Megaleia rufa)*

i) The Red Kangaroo's fur has better solar reflectance capacity than that of the fur of

Euro. They have tested with the help of Solarimeter. The Red kangaroo shows 58% capacity towards solar radiation, whereas Euro shows only 38%.

ii) The Red kangaroo loses less water through panting and evaporative loss as compared to Euro.

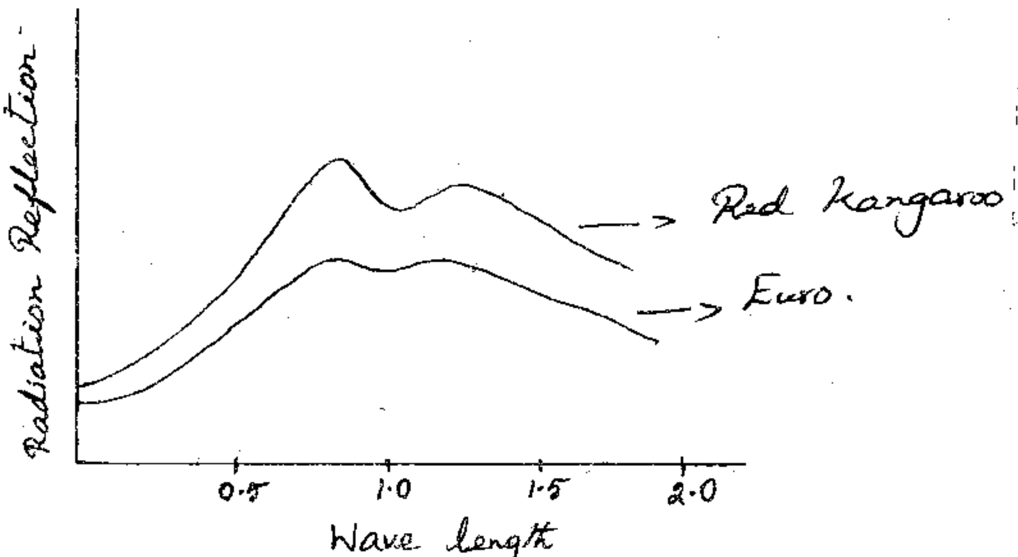

Fig. 13.1. Solar Reflectance capacity of Red Kangaroo and Euro.

13.7.1. Role of Adrenalin and Thyroid

The adrenalin seems to be an intermediary between the nervous system and the sweat glands. It is likely that in the desert animals, the adrenalin may be playing a dominant role in sweat gland activity which is responsible for evaporating cooling. In the sympathectomised animal, the adrenalin has no action at all. This shows that the sweat glands are under nervous control. But in the case of normal animals (without sympathectomy) the adrenalin acts on the sweat glands. This has given to the speculation for that adrenalin could be a transmitting substance. This is because the Acetylcholine, a neurotransmittor substance also activates sweat glands in horse. The sweat metabolites contained Ach.

In some animals the heat is generated by shivering of muscular processes which causes split of ATP in the muscle system by ATPase. This causes heat generation. This is also known as the shivering thermogenesity. In cold conditions, the desert mammal cannot adapt for such cold shivering mechanism. This is being superceeded by non-shivering thermogenesis by metabolic adaptation especially the role of thyroid.

The thyroid hormone, thyroxine and tri-iodothyroxin stimulates heat particularly useful in desert animals during arousal from hibernation or from cold burrial. The thyroid hormone splits the terminal high energy bond of ATP to ADP and Pi. This causes release of energy sufficient for maintenance of body temperature. This system is operative in calorigenic tissues, liver, muscle and kidney. Adiministration of thyroid activates ATPase system. Thyroid is mainly involved in heat production, either short term or long term exposure to cold. Exposure to heat has no significant effect on thyroxine release, whereas gluco-corticoides are produced during exposure to both cold and heat.

The other reason for the maintenance of low metabolic rate among the desert animals is the lower amounts of thyroid hormonecirculation in the blood. Experiments have shown that during hibernation low metabolic rate is associated with low amount of thyroid hormone.

13.7.2. Brown Adipose Tissue and Adptation to Cold Temperature

This tissue surrounds heart, brain and blood vessels. This is a biological furnace system and is useful in post natal life, cold acclimation and arousal from hibernation. During upstream of blood, the heat generated by brown adipose tissue is absorbed by blood which inturn warms up the tissues. The mitochondria of the tissue consists of the fat droplets which acts as a raw material for energy and heat generation through metabolic activity. In this tissue uncoupling of oxidative phosphorylation takes place which results in heat dissipation instead of phosphorylation.

Scheme of Thermoregulation

Thus the adaptation of animals to desert environment involves interaction of the nervous, endocrine,neurohaemoral and motar systems which synergetically bring action on cardio-vascular respiratory and other systems to balance the body temperature.

Hibernators

Some good example of hibernators are (i) Golden mantled ground squirrel, *Citellus lateralis* which cools temperature centre of brain, the preoptic anterior hypothalamus. These are regulatory centres. Another example is European Hamster, *M. marmota* produces the condition of respiratory acidosis which causes reduction in metabolic rate of enzyme. During arousal the acidosis is reversed.

13.7.3. Thermocutaneous Receptors and Thermoregulation in Cold and Heat

Mamals living in desert of arid environments are exposed to severe thermal stresses. The skin surface temperature is likely to be much above 40°C despite sweating which would normally cool the surface. It is found that in desert organisms particularly in the cattle, the surface temperature reaches 47°C. At such situations, the cutaneous receptors play a major role by (i) sensory physiology and (ii) thermoregulation. i.e., the receptors act as radar points and communicate to the nervous system for proper behaviour and also co-ordinate the target systems in the body for proper thermoregulation.

Four subsets of specific thermoregulators such as (i) cold receptor, (ii) warm receptor, (iii) hot and (iv) cool thermal noise receptors are identified. Of these the last two types of receptors area active at intense solar radiation whereas the first and second types are active at usual body temperature (25 to 35°C).

Functions of Cutaneous Thermoreceptors

1. To maintain the discharge of impulses at static skin temperature. The frequency of impulses is related to temperature change.
2. It shows a raise of frequency of discharge or decrease in the frequency of discharge when a change in the skin temperature occurs. For example the cold receptor increase frequency during a fall of temperature, whereas the reverse is the case for the warm receptor.
3. Intensitivity to non-thermal stimuli.

4. The skin shows small receptive feats. Each efferent fibre supplying only one or two spots of 1 mm square.

13.8. AQUATIC ECOSYSTEM AND TEMPERATURE

Till now we presented various adaptations of terrestrial animals to temperature. Now let us consider some important relationships between temperature and aquatic organisms. The specific heat of water is among the highest of all substances. This very great absorption capacity accounts for many features of the aquatic enironments. The water has the unique attribute of reaching its maximum density at 3.98°C rather than at freezing. These two characteristics will be important in consideration of thermal dynamics in waters.

13.8.1. Thermal stratification

Seasonal changes are highly marked in the lakes of temperature regions. The ice cover on the lake deteriorates in spring in a relatively slow progressive way. Loss of ice cover is rapid if associated with a wind current which is adequate to circulate the entire water column. As spring progresses, the surface waters are heated more rapidly and become less dense. Relative thermal resistance increases. From that point onwards, the water is divided into three regions of different temperature which are exceedingly resistant to mixing with each other. This is characterised by:

1. **Epilimnion:** Upper stratum of water more or less uniformly warm, circulating and mixed throughly by wind. Ranges from 2-20 m. It is a well lighted or trophogenic zone.
2. **Thermocline:** Stratum between epilimnion and hypolimnion; exhibits a marked thermal discontinuity and is termed as metalimnion or thermocline. It refers to the plane or "surface of maximum rate of decrease of temperature with respect to depth". The thickness of metalimnion may fluctuate with season, becoming thinner as summer progresses.
3. **Hypolimnion:** The cooler, denser, aphotic zone of the lake and the temperature is uniform.

13.8.2. Temperature Effect on Water Bodies (Temperate water bodies)

Spring: Following the ice melt, the surface water gradually warms to 4°C. At this point all the water is of uniform temperature and density (Fig.13.2). Hence the strong spring winds cause considerable stirring which results in complete mixing of water, dissolved oxygen and nutrients from the lake surface to the bottom, a phenomenon known as spring overturn. As spring progresses, the surface waters become warmer and lighter than the water at lower levels. As a result the lakes become thermally stratified. The upper stratum, which usually has the highest oxygen concentration and is characterised by a temperature gradient of than 1°C per meter of depth is the epilimnion. Middle layer of the lake typified by a temperature gradient of more than 1°C per meter is the thermocline. Bottom layer of water hypolimnion has less than 1°C per meter.

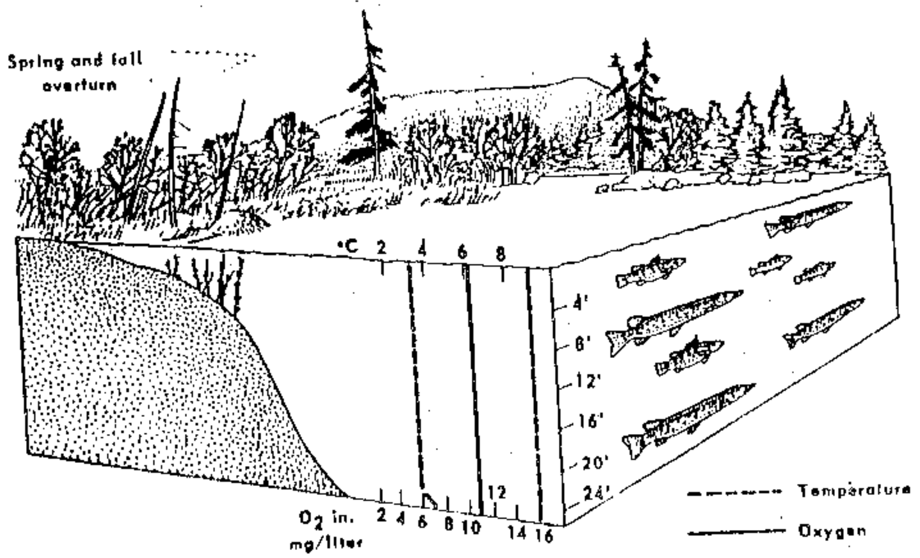

Fig.13.2. Spring and fall overturn in a lake ecosystem. Note that uniformity of temperature and oxygen distribution are expressed in disperal of fish through much of the lake from surface to bottom.

Summer: Unless the lake is exceedingly clear and permits phytoplanktonic photosynthesis, the hypolimnion frequently becomes depleted of oxygen in summer because of Biological Oxygen Demand (BOD) (fig. 13.3.)

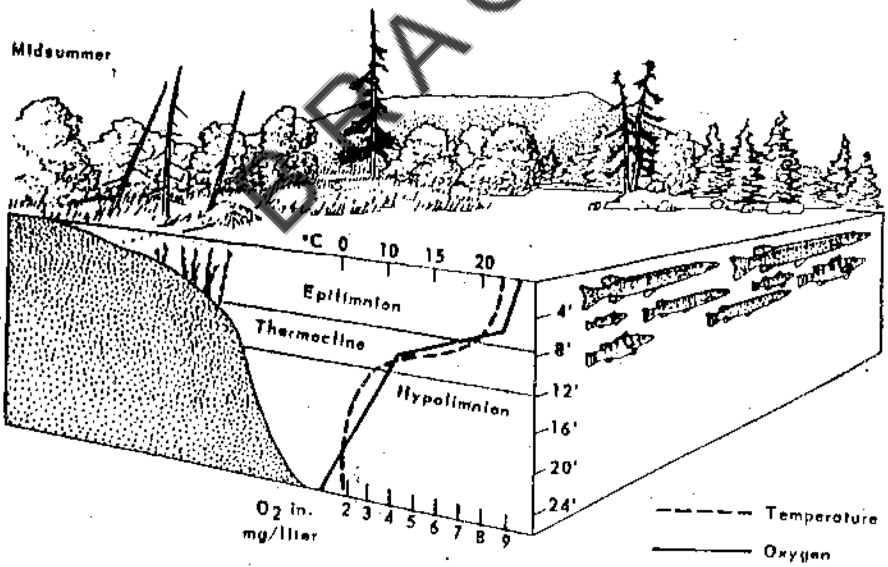

Fig. 13.3 Midsummer distribution of oxygen and temperature in a lake ecosystem. Note the stratification

Autumn: The surface waters gradually cool as a result of conduction, evaporation and convection. Eventually a point is reached where the lake attains temperature uniformity from top to bottom. So it becomes well mixed by wind and wave action and is known as "fall overturn".

Nutrients, dissolved oxygen and plankton becomes uniformly distributed.

Winter: As winter approaches, lake gets colder until the water attains a uniform temperature of 4°C. As the surface cools below 4°C it becomes lighter and eventually freezes at 0°C. The water at increasing depth is progressively warmer and more dense. Heaviest water has a temperature of 4°C showing inverted temperature stratification. The water remain relatively stable throughout the winter. Fish distribution and temperature effect is given in fig. 13.4.

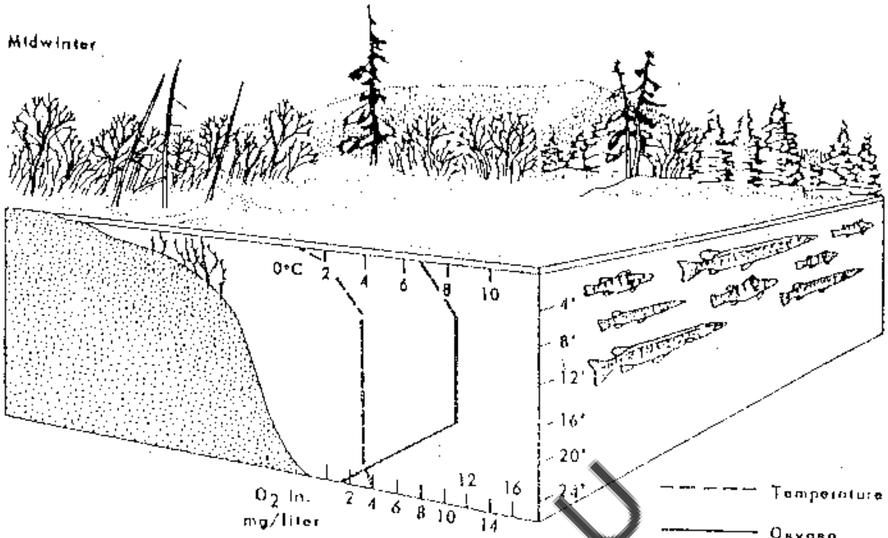

Fig. 13.4. Midwinter distribution of oxygen and temperature in a ecosystem. Note in influence on fish distribution.

13.8.3. Aquatic Animals and Temperature Regulation

Fishes

Lateral line system is important in regulating the temperature variations. Sensitive bulb is present in the ampullae of Elasmobranchs.

Behavioural Adaptations

1. Some fishes avoid thermal extremes by maintaining a constant body temperature.
2. Sharks operate specialised heat exchanges that are located in the heavy trunk musculature. They are of two kinds: Cutaneous or lateral retia (Blue tin tunals) and (b) Central or Hemal retia (Spik Jacks). They consume metabolic heat and maintain constant body temperature.
3. Swimming speed of fish is also increased.
4. Migration: Fishes choose mid or optimum temperature and move to that zone. These migrations though are mainly for breeding purpose, other migration is "over-wintering migration" to avoid the lower temperature.

Physiological Adaptations

1. In every cold environments several adjustments are known to prevent water crystallization which damage the cells. The tissues of some inter-tidal animals have been shown to tolerate considerable ice formation. Muscles have been found to survive at 20°C for several months in the Arctic region with about 75% of their body water frozen and their tissue fluids 4 times the normal concentration.

2. The damaging effects of low temperature can also be avoided by altering the freezing point. An increase in osmotic content of the body fluids will lower the freezing point and protect the organism from damage of ice formation.

3. Arctic and Antarctic fishes have significant resistance for freezing. *Trematomus* lives under the ice in Antarctica because its blood contains much glycoprotein. Glycoprotein has antifreeze capacity. Glycoproteins lower the freezing point more than would be expected solely on the basis of concentration.

4. Surface fishes that live in water at 5°C in summer and 1.5°C in winter, serum glucose increases and liver glycogen decreases during cold. Acclimatisation is more in winter than in summer.

5. Fishes make use of counter current heat exchange system. Generally active muscles maintain a uniformity in high temperture than the rest of the body.

6. Trout savelinus shows standard metabolism at the time of spawn and it is twice the level in March and April at late fall. This reflects temperature response.

7. Enzymes from Antarctic fish show much less capacity for acclimation than do corresponding enzyme from Tropical fish.

13.9. THERMAL POLLUTION

Thermal pollution may be defined as "the warming up of an aquatic ecosystem to the point where desirable organisms are adversely affected".

Some industries and virtually all electric power plants discharge heated waste water into aquatic systems. It is not hard to imagine some of the ways in which this heated effluent might adversely affect aquatic biota. In summer particularly in tropical climates, the water temperature already causes a chronic stress to some organisms. In such cases any further increase would crete lethal conditions for the organisms. The harmful effects are:

1. Reduction in dissolved oxygen
2. Interference with reproduction
3. Increase vulnerability to disease
4. Direct killing
5. Invasion of destructive organisms
6. Undesirable changes in Algal population; Food chain distortion.
7. Destruction of organisms in cooling water.

13.10. SOME ASPECTS OF TEMPERATURE AND ADAPTATIONS BY PLANTS

Morphological Adaptations

1. Root system generally very deep, extensive, reaching deeper layers of soil; several times larger than shoot, hard, woody.
2. Stem much dwarfed, branched, sometimes underground.
3. Leaves small, sometimes much reduced to scales or modified into spines, in some leathery and thick with shining surface and waxy coating, covered with hairs.

Anatomical Adaptations

1. Aerenchyma lacking
2. Cuticle, thick, well developed
3. Stomata less in number, generally confined to lower surfaces of leaves.
4. Palisade generally on both sides of leaves, cell and vacuoles small.
5. Chlorophyll mostly in stem and leaves.
6. Epidermal cells conspicuously thick-walled
7. Mechanical and vascular tissues very well developed.

Physiological Adaptations

Most of the features directed to reduce the transpiration rates; ephemerals complete life cycle in short period. High osmotic pressure and endurance of desiccation.

Check Your Progress - 2

The warming up of an aquatic ecosystem to the point where desirable organisms are adversely affected is called .

Note : (a) Write the answer in the space given below.

(b) Compare the answer with the one given at the end of this unit.

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13.11. SUMMARY

Based on responses of animals to ambient temperature the animals are classified into ectotherms and homiotherms. The animals show behavioural and physiological regulation. To know the temperature relationship, the study of desert animals would be very ideal. The desert animals show a number of behavioural adaptations like sun basking, contact with substratum, body orientation burrowing and biological rhythm. Animals also show physiological regulation wherein the kidney, skin, cloaca and urinary bladder play a major role. Hormones like adrenalin, thyroid & the thermocutaneous receptors also play a major role in the metabolism and other physiological aspects of animals. Temperature also affects water bodies and accordingly causes changes in physico-chemical factors. This turn affects distribution of aquatic animals. Thus terrestrial animals show relationship to ambient temperature. Aquatic animals also show both physiological and behavioural adaptations. Sudden changes in the aquatic environment is also caused due to thermal pollution affecting the organisms. Plants also show both morphological and anatomical adaptations to temperature.

These adaptations help the organisms to maintain the body temperature in the tolerable range for its survival.

13.12. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Homeotherms or endothermic animals are the warm blooded animals which tend to maintain a constant body temperature under most circumstances. Poikilotherms are the organisms having varying body temperatures and they have minimal capacities to regulate their body temperature physiologically.

2. Thermal pollution

13.13. MODEL EXAMINATION QUESTION

I. Answer the following questions in about 30 lines each.

1. Write an account on behaviorual aspects of regulation in desert amphibians.
2. Describe behavioural adaptations in desert reptiles.
3. Write a detailed account on stratification in a temperate lake.
4. Write an account on physiological adaptations in fishes.

II. Answer the following questions in about 10 lines each.

1. Write about Poikilotherms and Homeotherms
2. What are thermocutaneous receptors?
3. What are adaptations of plants to temperature?
4. Write a brief account on thermal pollution.

Prof. N.V Nanda Kumar

UNIT - 14 : RESPONSE TO CARBONDIOXIDE AND OXYGEN

Contents

14.1. OBJECTIVES

After going through this unit, you will be able to:

* explain the importance of oxygen and carbon dioxide as gaseous abiotic components of an ecosystem,
* describe the ability of animals to extract oxygen from various oxygen environments.
* list out and describe the factors that influence oxygen consumption of animsls,
* describe the biological significance, of carbon dioxide and phenomenon like hypercapnia and associated cybernetics.

14.2. INTRODUCTION

Lavoiser and Laplace (1780) stated that "life is a combustion". Combustion depends on the acquisition of oxygen, elimination of carbon dioxide and transport of these gases to and from the combustion sites in these tissues. Demands for oxygen vary widely among animals and with their state of activity. Thus the evolution of larger animals has been accompanied by the development of specialized system for extracting oxygen from and eliminating carbon dioxide to the environment. This exchange with environment by animals stands in a remarkable balance with botanical mass of the biosphere as plants utilize carbon dioxide yielding up oxygen which can then once again enter into animal metabolism.

Diverse means such as cell membrane, in unicellular and in metazoans gills, integument and lungs are employed for oxygen and carbon dioxide exchange. They all have in common, a large, well vascularized surface areas across which diffusion of these two gases occurs. This is not just sufficient to encounter the problem, for the site of combustion may be distant from respiratory exchange surfaces. This therefore necessitates the acquisition of specialized transport systems to move the gas to its destination. Thus, circulating systems under the control of delicate mechanisms that regulate local blood flows in balance with oxygen and other nutritive requirement of tissues. However as the solubility of oxygen is low in aqueous media especially oxygen holding capacity of plasma is very low, which is only a fraction of the oxygen circulated. Specialized pigments such as haemoglobin, haemoerythrin, haemocyanin etc. are acquired during evolution by animals. These pigments capture the bulk of oxygen at the respiratory exchange surface and deliver precious cargo at the tissue. These pigments, (heamoglobin) also enter into the transport of carbon dioxide on return trip to the respiratory surfaces.

Animals inhabiting different environments, have specific demands for oxygen as the oxygen in thse environments vary. Thus various environmental situations offer special respiratory problems. The solution of some of these problems will form the subject matter of this chapter. The oxygen content of the environment may be a limiting factor while other environmental variables such as carbon dioxide, temperature, altitude and salinity may impose demands for oxygen or affect, rate of exchange. The environmental restrictions in the availability of oxygen and some of the interrelated effects of the environments on metabolism and consequential responses of animals will be discussed here.

14.3. OXYGEN RESOURSES OF THE ENVIRONMENT

From the sea level to the topos of higher mountains, the earth's atmosphere has about 21 percent oxygen everywherre. But the exchanges of gas between the animal and its environment depends on concentration gradient and it is the actual number of oxygen molecules in any volume of gas rather than its volume which is important. Therefore pressure rather than volume is meaningful parameter for an air breather. Temperature is yet another factor of the environment which changes the volume of oxygen in a unit volume of air at any pressure. But this effect is of little physiological significance. However the solubility of atmospheric gases in water vary according to partial pressure, the solubility coefficient and temperature. Thus temperature affect the availability of oxygen in aquatic environment. The solubility of oxygen is also affected by the presence of dissolved salt and as a result in sea water dissolved oxygen is less than in the fresh waters. Here the importance of dissolved solids and the significance of temperature on the solubility of oxygen is great that a measure of partial pressure alone has little meaning to assess the availability of oxygen. The other important physical limitation on availability of dissolved oxygen to aquatic animals is the rate of diffusion. Diffusion of oxygen is much slower in water than in air and at times it cannot keep pace with its consumption thereby it becomes a limiting factor. Thus in aquatic environment, situations like anaerobic to super saturated oxygen media are often encountered. The former being characteristic of deep seas and latter in ponds where there is an active pohotosynthesis and in torrent at the base of water falls, where atmospoheric oxygen is carried deep enough to be dissolved in large amounts under the increased pressure. Under these circumstances the oxygen super saturation is sufficiently great to kill fish.

14.4. RESPONSES OF ANIMALS TO OXYGEN RICH AND OXYGEN DEFICIENT ENVIRONMENTS

In view of the above peculiarities seen with regards to the availability of oxygen in different media the extraction of oxygen from different media presents special problems and are resultant effect of physical characteristics of the environment. Hughes (1963) summarized the major contrasts of aquatic and aerial conditions :

Table 14.1 : Major contrasts between Aquatic and Aerial Conditions

	Condition	Aquatic	Air
1.	Viscosity of medium	100 times air	-
2.	Density of medium	1000 times air	-
3.	Diffusion rate of O_2	low	high
4.	O_2 content of medium on inspiration	Nct to 10mg/lit	100-130ml/lit
5.	CO_2 content of medium as expiration	low	100 ml/lit
6.	Ventilation	continuous	total
7.	% O_2 utilization for respiration	20	1-2

(Modified from *M.S. Gordan et al.*, Animal Physiology Principles and Adaptation, Macmillan Publishing Co., Inc. New York 1977).

14.4.1. Metabolism related to Environmental Oxygen

Evidences indicate that life commenced in oxygen less world but the animal evolution laid its foundation primarily on the adequacy of oxygen. Secondarily, however many animals have acquired the capacity for life with little or no oxygen. In few environments like bottom of water basin, certain soils and tissues of host for parasites, oxygen levels are continuously low and in others this condition develop occasionally or seasonally. Such animals lead the life of facultative anaerobes and switch to aerobic metabolism during oxygen availability. A few are obligate anaerobes which never require oxygen. Many animals resort to temporary anaerobiosis during short burst of muscular activity leading to oxygen debt, where the immediate demand for oxygen exceeds the rates of oxygen delivery at the site of activity. Metabolically, temporary anaerobiosis is different from sustained anaerobiosis. But the demarcation may not be sharp.

Here the minimum levels of metabolism are shown by lower horizontal line where oxygen requirements are at these lowest point. The environment which supplies this much oxygen in adequate is called incipient lethal level, but at any lower level a condition of anoxia may set in leading to the death. Such zone is called zone of resistance. The upper horizontal level indicates the active metabolic rate which occurs at incipient limiting level or Critical pressure (Pc) of Prosser (1973). At higher oxygen tensions most animals will maintain a steady independent rate until toxic levels develop. This is called respiratory independence or regation. In between zone, a resistance and respiratory independence, the metabolism or oxygen consumption depends on available oxygen and is known as respiratory dependence or conformity. The organism can tolerate the situation but operation of its machinery conforms to the oxygen supply. This in case of Poikilotherms is also modulated by ambient temperature.

14.4.2. Oxygen Demand Correlated Genetically Determined Life Habits

i. Species peculiarities in oxygen demand : The lethal and limiting levels are characteristic to animal species and are established during phylogeny due to varied oxygen level in those environments. In general, homeotherms have greater oxygen demand than poikilotherms. Compensation through acclimation and acclimatization may also alter the animal's critical oxygen demands. Such changes are due to enhanced ability to extract oxygen or due to changes in metabolic rate during acclimation. Such improvement is accomplished through improved gas transport due to changes in circulating respiratory pigments like haemoglobin and possibly adaptations in enzyme systems leading to improved oxygen supply where it is deficient. Such changes may be due to changed behavioural pattern. Compensation in metabolism through acclimatization is well documented in certain animals like fishes. Seasonal variations in poikilotherm oxygen consumption are also known to be caused by photoperiod.

ii. Adaptations to diving : Many air breathing animals survive long periods of submergence by virtue of auxiliary respiratory mechanisms, reduced oxidative requirements and changes in metabolic pattern. Pulmonate snails absorb significant amounts of oxygen by body surface, diving insects, may have plastron respiration by a maintained bubble or may have tracheal gills. Anurans under water can obtain 50% of their oxygen by cutaneous respiration when submerged and their O_2 consumption drops, the heart rate is slowed leading to bradycardia and some accumulate oxygen debt. When they emerge, the heart rate increases faster than the O_2 renewal and elimination of CO_2. Many fish exhibit bradycardia when removed from water and this is not caused by reduced O_2 as bradycardia does not follow transfer to hyperoxic water. Among birds and mammals some relax and slow the heart at submergence while others became excited, struggle and die. Maximum duration of dive for a few mammals is given below (Table 14.2).

Table 14.2. Maximum duration of dive for some mammals.

	Animal	Period of Dive
1.	Harber whale	15 minutes
2.	Sperm whale	1 1/2 Hours
3.	Fin back whale	1/2 Hour
4.	Man	2 1/2 minutes

In mammals the prolonged diving is made possible by interacting respiratory, circulatory and behavioural adaptations. Divers rate of O_2 consumption in air does not differ greatly from that of land mammals. But the tidal air in divers is significantly large, 80% in porpoise and 20% in men. The O_2 carrying capcity of haemoglobin in divers is higher than land mammals. Myoglobin is high in diving mammals thereby the oxygen store is enhanced. Metabolic variations are also significant in divers. Lactic acid does not accumulate in the blood to any great amount during the dive, which accumulates in the muscle from where circulation is virtually excluded. The circulation to the head is protected during dive while to the rest of the body is occluded. The occurrence of bradycardia in divers is not due to hypoxia. Divers are known to have high

BMR during winter. The sensitivity of respiratory centres in divers to CO_2 is larger than non-divers. Then diving ability based on factors like large tidal volume, oxygen storage, ability to tolerate oxygen debt, relative insensitivity of respiratory center to CO_2, lactic acid and shunted blood flow to selected areas during diving.

iii. Adaptation to high altitude : Reduction in partial pressure of gases is characteristic of environment at high altitudes. This would affect the percent saturation of oxygen. These in turn result in fall in respiration and cardiovascular function. The initial response would be hyperventilation. This result, in increase in alveolar pO_2 and decrease in alveolar pCO_2 resulting in alkalosis and upsetting acid base balance. Thus in high altitudes there is a physiological alkalosis. This results in cerebral vasoconstriction, where the initial vascular response results in increased cardiac output.

However in acclimatization, an increase in Haemoglobin content is noticed in high altitude. This would also bring about increased alveolar circulation, adjustment of acid-base balance, and adjustment of elevated cardiac output to normal. The curve relating to influence of CO_2 is shifted to left and slope is steeper. Hypoxic response however is lower than what is at sea level. The lung capacity is high and the hypertrophy of right ventricle is conspicuous. Biochemical changes are marked by increased oxidative enzymes and increased haemoglobin synthesis.

14.5. HYPEROXIA AND OXYGEN TOXICITY

14.5.1. Hyperoxia

Approximation of tissue pO_2 more closely to venous pO_2 than to arterial pO_2 results in rise in venous pO_2. Such increase is called hyperoxia and it is trivial, when breathing 100% oxygen at normal barometric pressure and it is necessary to breath oxygen at 3 A T A pressure before there is a large increase in venous and therefore tissue pO_2. Thus two degrees of hyperoxia are recognized. The first being inhalation of oxygen enriched gas at normal pressure while the second is inhalation of oxygen at raised pressure and is called hyperbaric oxygenation. In hyperoxia, at normal pressure, there is a prevention of arterial hypoxemia (anoxic anoxia). It also helps in bringing relief during air embolus and pneumothorax and intestinal distensions. It is also used as an antidote to carbon monoxide poisoning where the oxygen enrichment brings about increased rate of dissociation of Carboxyhaemoglobin. Hyperbaric oxygenation has many clinical application like antibacterial effect, would healing, improvement of micro circulation during treatment of burns, and in radio therapoy in tumour radiation and multiple sclerosis.

14.5.2. Oxygen Toxicity

Oxygen in ground state exists as di oxygen, and it is a powerful oxidizing agent. It is stable and has an indefinite half life. However the oxygen molecule can be transformed into a range of free radicals and other highly toxic substances. These would affect DNA, lipids and sulphydryl group containing proteins. All these are sensitive for ionizing radiation. However the living systems have evolved a powerful antioxidant defences like enzyme superoxide dismutase and catalase, free radical scavengers like tripeptide Gly-Cyst-Glu and glutathionine.

Check Your Progress - 1

What is oxygen toxicity ?

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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14.6. FACTORS AFFECTING OXYGEN CONSUMPTION

Rate of oxygen consumption is influenced by activity, temperature, body size, stage in life cycle, season, time of day and genetic background.

Activity : Activity is one of the intrinsic modifier of O_2 consumption and most difficult to control in muscular and other activity when standard and activity metabolisms are measured as a function of same environmental parameter. The differences between the two curves is the scope for activity. Activity and standard metabolisms involve some what different enzymatic pathways.

Temperature and Seasons : In general homeothermic animals have a range of minimal metabolism at neutral temperature and their O_2 consumption rises both when body temperature rises and in the cold. In most poikilotherms the metabolism fluctuates with body temperature by about two and half times per 10^{0} C in the physiological range. The net effect is to compensate for environmental changes with season and latitude.

Salinity : The O_2 content of fresh water animals is higher than that of marine species. Euryhaline species consume more O_2 in dilute media, while stenohaline consume less. Thus the metabolism is related to salinity and physiological ability.

Photoperiod and Rhythum : Many animals exhibit diurnal and lunar rhythms of O_2 consumption. Similarly photo period can also affect metabolism. This is more pronounced in aquate Difference in activities of enzymes of T C A cycles are recorded in nocturnal and diurna animals.

Hormones : Sexual distinction in O_2 consumption is recorded in animals. They are known to be mediated by hormones. Thus sinus gland of crustacean may regulate O_2 consumption indirectly. Removal of eye stalks in crustaceans increase O_2 consumption, while the injections of eye stalks that have endocrime glands, reduced O_2 consumption. Thyroid extract increases metabolism in amphibians but has no effect on fishes, however, tissue respirations in repitiles increases under thyroxine influence.

Development : Stages in development or life cycle may affect metabolism independent of body size. In general aged animals have less O_2 consumption than young ones but embryos have less O_2 requirement and however it increases with development. In holometabolous insects there is an increase in O_2 consumption in larval development but it drops in pupal stages.

Body Size : Size and volume have a definitive effect on O_2 consumption. The unit O_2 consumption, recorded as volume of O_2/g weight of animal as a funciton of size of the animals, the total is found to be more in larger animals. However, the metabolic rate is greater in smaller animals. Hence, O_2 consumption is expressed as a power function of body size. It is denoted by a formula $M=K^{wb}$ where K denotes standard O_2 consumption. Experimental evidences indicate that O_2 consumption is nearly proportional to cell-surface and size takes importance in multicellular organism. In these the enzyme quantities increase with increase in size. The difference of O_2 consumption in small animals and larger animals is due to disproportionate increase in low metabolic tissues like skeleton, fat and connective tissue. This is also due to variations in the content of oxidative enzymes and total mitochondria mass. The relation between size and metabolic rate is a complex allometric adaptation.

14.7. RESPONSES TO CARBON DIOXIDE

Carbon dioxide is a vital physiological constituent and acts in many different ways to modify oxygen demand of respiring living organisms. All living organisms are producers of CO_2 and as a consequence it forms a part of vast cycle of CO_2 production. It is produced in nature by animal metabolism and by the decomposition, fermentation, oxidation and combustion of organic matter. CO_2 is removed by green plants from the atmosphere from where it moves through the biosphere of the ecosystem involving many processes. Thus a cyclic movement of CO_2 exists in nature. Atmospohere and oceans constatly exchange CO_2. Thus there is a vast ocean reservoir which stabilizes the steady state of atmosopheric CO_2 concentration. CO_2 in the atmosphere is uniformly mixed by convection upto an altitude of 90 - 100 Kms and above this range CO_2 disassociates under the effect of solar UV radiation. Thus our atmosphere contains 0.0314% volume of CO_2. However, this volume may fluctuate in relation to time and place. Despite these fluctuations, CO_2 concentration remained relatively constant due to a natural balancing process of production and cycling through the biosphere.

CO_2 has many unique characters like bond length, solubility, fugacity, its distribution in the air and water and its ability to react with hydroxylic groups of water. These result in variations in characteristics of water. It is also a relatively stable compound. Its diffusion through memebranes of polymers is outstanding, thereby it forms an unique constituent of the ecosystem. It also plays an important role in physiological processes specially with body fluids as a regulator of pulmonary ventilation, as regulator of cerebral blood flow, as a component buffer defence system and as a substance for carbamate formation. Hence many biochemical reactions involving CO_2 occur in living systems.

14.8. BIOCHEMICAL REACTION OF CO_2

i. CO_2 combines with amino acids, free or amino groups of amino acids associated with peptides and proteins to form carbamino groups, the linkage resembles that of peptide bond.

ii. Biological oxidation leads to the formation of CO_2 which involves many cycles, mechanisms in association with a battery of enzymes.

iii. CO_2, although is a metabolic waste, it is involved in the production of/or synthesis of fatty acids, purines and pyrimidines. Such processes are called CO_2 fixation involving several biochemical pathways.

14.9. CO_2 AND BIOLOGICAL SIGNIFICANCE

Although CO_2 production is resultant effect of metabolic breakdown of organic products in biological systems, it performs many distinctive regulatory activities. It modifies the rate of ventilation by stimulating the centres of respiratory control. It alters the oxygen combining capacity of haemoglobin. It acts directly on vasomotor centres and thus influences the blood pressure. It is a signal for oxygen demand of tissues and is accomplished through modulation of pH of the body fluids. At very environmental levels, CO_2 becomes toxic through depressing action on nervous system. It is a useful anaesthetic of insects.

Under natural conditions, low oxygen is likely to become limiting long before CO_2 levels are elevated sufficiently to alter metabolism. The CO_2 tension in sea water is 0.25mmHg while in fresh water, it is about 5mmHg. Thus, there is no change in aquatic organisms' respiratory metabolism until it raises by a considerable degree. However, this depends on another ambient factor, the temperature. But under experimental conditions, it was noticed that the standard metabolic rate, although remained passive to CO_2 changes, the active metabolic rate declined exponentially with increase in CO_2 in ambient medium. It seems likely that the above responses are due to modified ventilation and affected transport systems. The transport pigments are also modified by CO_2. A fall in O_2 combining capacity in relation to CO_2 tension is a common feature. However, it is characteristic of the species examined. Thus, two types of situations are encountered by animals in relation to CO_2 concentration in the ambient medium. They are hypercapnia, where increased CO_2 pressure within a biological system and a situation opposite to the above. Thus animals are exposed to situations of CO_2 atmosphere of different degrees.

14.10. HYPERCAPNIA

Hypercapnia usually is associated with systems where there is a promotion of oxidation of organic matter. The CO_2 may accummulate at the bottoms of the wells, in caves, grottos, in burning buildings and in confined spaces after explosions. Miners encounter hypercapnia in improperly ventilated mines. Use of solid refrigerant creates another risk for hypercapnia. Hypercapnia is also encountered under conditions of hyperbaria or increased ambient pressure. This results due to synergistic effect of ambient pressure, one is the increase in partial pressure and the other being the expansion of the gas under pressure leading to alveolar hypoventilation resulting in retention of CO_2.

Effects of Hypercapnia

The first physiological response to hypercapnia is elevated respiratory rate driving to a situation of stimulation of cascade of reactions and consequential physiological aberrations. When pCO_2 of 76 torr occurs, it becomes intolerble, leading to difficulty in breathing and occasional occurrence of unconsciousness which may end in death. Experimental evidences have laid a limitation of 22.8 torr as upper limit and for prolonged exposures, 7.6 torr. Hypercapnia also affects the cardiovascular system acting directly on cerebral vasculature. It is the principal regulator of cerebral blood flow. During acute hypercapnia, hyperventilation occurs and this is accompanied by slow high amplitude waves as seen in electroencephalogram (EEG) and decrease in visual critical fusion frequency. Hypercapnia produces lactic acidiosis in the cerebrospinal fluid. Hypercapnia increases intracranial pressure, CO_2 produces local vasodilation in denervated areas. Acclimation to altitude involves adjustments to hypercapnia as well as hypoxemia.

The most toxic effects of hypercapnia are symptoms relating to the respiratory, cardiovascular and central nervous systems. Violent respiratory movements and convulsions are followed by unconsciousness. It often results in CO_2 necrosis. This results in lung failure. The CO_2 intoxication is associated with fall in body temperature. However, shivering is inhibited along with evaporative loss of water through hyperventilation. Acidiosis is the most prolonged effect of hypercapnia due to production of protons catalyzed by the reactions of carbonic anhydrase. Physical work becomes stress in CO_2 containing atmosphere.

Check Your Progress - 2 & 3

2. What is Hypercapnia?

3. Mention some important aspects of biological significance of CO_2.

Note : (a) Write the answers in the space provided below.

(b) Compare your answers with those given the end of this unit.

14.11. HOMEOSTATIC RESPONSES TO HYPERCAPNIA

A well established cybernetic system operates in animals to encounter hypercapnia. The cell buffers are the first line of defence in response to acute changes of pCO_2. This is to defend the physiological hydrogen ion concentration against stress of changing pCO_2, thereby changing the plasma bicarbonate ion concentration. The acid-bicarbonate buffer system of the body plays a key role in the neutralization of acidiosis. During hypercapnia, intracellular buffers release hydrogen ions (H^+) while chloride ions (Cl^-) and bicarbonate ions (HCO_3^-) exchange in opposite directions across the erythrocyte membranes. These reduce the extracellular bicarbonate ion concentration. The change in bicarbonate ion in relation to pCO_2 is curvilinear, while hydrogen ion is linear.

14.12. ACCLIMATIZATION TO HYPERCAPNIA

Chronic exposure to low concentrations of CO_2 results in certain responses that increase the tolerance of pCO_2. The ventilating response to CO_2 decreases with such exposures. The initial respiratory acidiosis is more rapidly compensated. The initial eupharia is followed by lassitude and impaired performance suggesting that subjects can moderately acclimatize to hypercapnia. The CO_2 acclimatization is an interplay of central and peripheral chemoreceptors.

14.13. SUMMARY

The exchange of O_2 between animal and its environment depends on concentration gradient and partial pressure. In aquatic media, dissolved O_2 content depends on diffusion, dissolved salts, salinity, temperature and pressure. Many animals resort to temporary anaerobiosis leading to oxygen debt due to demand for O_2 exceeding the rate of O_2 delivery. The environment that provides lowest adequate O_2 is called incipient lethal level. Land animals basing on O_2 availability get demarcated into zone of resistance and zone of independence. O_2 demand is correlated to genetically determined factors like species specificity, diving and life at high altitudes. O_2 which exists as dioxigen can form free radicals which would alter the configuration of DNA, proteins and lipids in the cell. However, cells have protectants in the form of antioxidants like Superoxide Dismutase and Glutathionine. O_2 consumption is also related to activity, temperature, seasons, salinity, hormones, stage of development and body size. The body size is denoted by a formula $M=K^{wb}$ in relation to O_2 consumption.

CO_2 is produced as a metabolic waste, if exhibits a cyclic movement through biosphere. CO_2 has a strong binding capacity with organic matter rich in amino groups. Hence it forms carbamates which are toxic and are also utilized in synthesis of many important metabolic products like purines and pyrimidines. CO_2 has a strong influence on respiring living system where it alters the functioning of lungs, the CNS and the heart. It is anaesthetic of insects. CO_2 concentration in blood brings about local acidiosis and its withdrawal results in local alkalosis. Increased CO_2 pressure in biological systems is hypercapnia whose antonym is hypocapnia. Hypercapnia has multiple effects and cellular cybernetic systems counter these effects. Chronic exposure to CO_2 concentrations lead to acclimatization with varied physiological modifications.

14.14. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Oxygen in ground state exists as di-oxygen and it is a powerful oxydizing agent. It is stable and has an indefinite half life. However, the oxygen molecule can be transformed into a range of free radicals and other highly toxic substances. They would affect DNA lipids and sulphydryl group containing proteins. All these are sensitive for ionizing radiation. However, the living systems have evolved a powerful antioxidant deferences.

2. Hypercapnia is a situation encountered by animals in relation to CO_2 concentration in the ambient medium. In Hypercapnia there is increased CO_2 pressure in a biological system, hence the animals are exposed to situations of CO_2 atmosphere of different degrees.

3. Although CO_2 production is resultant effects of metabolic breakdown of organic products in biological systems, it performs many distinctive regulatory control. It alters the oxygen combining capacity of haemoglobin through Bohr's and Root effect. It acts directly on Vasomotor centres and this influence the blood pressure. It is a signal for oxygen demand of tissues and is accomplished through modulations of pH of the body fluids. At very high environmental levels CO_2 becomes toxic through depressing action on nervous system. It is useful anaesthetic of insects.

14.15. MODEL EXAMINATION QUESTIONS

I. **Answer the following questions in about 30 lines each.**

1. How do animals subsist in O_2 deficient environment ?
2. Describe factors that alter the O_2 demand of animals.
3. Give an account of hypercapnia and mention how animals overcome excess pCO_2.
4. Define acclimatization and discuss it with reference to life at high altitudes and hypercapnia.

II. **Answer the following questions in about 10 lines each.**

1. Describe oxygen resources of the environment.
2. Give an account of the responses of animals to O_2 rich and deficient atmospheres.
3. What are biochemical reactions associated with CO_2. ?
4. Discuss O_2 debt.
5. Describe the protection exhibited by animals against the effect of hyperoximea.
6. Define hypercapnia and discuss its biological significance.

Prof. P. Uma Maheshwar Reddy

BLOCK - 4

ENVIRONMENTAL TOXICOLOGY

UNIT - 15 : BIOLOGICAL EFFECTS OF POLLUTANTS

Contents

15.1. OBJECTIVES

By the end of this unit, you will be able to:

* classify the pollutants of the ecosystem,
* list out various principle toxic pollutants,
* describe different toxicological considerations,
* explain the effect of toxic pollutants on various organ systems of the human body.

15.2. INTRODUCTION

Great studies made in recent years in the field of increased production and use of man made substances and their persistence in the environment have led to growing concern about their effects on non-target organisms and human beings. The increasing number of foreign chemicals also known as xenobiotics including drugs, pesticides, environmental pollutants, industrial chemicals and food additives with which human race is confronted, needs more attention particularly concerning their saftey. These compounds gain access into the body of the organisms and human beings through food chains and food webs. The mechanism of bio-accumulation of certain pesticides in the soil,water, fatty tissues of animals and plants increases the pestic load on the fragile environment. These residues are highly toxic and can persists in the environment for over 20 years causing irreversible gene mutation and series of implications of life on earth. The interaction of this foreign compounds with a biological system is two fold: i.e., there is the effect of organism on the compound and the effect of compound on the organism.

The first of these include absorption, distribution, metabolism and excretion of xenobiotics which have biochemical basis. The second category of interaction includes the mode of action of toxic compounds, in the interaction with cellular components and at the molecular level with structural proteins and other micro molecules, enzymes and receptors and the type of toxic response the toxicants produced. However, the biological system is a dynamic one and therefore series of events may follow the initial response. For instance, a toxic compound may cause liver or kindney damage and there by limit its own metabolism or excretion.

Many of the pollutants act as potential mutagens, carcinogens, teratogens, neuro and hepato toxicants. The domestic, industrial and agricultural uses produce large quantities of waste products and water wastes provide a cheap and effective way of disposing of many of these products. Thus, almost all Indian environmental components are being loaded with toxic pollutants. All these human activities disturb the eco balance by deteriorating the environmental conditions suitable to sustain life.

15.3. CLASSIFICATION OF POLLUTANTS

Odum (1971) has divided the pollutants into two basic types from an ecosystem point of view as follows:

(i). Non biodegradable pollutants

(ii) Biodegradable pollutants

The non-biodegradable pollutants are the materials and poisons like alluminium cans, mercuric salts, long chain phenolic chemicals and pesticides. These are having the following properties:

* Either do not degrade or degrade very slowly in the ecosystem in natural conditions
* Not recycled in the natural environment.
* Not only accumulate but are often "biologically magnified" with their subsequent movement in biogeochemical cycles and along the food chains.
* They frequently combine with other compounds in the environment to produce additional toxic substances.

The biodegradable pollutants are:

* Domestic sewages - that can be rapidly decomposed under natural processes are in engineered systems.

Check Your Progress - 1

What are the non-biodegradable pollutants?

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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15.4. TYPES OF TOXIC POLLUTANTS

The various principal toxic pollutants are:

* Metals - such as lead, nickel, cadmium, zinc and mercury - arising from many industrial processes and some agricultural uses.

* Organic pollutants - such as organo chlorine pesticides, herbicides, polychlorimated, biphenols (PCBS), chlorinated aliphatic hydrocarbons, solvents, petroleum hydro carbons, polynuclear aromatics, chlorinated dibenzodiorins, organo metallic compounds, phenols, formaldehyde - These originate from a wide variety of industrial, agricultural and some domestic sources.

* Agricultural pollutants - pesticides, herbicides, fungicides and fertilizers are included in this category.

* Gaseous pollutants - such as oxides of nitrogen (nitric oxide (NO); nitrogen dioxide (CNO_2), sulphur dioxide (SO_2); hydrogen sulphide (H_2S); carbonmonoxide (CO); halogens (chlorine, bromine, iodine) and ammonia.

* Anions-such as cyanides, fluorides, sulphides and sluphites.

* Acids and alkalies.

It is generally considered that metals and pesticides head the list of environmental hazard (Kotre, 1976). Environmental pollution by heavy metals become widely recognized with Minamata disorder in Japan when, several thousand people suffered mercury poison from eating fish caught in Minamata bay, which is receiving mercury released from Vinyl chloride plant. (Smith and Smith, 1975). The toxic metallic compounds are continually released into the environment from natural processes such as volcanic activity and weathering of rocks. Industrial processes have also greatly increased the mobilization of many metals in the environment.

An other major cause of environmental hazard is the indiscriminate usage of pesticides. India is equal to the advanced countries in cash crops and intensive cultivation with regard to use of pesticides (Bami, 1989). The total production of pesticide in India during 1994-1995 was estimated around 100 thousand metric tonnes and consumption is over 80 thousand metric tonnes both in agriculture and public health (Dhaliwal, et.al, 1993). As India continues to be a predominantly agricultural country, the consumption of pesticides is bound to go up in the years to come.

Besides manufacture of millions of tonnes of pesticides many toxic intermediary produces and effluents are thus being discharged regularly into the atmosphere, water and soil, thereby altering the eco environmental profile of vast areas. The other non-target animals and the human population are also bound to be exposed to such pollutants and toxicants.

15.5. TOXICOLOGICAL CONSIDERATIONS

The concept of toxicity is an important one, it involves a damaging, noxious or deleterious effect on a living system which may or may not be irreversible. The toxic response may be a transient biochemical or pharmacological change or a permanent pathological lesion. The extent of injury produced by a compound will depend on several factors such as physical state, concentration and duration of exposure.

A hypothetical substance of extreme hazard would be the following properties:

* Rapidly absorbed by inhalation, skin contact or ingestion.
* Slowly metabolised and/or slowly excreted, thus resluting in accumulation in the body
* Capable of rapidly causing irreversible effects or death.

Alderidice (1967) has distinguished two general categories of toxic effects.

* Acute toxic effects
* Chronic (sub-acute) toxic effects.

15.5.1. Acute Toxic Effect

Hunter and smeets, 1977 have defined the acute toxicity as "the total adverse effects produced by a toxicant when administered as a single dose". The acute toxic responses are usually readily quantifiable. The most dramatic manifestations of acute toxicity is death.

The statistical analysis of the toxicity data allows the calculation of Median lethal dose are LD_{50} that is the ability of a chemical substance, which would kill half of the animals in a test group if administered once only. The smaller is the required dose the greater is the acute toxicity of the substance.

The term then calculated is the LC_{50} which is similar concept to the LD_{50}. It is the concentration in the air are water surrounding experimental animals, which causes 50% mortality. It is convenient index for studying vapours inhaled by mammals or water soluble pesticides in contact with fish. Related terms are ED_{50} and EC_{50}, i.e., 50% effective dose and 50% effective concentration are applicable when some criterion of toxicity other than death is adopted. The I_{50} is similarly the concentration which inhibits by 50% an invitro enzyme system.

When the data are plotted, the usual form is a sigmoid curve, as shown in figure 15.1. The curve is steepest in the region of 50% response. The dose which kills half of organisms is thus a more sensitive index of toxicology than any other dose, and this is why the LD_{50} is usually adopted as a standard for comparing the relative toxicity of substances.

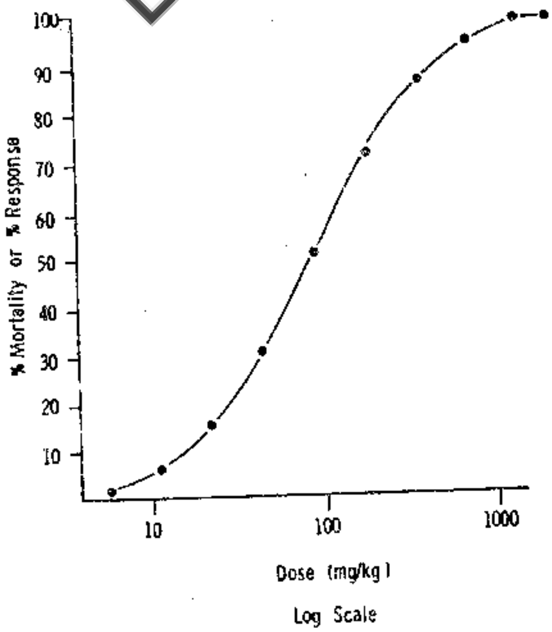

Fig. 15.1. Sigmoid Curve.

Check Your Progress - 2

Define lethal dose or LD_{50} and explain how it can be determined.

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

15.5.2. Chronic Toxic Effect

In environmental situations most of the problems are cuased by the reponse of organism to concentrations of toxic substances which are harmful only after long periods of continuous exposure - i.e., the chronic effect occurs when an organism is exposed to repeated small and non-lethal doses of potentially harmful substances.

By analogy with a definition of acute toxicity, chronic toxicity may be defined as "total adverse effects produced by toxicants when administered continuously over a long period of time".

Repetitive intake of small quantities of highly stable and lipid-soluble substances result in indefinite linear accumulation with time. A nearly constant internal level is eventually reached when an organism is exposed to a constant small daily intake. Various mechanisms which lead to detoxification establish a steady state between uptake and elimination. It is not unusual for the presence of a poison to stimulate detoxifying systems and thus to accelerate the rate of its own decomposition or elimination. When this occurs, the internal level may actually fall after a certain period of time, eventhough the daily intake remaining unchanged.

Check Your Progress - 3

Define chronic toxicity.

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

15.5.3. Mixture of Poisons

Industrial pollutants, the major group of toxic pollutants are the mixture of different types of chemicals may exert chemical interaction or joint action. In a joint action the toxicity of one group of compound may be antagonised or potentiated, when they are in combination with various drugs, insecticides or other chemicals. Since many interactions are biphasic in nature either antagonism or synergism may be observed. The word "synergism" was first described by Bliss to characterise mixtures which were more potent than would be predicted from their action separately. "Antagonism" (as suggested by Finney) described the opposite effect. Fig 15.2. show the mixture of poisons in relation to increased or decreased potency.

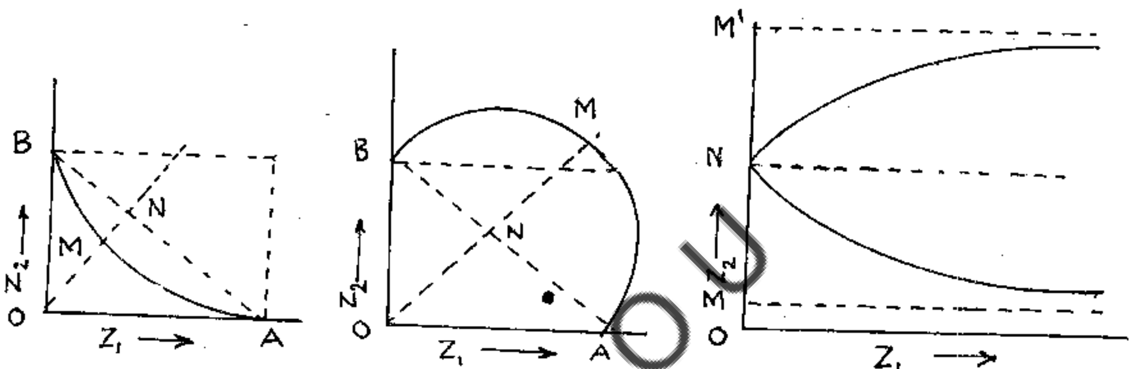

Fig. 15.2. Statistical Relationships. Left and Centre, for a pair of poisons each separately active. The line AB represents additive action. The joint action ratio R=ON/OM. In the left diagram the posions exhibit potentiation; in the centre diagram they exhibit antagonism. Right, for a poison and a synergist. The isoboles are asymptotic to lines parallel to the line for additive action. The joint action ratio is ON/OM for synergism and ON/OM' for antagonism.

15.5.4. Teratogenic, Carcinogenic and Mutagenic Effects

Teratogenic, carcinogenic and mutogenic effects must be given special attention. Teratogenic effects are those which cause malformation of the embryo. Teratogenesis involves interference with the normal development of either the embryo or the foetus in uterus, giving rise to abnormalities in the neonate. The teratogenic agents may be drugs taken during pregnancy, radiation, both ionizing and nonionizing, environmental pollutants, chemical hazards in the work place, dietary deficiencies and natural contaminants. Although the mutations occuring in germ cells may give rise to abnormalities in the neonite, such as Down's syndrome. Teratogenecity is normally confined to the effect of foreign agents on somatic cells within either the developing embryo or foetus and the consequent effects on that individual, rather than inherent defects.

Carcinogenic effects are those which cause cancer, which may be defined as a disordered growth of cells which can invade and destroy tissues. The characteristic symptom is the formation of cell masses called tumours. Tumours which cause cancer are said to be malignant and those which do not are said to be benign.

It has been established that a high proportion of human cancers are attributable to environmental agents, mainly environmental chemicals. The distribution of potential carcinogens in the environment is ubiquitous. Water sources may contain carbon tetrachloride and other chlorinated compounds or metallic salts, that may be potentially carcinogenic.

Laboratory and industrial solvents such as benzene and carbon etrachloride may also be carcinogenic. Nitroso compounds may represent another important type of potential carcinogens.

Mutagenic effects are those which cause chromosome alterations and thus alter genetic characteristics of cells. Toxicants which are mutagenic frequently exert teratogenic and carcinogenic effects in consequence. In Mutagenecity the structure of deoxyribonucleic acid (DNA) in chromosomes alters and cause a potential genetic aberration or mutation.

Check Your Progress - 4

What is teratogenesis

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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15.6. EFFECTS OF POLLUTANTS ON BIOLOGICAL SYSTEMS

Although many organ systems are effected by the actions of toxic pollutants, the central nervous system, liver and kidney are organs most commonly associated with the tissue damage from toxic compounds.

15.6.1. Neurotoxicity

Of all the systems in the body of animals the nervous system is the most sensitive one. Even the slight damage to this system results in the appearance of signs or symptoms which are characteristic and easily identifiable. The role of the central nervous system in cognitive and emotive processes is recognised by both scientists and laymen. Neurotoxicology is concerned with adverse effects of chemical agents on the nervous system.

The central nervous system is obviously a highly complex network of specialised cells and destruction of sections of this system may have prolonged effects on the function of the organism which will probably be permanent as nerve cells do not regenerate. The cells of the nervous system are particularly sensitive to changes in their environment which may be caused by toxic compounds. Anoxia, restriction of blood flow, lack of glucose and other essential metabolites and inhibition of intermediary metabolism may also cause damage to nerve cells and direct damage may be caused by cytotoxic agents. The toxic effect of some compounds also lead to the development of peripheral neuropathy. Some of the cholinesterase inhibitors are particularly active in this respect and so is methyl mercury which is famous because of its association with Minimata disease in Japanese people living around Minimata, discussed earlier in this chapter.

Among the pollutants the pesticides are known as effective neurotoxins. A major portion of the modern synthetic insecticides viz. the organophosphate compounds and carbomates, have the ability to inhibit the Acetylcholinesterase (Achase) activity. This inhibition of Achase is the cause for the development of nervous symptoms. As the result of the inhibition of the activity of enzyme Achase by organophosphate compounds there is an accumulation of acetylcholine in the cholenergic synapses. This is brought about by the property of the OP compounds to mimic the gross molecular shape of the natural substrate of cholenesterase, acetylcholine. Normally Ach combines with the enzyme cholenesterase (Chease) by the process of acylation whereas the OP compounds combines with Che by phophorylation. During the process of enzyme recovery the process of deacylation from the enzyme occurs very rapidly but recovery of enzyme by dephosphorylation taken place at an extremely slow pace. Therefore, most of the enzyme remains bound to OP compounds and is not easily recovered. This in turn results in excess accumulation of Ach, which causes the neurotoxic effect.

Compounds Causing Neurotoxicity (neurotoxins)

Neurotoxins are polypeptides that contain 61-74 aminoacid residues. Neurotoxins show no effect on the central nervous system, but rather act as neuromuscular blocking agents by reducing end-plate depolarisation by acetylcholine. Neurotoxic effects are additive to curare and are antagonised by anticholinesterase agents.Neurotoxins are lethal because they have the ability to cause respiratory failure.

Some of the possible central nervous system toxicants are :

* The animal products
* Microbial and fungal toxins
* Plant products

The animal products are most often associated with human health are :

* snake venoms for e.g., Cobra neurotoxin, crotoxin from tropical rattle snakes and
* venoms from other reptiles such as Gilamonster.

Microbial and Fungal Toxins

This group of toxins includes those of bacterial and fungal origin. An important group of bacterial toxins are proteins produced by numerous species of the genus *Clostridium*. This bacterium produces a protein of 70,000 Daltons called "tetanospasmin" which moved into the nerve cells until it binds or is fixed to ganglisides in the nervecord. There it blocks inhibitory synaptic input on spinal motor neurons, resulting in paralysis.

There are many neurotoxins that are constituents of various fungal species. For e.g., ergot fungus alkaloids, the *Amanita* species of mushrooms which have delayed cerebrotoxicity.

Plant Products

The plant extract that has effected the greatest number of people and has also been an important biochemical tool is "morphine" an alkaloid of *Opium poppy*.

The most successful botanical product has been pyrethrin, a mixture of natural esters extracted from chrysanthimum flowers grown principally in Kenya. This insecticide, particularly effective against flies, mosquitoes, stored grain insects, aphids and many other household pests, was introduced in the United States in about 1885 by C.V. Riley. It is a contact nerve poison giving extremely quick knock down effect and having minimum toxicity to mammals and human race. Consequently, it has proved very useful as household spray (Hodgson and Kuhr. 1990)

Check Your Progress - 5

Write brief note on Neurotoxins?

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

15.6.2. Hepatotoxicity

Humanbeings, in their living and working environment, ingests, inhales and absorbs many chemicals that can import stress either subtle or obvious, on numerous biochemical mechanisms. The liver, being the primary site for biotransformation of foreign compounds, is particularly vulnerable to those chemical assaults. Activation of xenobiotics to highly reactive intermediates occurs to such an extent that many of those chemicals are transformed to hepatotoxins and as such are involved in the etiology and pathogenesis of a liver disorders both carcinogenic and non-carcinogenic.

Carcinogenic disorders

* Liver necrosis
* Faulty liver
* Cholestasis
* Cirrhosis

Liver Necrosis - Tissue Lesions

Liver necrosis may be defined as the death of the hepatocytes. The underlying biochemical lesions is the inhibition of one or more essential metabolic processes in the hepatocytes, such as:

* Severe inhibition of RNA and DNA.

* Inhibition of protein synthesis resulting from neural and endoplasmic reticulum damage.
* Disruption of mitochondrial energy generation and control.
* Damage to lysosomes causing autolysis
* Depletion of ATP and uridine 5 - triphosphate
* Drastic shifts in the Na^+ and K^+ balance between hepaatocytes and blood.

Any of these events may contribute to cell death.

Liver necrosis is an advanced and usually irreversible stage of degeneration and is characterised by the presence of cell fragments or dead hepatocytes without nuclear staining. The type of liver injury produced depends on the particular toxic substance and its mode of action. Certain compounds cause periportal necrosis whereas many produced centrilobular necrosis. The degree of liver damage depends on the dose, ranging from single cell necrosis in the centrilobular region to massive necrosis throughout the liver.

For instance, low doses of carbon tetrachloride which has caused major toxic effect on liver cause only faulty liver and destruction of hepatic cytochrome P-450, which is the maximum in the region near to the central vein. However, chronic administration or exposure leads to liver cirrhosis, in some instances liver cancer and also kidney damage.

Paracetamol is a widely used analgestic and antipyretic drug which has remarkably little toxicity when taken at prescribed therapeutic doses. Overdoses of this drug (increasingly common in suicide attempts) it causes a centrilobular hepatic necrosis and in some cases renal damage.

Faulty Liver

A faulty liver is defined biochemically by liquid content greater than 5% by weight and histochemically by the presence of an excess of stainable fat. The accumulation of triglycerides in faulty liver is a common hepatic response to toxic compounds. Faulty infiltration in the liver is a common pathological conditon resulting from distrupted lipid metabolism. Many xenobiotics, nutritional imbalances and some diseases cause such abnormal accumulation of fat. For e.g., ethionine is a hepatotoxic analogue of the aminoacid methionine. After acute doses ethonine causes faulty liver but prolonged administration results in liver cirrhosis and hepatic carcinoma.

Toxic substances may act directly upon hepatocytes either as the parent compound or a toxic metabolite or they may act upon a hepatic process such as bile secretion. For instance acute doses of napthylisothiocyanate educe biliary flow and cause a cholestatic type of liver damage. It is thought that bile salts retained as a result of the bile stasis and hyper bilirubinaemia contribute to the hepatic damage. An alternative mechanism of hepato toxicity may involve immune response. For instance, one of the mechanisms proposed for the hepato toxicity of the anesthetic holothane involves alterations of the hepatocyte membrane by a covalent interaction with a reactive metabolite of the drug. The altered self surface which results is antigenic and stimulates all the sub-cellular organ cells. Example of this class include carbon tetrachloride, chlorinated hydrocarbons and some metals. They all cause necrosis usually accompanied by cholestasis.

Compounds Causing Liver Damage

A wide range of naturally occurring and synthetic chemicals are known to be hepatotoxicants. Based on the mechanism of injury, hepatotoxicants have been classified either as intrinsic or host idiosyncratic.

The type of injury inflicted by agents of either group may be either cytotoxic (leading to necrosis) or cholestatic (producing faulty liver) or mixed. Intrinsic toxicants may be subdivided into direct and indirect classes. The direct toxicants are cytotoxic agents that damage other organs besides the liver. In the liver, their attack tends to involve pesticides and other agents have been implicated in hepatotoxicity. Several therapeutic agents used as anaesthetics, tranquilizers, antidepressants, anticonvulsants, antimicrobial agents or antituberculosis drugs as well as some drugs prescribed in cardio vascular, nervous, endocrine, rheumatic and neoplastic diseases have been found to have hepatotoxic potential.

Some plant species yielding hepatotoxins include, *Lantana camera, Sassafras albidum* and more than 200 species of crotalaria.

In addition to these, several industrial solvents and raw materials, organophosphorus production of an antibody which renders liver cells susceptable to attack by cytotoxic lymphocytes, thereby destroy the hepatocytes.

Check Your Progress - 6

What is the common hepatic response to toxic compounds?

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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15.6.3. Renal Toxicity

The blood passing through the kidney represents 20-25% of the cardiac output and the function of the kidney is to filter out of this blood waste products and toxins. The kidney is a complex arrangement of vascular endothelial cells and tubular epithelial cells, the blood vessels and tubules being intertwined. The functional unit of the kidney is the "nephron" which passes from the cortex to the medulla.

The environment inside and outside of the nephron varies along its length and this influences the type of toxic effect produced by nephrotoxic agents.

The kidney has a marked ability to compensate for tissue damage and loss and consequently unless it is evaluated immediately a nephrotoxic effect may not be recognised. Similarly, chronic nephrotoxicity may not be recognised because of this compensatory ability.

It is clear that the tissues of the kidney are often exposed to higher concentrations of potentially toxic compounds from most other tissues. In many casses the metabolites are less toxic and more polar and water soluble than the parent compound, and the higher concentrations in the kidney do not result in toxicity. If the metabolite exerted is more toxic, the kidney is in a particularly vulnerable position.

The pH of the lumen tends towards acidity, this may cause, hydrolysis of metabolites or changes in the solubility. For e.g., some of the early sulphnamides, which were given in high doses, were found to cause renal tubule necrosis. In some cases this was due to crystalisation of the less soluble acetylated metabolites in the lumen of the tubule with consequent irritation of the surrounding cells and eventual necrosis. Some disorders associated with the renal failure are discussed in Table 15.1.

Table 15.1. Renal disorders associated with renal failure.

Agent	Effects Observed
Lead	Interstitial nephritis
Cadmium	Tubular Proteinuria (low MW Proteins) renal stones.
Mercury	Nephrotic Syndrome; Glomerulo nephritis; Proteinuria
Beryllium	Renal stones Hyper calciuria
Silica	Immune - Mediated glomerulo nephritis; Interstitial nephritis.

15.7. GENETIC TOXICOLOGY

The unit of heredity is gene, a stretch of DNA with a specific function. Usually, this function is to produce a protein or protein component. Any substance which affects the function of the gene is genotoxin.

The genetic poison acts upon the gametogenic cells of the gonad to decrease the number of gametes produced or to alter deleteriously the genetic information of gemetes. It is now generally recognised that many factors in our environment are potential causes of cancer and mutation. These include a broad spectrum of chemicals both naturally occurring and synthetic, present in the air, water, food and our environment. A number of food additives, pesticides, insecticides and other industrial chemicals exhibited carcinogenic activity.

15.7.1. Genotoxic Agents

Two major categories of genotoxic agents that humans can be substantially exposed to are :

* the halogenated hydrocarbons
* alkylating agents

There has been serious concern over the environmental and toxicological effects of halogenated hydrocarbons, primarily the organo chlorine pesticides and related derivatives, many of which are tumourogenic.e.g., DDT, heptachlor, endrin.

Other suspected genotoxins included chlorinated alkanes and alkenes, numerous members which have extensive utility as solvents, fumigants, aerosol propellants, de-greasing agents, dry cleaning fluids, refrigerants, flame-retardants, synthetic food additives, cutting fluids, the intermediates in the production of textiles and plastics.

Automobiles and diesel exhaust, coal fired power plants, cigaratte smoke, carbon block and xerographic toners are the major sources for release of trace amounts of Nitropyrenes and Nitropolycyclic aromatic hydrocarbons into the environment. Mono and dinitropyrenes are usually potent frameshift mutagens. Several nitrated polycyclic aromatic hydrocarbons have been reported to cause cellular transformation.

The use of PCBs, PCP, Phenol, 2,4,5-T and hexachlorophene in industry agriculture and forestry have been the cause of considerable concern as these chemicals and related compounds have been found to contain trace levels of highly toxic dibenzo furans and polychlorinated dibenzo-p-dioxins.

Role of Diet in Gene Poisoning

The Diet is an important factor in the etiology of certain human cancers. There are five possible ways whereby diet may affect the incidence of cancer :

(i) ingestion of powerful, direct acting carcinogens or their precursors;

(ii) affecting the formation of carcinogens in the body;

(iii) affecting activation and transport of carcinogens;

(iv) affecting "promotion" of cells; and

(v) over nutrition.

The mutagens are formed in the charred parts of boiled meat and fish. Mutagens have been found present in the basic fraction of cooked beef extract. Mutagens have also been obtained from lysine, soyabean globuline and boiled sordine.

15.7.2. Implications for Human Health

The major classes of mutational changes are :

(i) gene mutations;

(ii) alteration in chromosome number and structure.

These genetic alterations have implications for human health and disease.

Gene Mutation

Heriditary material or gene formed of DNA is the most stable chemical molecule of the biological world. It contains heriditary information coded in a specific sequence of four nitrogenous bases - Adenine, Guanine, Cytocine and Thymin. Its coded information can be duplicated and transmitted during heridity and transcribed and translated during development and during the completion of various physiological activities of the body. Thus the stability of heriditary material depends on the accuracy with which the base sequence is conserved and copied. slightest inaccuracy at any one of these levels introduces changes in the arrangement of nucleotides in the polynucleotide pair in the DNA molelcule. This may change the reading of genetic code and ultimately may be manifested into an altered genotype. For example : Sickle cell trait in human beings.

Chromosomal Damage

The maintenance and replication of the genetic materials of a cell are active processes that can be disturbed by alterations in their intimate environment. Any toxicant presented to cultured cells in near lethal concentration many damage their chromosomes. Under these conditions many different types of compounds have been able to break chromosomes.

Relatively few agents are effective *in vivo* and at low concentrations. These agents include analogs of DNA components and antibiotics that inhibit DNA synthesis, but the most potent are: 1) Alkylating agents, 2) Radiation exposure.

Alkylating Agents : The alkylating agents induced deletions, inversions, and translocation. These terms refer to loss of a chromosome segment (deletion), reversal of a segment (inversion) and the shifting of a segment from its normal position (translocation). The segment may be translocated in the same chromosome or it may become attached to a nonhomologous chromosome. For e.g., Ethyl Methane - Sulphonate(EMS), Methyl Methane Sulphonate(MMS), Nitrogen mustar,Ethyleneamines and others act perfectly after intraperitonial injections.

The consequences of these aberrations are several :

* Loss of chromosomal material results in a deficient genome, which is usually lethal, possibly when heterozygous and invariably when homozygous.
* Inversions and translocations lead to pairing difficulties in meiotic prophase. This inturn may suppress crossing over and the cell lethality can result from crossing over within the inversion. Another possibility, if offspring survival are viable, is the "position effect" in which a change in expression of one or more genes accompanies the chage in position with respect to neighbouring genes.

Radiation Exposure

The usual exposure of human beings and animals to external ionizing radiation is either natural or man-made sources of X-ray or gamma irradiation and also under certain conditions such as in radium therapy, space flight and accident situations. Other types of radiation such as neutrons, protons and beta particles may also be sources of external irradiation.

Ionising radiation produce gene mutations, and chromosome aberrations. Mutated germcells involved in the production of new organisms may be abnormal in various ways and to various degrees. Mutations from ionising radiation are not different from "Spontaneous" mutations or those produced by other mutagens.

The ionizing radiation can produce chromosome aberrations in both somatic cells and germ cells. These aberrations are produced by the breakage of chromosomes. Many of these will rejoin leaving no visible effect in the cell. Others may fail to rejoin or rejoin in abnormal configurations leaving deletions, duplications, inversions or translocations. Many of these chromosome aberrations result in cell death at the time of cell division. In the case of germ cells, some of these chromosome aberrations may be passed to offspring. Errors in chromosome distribution may result in individuals with too many or too few chromosomes, producing such abnormalities as "mangolism" a condition in which individuals have an extra representative of specific chromosome.

In India, 10-50 percent of the urban population may be under various ecological stresses almost daily, the durations and doses varying with different segments of human populations. So it is imperative that these situations should be primarily monitored to unravel any harmful genotoxic potential.

It has been reported that six percent of all liveborn intants suffer from genetic defects of malformations. In additon chromosomal abnormalities also contribute to prenatal death. It has also been estimated that six percent of still births and 50 percent of the spontaneous abortions that occur between 8 to 20 weeks of pregnancy are chromosomally abnormal. Unfortunately the magnitude of the contribution of environmental mutagens to the burden of disease, disability and foetal deaths is unknown. Minimizing exposure to mutagenic agents that may contribute to all these disabling conditions, should receive high priority.

15.8. SUMMARY

Pollution is a reduction in the quality of environment by its interaction with impurities. Metals, organic pollutants, agricultural pollutants, gaseous pollutants, anions, acids and alkalies are some of the different pollutants that are more hazardous to the living organisms and to the environmental components.

To asses risk, test of short-term lethality and acute toxicity have long been used. In many environmental situations most of the problems are caused by the toxic substances which are harmful only after long periods of continuous exposure or chronic toxicity.

The pollutants are responsible for teratogenic, carcinogenic and mutagenic effects on the organisms. The nervous system, liver, and kidney are the important vital organs most commonly associated with tissue damage from toxic compounds. Genetic poisons affect the functioning of the genes and cause serious implicatons for human health such as gene mutations and chromosomal damage.

15.9. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The non biodegradable pollutants do not degrade or degrade very slowly in the ecosystem. They not only accumulate but are often "biologically magnified" with their food chains.

2. Median lethal dose or LD_{50} is the ability of a chemical substance, which would kill half of the animals in a test group is administered once only.

3. Chronic toxicity may be defined as "total adverse effects produced by a toxicant when administered continuously over a long period of time".

4. Tereatogenisis involves interference with normal development of either the embryo or the foetus in uterus, giving rise to abnormalities in the neonate.

5. Neurotoxins are lethal and have the ability to cause respiratory failure Neurotoxins show no effect on the central nervous system, but rather act as neuro muscular blocking agents by reducing and plate depolarisation by acetylcholine.

6. A faulty liver (the accumulation of triglycerides) is the common hepatic response.

15.10. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write an essay on Non-carcinogenic disorders of the liver?

2. Define tha acute toxicity? Explain the response of acute toxic effect on organisms?

3. Write an essay on genetic alterations in human beings?

I. Answer the following questions in about 10 lines each.

1. What are the mutagenic effects ?

2. What is the cause for the development of nervous symptoms in organophosphate compound (synthetic insecticide) treatment?

3. What is the impact of genetic poisons on the gemetogenic cells?

4. Discuss the impact of inversion and translocation in meiotic prophase?

Dr. I. Damayanthi Devi

UNIT - 16 : ABSORPTION, DISTRIBUTION, ELIMINATION OF SELECTED POLLUTANTS

Contents

16.1. OBJECTIVES

After going through this unit, you will be able to:

* list out and explain the routes of penetration,
* describe the factors influencing penetration and the mechanism of penetration.
* describe the distribution and elimination of toxicants

16.2. INTRODUCTION

Sources and nature of pollutants vary with location. Once the chemicals are released into the environment rarely remain in the form, or at the location of release. These chemicals enter different types of environments and enter the living creatures resulting in an increased concentration or bioaccumulation.

Earlier i.e., upto middle of this century it was thought that skin and other body barriers were playing an effective role in preventing the entry of pollutants into the body. Now it is clear that almost every toxicant can pass through one or more portals of entry. However, considerable variations are recorded in rates of absorption of chemicals in different routes. Absorption is the process where by toxicant (usually referred as pollutant or xenobiotic compound) moves through body memberanes and enter the circulation.

The biological effects of xenobiotics depends on many factors such as toxic properties of toxicant, the initiation, intensity, and the duration of exposure etc. Every factor has a role related to the ultimate interaction of toxicant with active site.

16.3. ROUTES OF PENETRATION

Xenobiotic compounds entering into the body depends on the toxicant form and its location in the environment. The primary routes of entry of environmental contaminants (xenobiotics) are: Dermal, Gastro intestinal, and Respiratory. Number of methods for studying these routes have been developed. These specialised techniques are described else where.

16.3.1. Dermal Penetration

It is needless to mention here that skin is very complex multilayered tissue. While maintaining basic structural similarities exhibits variation in different organisms. The skin of average human male comprises of 18,000 cm^2 of surface area. It is impermeable to aqueous solution and metal ions. However, it is permeable to large number of xenobiotics (solid liquid and gaseous state). Several studies reported on the dermal poisoning by the pesticides in the agricultural operations indicated that large number of chemicals can penetrate through dermal barriers.

Though skin permits the entry of several chemicals, the skin tissue appears to afford the greatest deterrent to absorption. This can be appreciated only when you look at the structure of skin (Figure 16.1). The epidermis of the skin is multilayered tissue varying in thickness from 0.15 mm (eye lids) to 0.8 mm (palms). The lower most layer of epidermis is called as stratum germinativum capable of proliferative activity. The cells of the germinal epithelium are columnar nucleated measures approximately 6μ in width. During proliferation the basal cells move towards the surface. As it moves towards the surface, the basal cell loses its columnar shape, becoming rounded and finally gets flattened.These morphogical changes further differentiates the epidermis into three loosely defined layers, called stratum spongiosum,stratum granulosum and stratum lucidum. The morophogical and biochemical changes that occur as the cell progressively die and finally becomes stratum corneum.

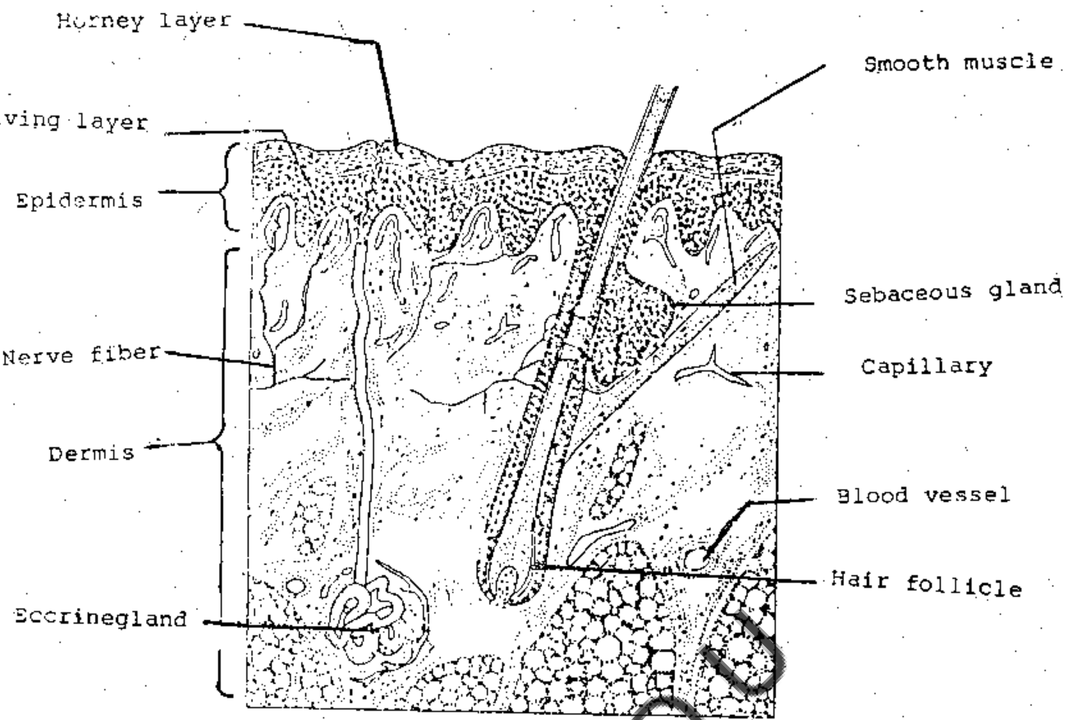

Fig. 16.1. Histology of skin.

The formation of stratum corneum is associated with production of fibrous, insoluble keratin that fills the cells with sulphur-rich amorphous protein that comprises the cell matrix and thickened cell membrane. Therfore, it provides primary barrier consisting of 8-16 layers of flattened, stratified, highly keratinised cells. The sequence of events from basal cell to stratum corneum requires about 4 weeks. The keratinised cells are approximately 25-40 µm in width, lie tangenital to the skin surface.

Investigations have shown that the disruption of stratum corneum removes the deterrant to penetration. An experiment "Stripping of adhesive" from Skin repeatedly removed progressive sections of the corneum. At some critical point skin was found to loose the ability to reretard panetration of xenobiotics. Stratum corneum has been calculated to offer 1000 times resistance to penetration.

Once the xenobiotics crosses the epidermal barrier, it reaches the dermis, which is highly vascularised and therefore provides ready access for the distribution. However, this distribution is affected by factors that influence blood supply to the dermis such as neural and humoral factors. Primary appendages, sweat glands, hair, sebaceous glands, as they extend to the outer surface are known to favour the penetration of chemicals. Passage through skin is passive and there are no evidences recorded for the active transport.

Factors influence the penenetration includes: polarity and size of the molecule. For nonionised compounds the penetraton rate varies from region to region because of the variation in the thickness of the skin. The rate of penetration for the nonionised compound is observed in the following order; Scrotal > fore head > axilla = scalp > abdomen > Palm and Plantar.

The palm or plantar regions are highly vulnerable to chemical exposure but their greater thicknes (100-400 times than that of other regions) becomes advantageous and introduces a deterrent or time lag in the diffuse or penetration.

Repeated use of highly concentrated soaps and detergents damage skin and permits the rapid penetration of xenobiotics. Organic solvents applied at higher concetration damage the skin. These substances induce alteration in the structure of corneum and causes increased penetration of chemicals. Amongst organic solvents, there are several damaging solvents which include: methanol, acetone, ether, hexane, and mixed solvents such as chloroform -methanol, or ether - ethanol. These solvents are used to extract proteolipids from the tissues. Therefore we can expect alteration in the permeability. These solvents may not alter strength of stratum corneum but the delipidization process produces more porous and non-selective surface to permit all types of chemicals. Extremely lipid soluble chemicals may be trapped in lipid deposited areas and may not be subjected to mobilization to reach target areas, for e.g., parathion a lipid soluble chemical applied on skin can't be removed by washing with soap and water. Solvents such as higher alcohols, esters, olive oil do not damage the skin appreciably. Therefore solutes dissolved in them, can't be penetrated rapidly. Though we can draw some generalization with regard to rate of penetration, the human skin when compared to the skins of cat, dog, rat, and mouse etc is more impermeable, there by exhibiting a species specificity in penetration rates. Several other factors such as temperature relative humidity, concentration of toxicants, occlusion, age and hyperemia, surface area synergestic and antogonistic actions are known to influence the penetration. A number of physico-chemical properties of xenobiotics and physiological factors of species may also alter the penetration.

16.3.2. Gastrointestinal Penetration

Xenobiotic compounds reach the gastrointestinal system through various pathways. The toxic substances which enter through oral route may be purposeful (as in suicidal cases) or accidental ingestion of poisonous material. Food additives, food toxins, number of airborne particles which are exclued from the passage to alveoli etc may also enter into digestive system. The digestive system is lined by a single layer of columnar cells and usually protected by mucous. However, mucous may not play an appreciable role in the prevention of penetration of toxic substances. Once toxicant crosses the epithelium it enters the vasculature which is approximately 30-50 μm from the epithelium. The vasculature through hepatic portal system transports the toxicant to liver, where it may be detoxified. Intestinal area offers maximum opportunity for absorption because of the large absorptive surface due to the presence of micro villi which is estimated to contain 2000 sq.ft area. Therfore, it is generally accepted that penetration is greater in gastrointestinal area. The absorption of toxicant would depend on duration of toxicant held in different parts of the G.I.T. (Gastro intestinal tract). Some times greater amount of toxicant may be absorbed through stomach if the toxicant remain in stomach for a considerable time.

The interesting aspect of gastrointestinal system is that it has areas of highly variable pH which influence permeable characteristic of ionic compounds to an appreciable degree. Passive diffusion is greatly limited except for unionised and lipid soluble toxicants. Unlike skin there is some evidence for an active transport of toxic substance, utilizing the mechanisms meant for endogenous substances like amino acids, sugars and ions. For e.g., 5 - bromouracil utilizes the pyramidine pathway.

In addition to the above, a number of other factors such as, particle size, organic solvents, emulsifier, rate of dissolution play an improtant role in the penetration of toxic substances. Apart from this, presence of microorganisms hydrolytic promoting pH, binding to the gut contents, intestinal motility, rate of emptying, temperature of food, hormonal secretions influence gastrointestinal absorptions. The secretion of conjugated metabolites in liver reaching intestine through bile duct may result in conditions for enterohepatic circulation of toxicant which will maintain toxicant for lengthy periods and cause long term toxic effects.

Some times larger compounds also enter through intestinal villiby processes other than simple diffusion and active transport. For example bacteria exotoxins, particles of azo dyes averaging 300°A polystyrene latex particles of 2200°A, and carragenens with a molecular weight approximately 40,000 are absorbed through intestinal tract, probably by the mechanisms similar to pinocytosis.

16.3.3. Respiratory Penetration

Respiratory surface is another important area through which toxicants can penetrate easily. The respiratory system varies markedly in different animals. The important respiratory structures include gills which are located either internally or externally. Dissolved toxicants can pass through gills. In terrestrial forms lungs are present for gaseous exchanges. A number of toxicants such as CO, NO_2, vapour of benzene, CCl_4 and aerosol (Lead from automobile exhaust, asbestos, silica) are some of the very important chemicals that may enter via respiratory system. Surface area of the lungs are very large (50-1000m^2); some times it is estimated to be 50 times the area of skin.

Alveolar system of lung, structurally specialized, possess exceedingly thin membrane and intimately associated with vascular system. The distance between exterior alveolar membrane and the vasculature is about 1.5 μm in contrast to gastrointestinal cells (30 μm) and skin (100μm). The structural advantage of alveolar membrane facilitates the movement of carbon dioxide in 5 seconds while O_2 moves in 1/5 seconds. A thin film or wetting fluid on the alveolar membrane helps in the initial absorption of toxicant from respiratory air. Lipophilic toxicant interact with phospholipids of cell membrane and the uptake may be delayed in some cases.

Several factors influence the absorption or uptake of toxicants by alveolar system. These includes capacity of the lung, particles deposition and retension, total lung capacity for the residual volume, the amount of air retained by the lung despite maximal expiratory effort. Many expirations are needed to get rid of residual toxicant from the lung air. Therefore toxicant remain available to alveolar suface for considerable amount of time.

In addition the entry of toxicants in a vapour form is controlled by alveolar ventilation rate and toxicant comes in contact to alveolar surface in an interrupted fashion for about 20times/min. Diffusion co-efficient of gas in the fluids also play important role in the penetration. The rate of entry of the toxicant gas some times determined by solubility of the toxicant in blood.

Number of factors affect the entry of aerosol and particular matter, as these are specially designed to preclude their entry. For example, a specific cases can be described here. A coal miner is subjected to inhalation of 6000 g coal dust particles during occuptional exposure in a life time and only 100 g of coal is found at the time of postmortem. This clearly indicates that there are some protective mechanisms for clearing the coal particles. The parameters like air velocity and wind direction favour impaction of particles in upper respiratory system. Particle characterstics such as size, coagulation, sedimentation, electrical charge and diffusion are considered important for retension, absorption or expulsion of air borne particles. Lung characteristics such as presence of mucous blanket and its ciliary action propells and clears the tract of particles and directing them to gastrointestinal system (via glottis) or to the mouth for expectoration. Such mechanism is expected to clear 80% of the toxicant from the lung. Further, particles more than 2 μm do not reach the alveolus. Phagocytic mechanism also prevent the entry of toxicants. Thus ninety percent material deposited in the lung may be cleared in less than one hour.

Despite the effectiveness of ciliary movement which takes the mucous blanket to glottis or mouth for the clearance, the cumulative effects of silica, asbestos, or coal may contribute to the chronic toxicity. There is little evidence for active transport of toxicants through respiratory system. Pinocytosis may be of some importance for the penetration. Though lung is metabolically active, detoxification mechanisms do not appear to be major importance. It is also well known that lung acts as excretory organ for gaseous pollutants.

16.4. FACTORS INFLUENCING PENETRATION

What ever may be the route of entry for the toxicant, first it encounters the plasma membrane. There may be several layers of cells or single cell, but a Unifying concept is the basic similarity of all the membranes - whether it is tissue, cell and organelle.

There presumed to be number of pores of an approximate size of 4°A on the membrane. These pores permit water and small molecules with molecular weight less than 100. Specialized membranes present in the kidney possess pore of size 40°A, permit the passage of compound with molecular weight greater than 50,000. Amphipathic nature of the membrane creates barrier for ionized and highly polar compounds, although it does not completely exculude them.

16.4.1. Ionization

Nonionised tixicants are more permeable than the ionised. This was first explained in case of alkoloids. Alkoloids such as nicotine and others when introduced into a gastrointestinal area in a strong acidic medium, the absorption was found extremely less and there fore toxic effects on the animal could not be witnessed because under acid medium alkoloids were highly ionised and ionised compoounds could not penetrate through plasma membrane and hence toxic effects could not be noticed. A strong alkali was introduced into the gastrointestinal tract (G.I.T) was the toxicant and converted into nonionised form which was immediately absorbed and the animals were perished.

Therefore, ionizaion plays an important role in the penetration or apermeation of toxicant in the gastrointestial system, where, variety of pH conditions manifest. Ionised and unioised form of chemical substance depends on its negative logarithm of acidic dissociation constant (i.e. PKa values) and the bathing pH medium. Whenever pH of solution is equal to PKa of the dissolved compound, there exists an equilibrium between ionised and unionised forms.

In addition to the above some isolated instances, were reported where in highly ionised compounds such as paraquat, and diquat etc were absorbed in an appreciable levels in gastrointestinal tract. However mechanism for the absorption of such ionised lipid soluble compounds is not very clear.

16.4.2. Partition Coefficients

Partition coefficient is defined as ratio of solubility of toxicant in organic solvents to solubility of toxicant in water. It is an important property, known to influence permeability of toxicant. Studies indicated that there is good correlation between partition coefficients and rate of penetration. However, the rate of penetration varies according to degree of partition coefficients. Substances which have low partition coefficients i.e. poorly lipid soluble were found to penetrate easily than the substance having higher partition coefficients and more lipid solubility. The contrast of correlation of compound with low and high partition coefficients are graphically represented as follows:

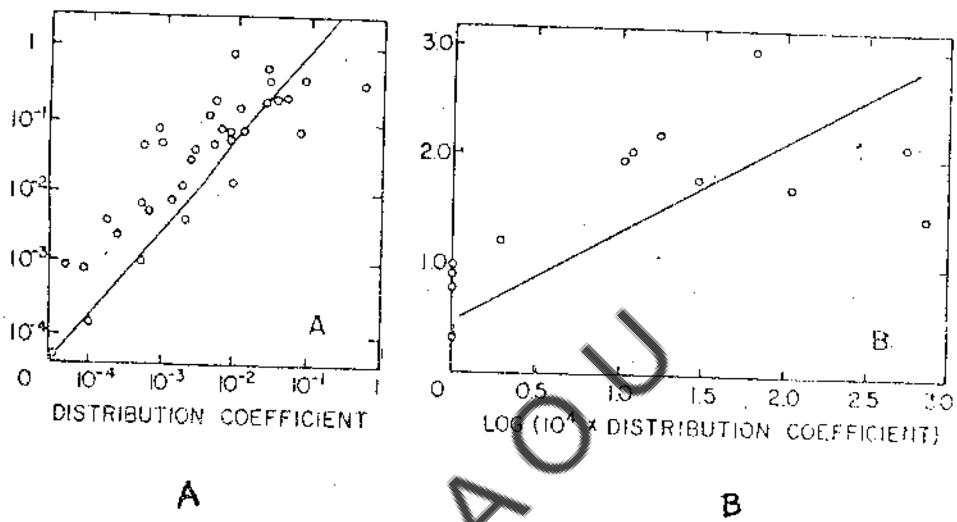

Fig.16.2. Correlation between partition coefficients and penetration. A Positive correlation. B. Less positive correlation.

Therefore, there exists a general relationship between partition coefficients and rate of penetration. However, certain amount of lipid solubility is nessary. Compounds with higher partition coefficients remain in the membrane rather than to pass through them. Chemical similarity, size of molecule, conformational similarities all contribute to correlative feature of partition coefficient.

16.5. MECHANISMS OF TRANSPORT

Mechanism of transport, or absorption of drugs have received considerable attention, may be because of pharmacological significance. But the transoprt of xenobiotics through membrane has been a neglected area of research. Four different mechanisms have been identified.

16.5.1. Passive Transport

Passive transport mechanism is considered as primary mechanism for the absorption and transport of toxicants. In this the toxicants move by a simple diffusion. Appropriate partition coefficients are manily responsible for such movement through membranes. Ionised compounds have a considerable difficulty to move through the membranes, because they are sparingly soluble in lipids and there is also a possibility of ionic interaction among xenobiotics, lipids and proteins in the membrane.

16.5.2. Filtration

The membrane bears number of pores (approximately 4°A). Water and small molecules having molecular weight 100 or less will penetrate more quickly. Large molecules in general are excluded from penetration (except in the membranes of kidney where the pore is around 40°A), permit the entry of compounds having molecular weight greater than 50,000).

16.5.3. Special Transport

In special transport, the toxicant movement into the body is effected by the system that help the transport of endogenous substances across the cell membrane. A number of such special transport systems are found in the gastrointestinal tract. For example the toxicants like 5-fluoro uracil transported by pyramidine pathway, thallium is transported by mechanism that transports iron and lead is transported by a mechanism that transports the calcium. These processes may require energy to conduct the transport of a toxicant aganist the concentration gradient (active transport) or may not require energy and unable to conduct the transport of toxicant aganist a gradient (facilitated transport). A carrier molecule, postulated to be a protein associates with toxicant for both active and facilitated transports. This mechanism helps the movement of toxicant across the membrane, and this mechanism benefits the compounds that lack sufficient lipid solubility to move rapidly through membrane.

16.5.4. Endocytosis

This is a specialised transport in which the cell membrane invaginate or flow around the toxic compound to engulf to allow its transfer of substance across the membrane .Such transfer of substance across the membrane is termed as endocytosis. Pinocytosis (transport of liquid) phago cytosis (transport of solid substances) are the examples of the endocytosis. Absorption of carragenens (Molecular weight ~ 40,000) in the gut by this mechanism gains the initial entry. Engulfment of solid particles in the lung is commonly observed as lung phagocytosis.

16.6. RATES OF PENETRATION

The rate of penetration or diffusion of toxicants depends on number of factors; size, spatial configuration degree of ionization and lipid solubility of the toxicant are considered to be some important factors. The rate of diffusion related to the concentration gradient accross the membrane is explained by the equation given below.

Rate of diffusion $= K\, A\, (C_1 - C_2)/d$

where

K	=	Diffusion constant.
A	=	Surface area available for transfer
C_1-C_2	=	Related to the concentration gradient
d	=	Thickness of the membrane.

However, slight deviation may be noticed in case, appendageal shunts, carriers, injury to the surface membranes etc.

Check Your Progress - 1, 2, 3, 4

1. What are the main routes of toxicant penetrations into the body?
2. In what order nonionised xenobiotics penetrate various regions of the body? Give a reason for variation.
3. List out some of the factors that influence penetration of toxicant through skin.
4. Why intestinal area offers maximum opportunity for absorption?

Note : (a) Write the answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

16.7. DISTRIBUTION OF TOXICANTS

Immeadiately after absorption, a toxicant may be distributed to site of toxic action, or transferred to a storage depot, or transported to organs of detoxication or biotransformation or eventually eliminated. Toxicant distribution mainly occurs through body fluids or by variety of biological constituents.

16.7.1. Distribution Through Body Fluids

Body fluids, like vascular fluid, plasma, interstitial fluid and intracellular fluids play an important role in the distribution of toxicants, Human plasma amounts to about 4% of the body weight and 53% of total blood volume, where as interstitial tissue fluids account for 13% and intracellualr fluids comprise 41%. Concentration of toxicant in the blood following the exposure verv much depends upon its apparent volume distribution. Concentration of toxicant usually high when compared to interstitial tissue fluids and intracellular fluids. Many of the toxicants are soluble in aquous component of the blood to account for a simple solution as route of distribution. Once toxicant gains an entry into circulatory system, it is distributed throughout the body and may accumulate at the site of toxic action, or may be transferred to organs wherein it is subjected to biotransformation such that it will be detoxified / intoxified or may be sent to an eliminatory route.

The transport of toxicant through lymph is considered to be less important, as the rate of blood flow is 500-700 times greater than intestinal lymph flow. However, in case of certain xenobiotics, RBC and lymph were recognised to play an imortant role in the transportation. Through vascular system the primary mechanism of transport and distribution appears to occur in association with plasma proteins. Cellular components to certain extent help in the transportation of toxicants but such transport is notappreciated quantiatively. Toxicant in course of its distribution if stored in depot may not be manifested immediately. However, its potential risk of toxicity exists. Bihenyl stored in fat and lead in bone can be taken as examples for this. Toxicant tends to maintain an equilibrium between storage depot and plasma. Such a situation leads to constant exposure of target tissue to toxicant leading to manifestation of chronic toxicosis.

16.7.2. Factors Governing Distribution

Several factors are known to influence the distribution of toxicant. These includes lignand protein interactions, types of bindings, number of binding sites, numbers of lignand molecules bound per a protein molecule and binding affinities etc.

Lignand Protein Interactions

Toxicants are reversibly bound to variety of biologcal constituents. In lignand protein interactions, in most of the cases a reversible binding is established, which obeys law of mass action, providing an efficient mechanism of toxicant transport to the various tissues. The toxicant protein interaction can be explained by the equation as follows:

$$(T)_f \quad \text{(Freesites)} \quad \underset{K_2}{\overset{K_1}{\longrightarrow}} \quad (T)_b$$

Where $(T)_f$ and $(T)_b$ are free and bound toxicant molecules, K_1 and K_2 are the association and dissociation rate constants. K_2 governs rate of binding of toxicant to protein and therefore it dictates rate of toxicant release at storage depot or site of toxicant action. The ratio of K_2/K_1 is equal to K diss. Smallest K diss indicates strong binding whereas highest K diss indicates weak binding. Once molecule binds to plasma protein, it moves throughout the circulation until it dissociates. Dissociation generally occurs when ever the toxicant affinity to another biomolecule or tissue becomes greater than that of a plasm protein molecule to which toxicant is orginally bound. K diss is influenced by ionic strength, pH, temperature etc. As long as binding is reversible redistribution will occur and this process must occur in order to maintain toxicant in equilibrium between plasma and storage tissue.

Types of Binding

Toxicants, in its orginal form or a metabolised form interacts with proteins or sub cellular fractions to form a lignand. The protein lignand interaction occur by a veriety of mechanisms in which nature of binding varies.

Covalent Binding

The covalent binding is almost an irreversible binding. Therefore, there is no true distribution of lignand, as K_2 is a non existent and there is no opportunity for dissociation. Some potentially carcinogenic polychlorinated hydrocarbon or their metabolites covalently bound to tissue proteins. In this kind of interaction binding might have profound effect on the organism due to the modification of essential molecule. In this covalent binding, there may not be an opportunity of release of toxicant unless the protein breaks down by itself.

Non-Covalent Binding

In contrast to the covalent binding, in non covalent binding there is an opportunity for toxicant to dissociate itself from the lignand after transport. Non-covalent binding is of primary importance with respect to distribution. Only in rare cases noncovalent binding may be tight (K diss is small) in all such cases the toxicant remains in blood for a longer time and therefore increases biological half life values of the toxicant. The types of interactions in the non covalent binding include the following :

Ionic Binding

Ionic binding takes place, between oppositely charged ions. Electrostatic forces of attraction between toxicant and protein due to the presence of opposite charges makes an ionic interaction. The degree of ionic binding varies with chemical nature of each compound and the net charge. Dissociation of ionic bonds usually occurs readily, but some members of transition group of metals exhibit high association constants (low K diss values).

Hydrogen Bonding

Hydrogen bonds arise when hydrogen atom co-valently bound to an electronegative atom, is "shared" to a significant degree with another or second electro negative atom. Electronegative atoms like O,N and F form stable hydrogen bonds. Hydroxyl, amino, carboxyl, imidazole and carbamyl groups present in the protein side chains can form hydrogen bonds. This bond plays an important role in the structural configuration of proteins. However, toxicant interaction with protein by hydrogen bonding cannot be ruled out.

Vander Waals Forces

Vander Waal forces are very weak forces that are known to occur between the nucleus of one aotm and the electrons of another atom. The binding forces critically dependent upon the proximity of interacting atoms. These forces reduce rapidly when distance increases between interacting atoms. These forces, when summed up over a large number of interacting atoms that "fit" together spatially, they can play a significant role in determining specificity of toxicant protein interactions.

Hydrophobic Interactions

Hydrophobic interactions occur when two nonpolar groups come together. Nonpolar groups interact together by excluding water between them. This mutual repulsion of water results in hydrophobic interactions. These interactions can lead to the formation of stable complexes.

Check Your Progress - 5, 6 & 7

5. How are toxicants transported for the distribution to various organs in the body.

6. Some times toxicant does not cause toxicity inspite of its entry into the body. Why?

7. Which situation leads to constant exposure of target tissue to a toxicant and what happens in constant exposures.

Note : (a) Write the answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

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16.8. ELIMINATION OF XENOBIOTICS

Metabolic wastes ar eliminated from the organism through well defined mechanisms and these mechanisms are evolved during the course of evolution from a cellular aquatic organism to highly developed terrestrial animal species. Toxic substances were found in the atmosphere or environment much before the existence of the life. Unicellular forms in an aquatic medium existed along with toxic substances. These organisms either struggled to thrive or perished according to prevailing conditions in the environment. Xenobiotic compounds in these primitive forms passively diffused out into aquatic environment along with endogenous wastes. However this process of elimination, required large volumes of water. In higher animals excretory pathways and patterns of elimination are highly evolved and produced complex excretory systems to suit the animals hibitat. The process of conservation of water, minerals and nutrients further complicated the structure and functions of different eliminatory organs. Xenobiotics are readily absorbed but not readily excreted. Studies revealed that metabolic conversion of xenobiotics to more polar compounds determines the rate of excretion. Metabolised xenobiotics are eliminated through renal route, hepatic and also through lungs. Apart from these routes some minor routes of elimination are found, which account for a very small quantities of elimination.

16.8.1. Renal Excretion

Kidneys apart from eliminating the biproducts of normal metabolism, also acts as primary excretory organs for polar xenobiotics and hydrophilic metabolites of any lipophilic xenobiotics that are encountered by the animal. You are aware of the functioning of the kidney, it is made of several functional units namely nephrons. The components of nephron are shown in Figure 16.3.

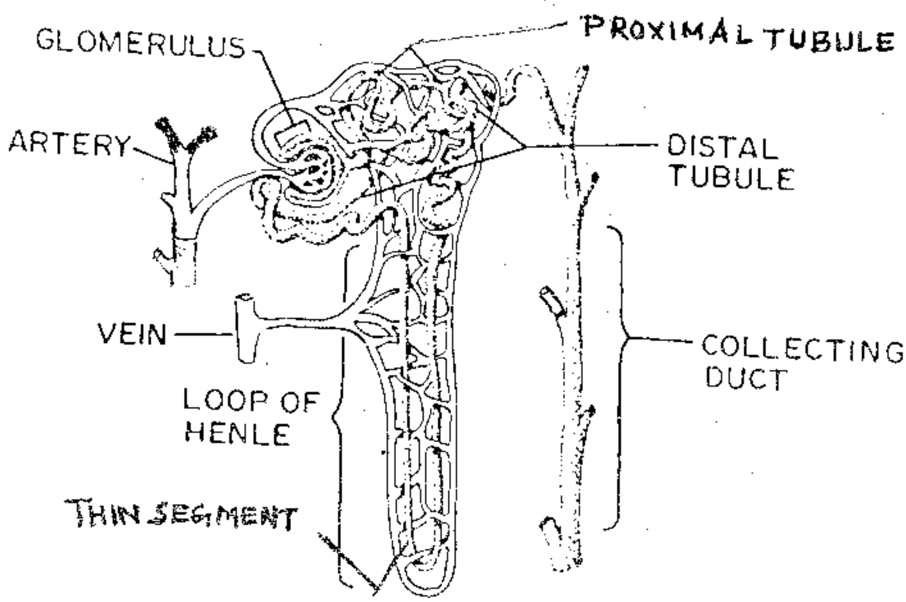

Fig. 16.3. Components of Nephron

Glomerular Filteration

The wastes mainly non gaseous nitrogenous substances generated in the tissues, along with metabolized xenobiotics reach the kidney through blood. The initial step for the elimination of wastes is the formation of urea through glomerular filteration. The plasma is passively filtered as it passes through numerous glomerular pores that are 70-100°A in diameter. The rate of glomerular filteration in about 70kg man is 125 ml / min or 180 litres per day. Except the molecular size no specificity is seen in the ultrafilteration, Any free solute in the plasma small enough to proteins do not appear in the ultra filterate and these must be further altered or must be eliminated by other avenues. Since glomerular filteration occurs due to the hydrostatic pressure, it is logical to consider that any factor that affects the hydrostatic pressure or integrity of glomerulus will also affect rate of filteration and perhaps result in the elevated concentration of excretory substances in the plasma.

Tubular Reabsorption

The glomerular filtlrate along with nitrogenous wastes and xenobiotic substrate contain large number of solutes like water amino acids, glucose, ions etc which are very essential for the normal functioning of the body. Therefore, the process of reabsorption is a very important step, that takes place on the body of the tubule to recover all the essential substances. The reabsorptive mechanisms that reside in the proximal segment of the tubule accounts for 65-90% reabsorption of glomerular filterate (glucose, cations, amino acids and number of organic acids are actively reabsorbed). Water chloride and other ions are passively reabsorbed due to osmotic and electrochemical gradients generated by active transport of sodium and potassium. Henle's loop functionally regulate the osmolarity of fluid in the collecting duct. The remainder of water and ions reabsorption occurs through distal tubule and collecting duct.

Reabsorption of metabolised xenobiotics is usually passive and regulated by the same principles, that permit the reabsorption of endogenous molecules, lipophilic xenobiotics readily reabsorbed when compared to polar xenobiotics. Renal excretion of lipophilic xenobiotics is proportionally less. One important aspect to be considered here is that major amount of reabsorption takes place through proximal tubule, hence, it is very often becomes site for toxic action.

Tubular Secretion

It is an important mechanism where by solutes may be excreted by the kidney. This mechanism may be either active or passive and permits the transport of solutes from the peritubular fluid to the lumen of the tubule. One active mechanism permits the excretion of number of organic acids, including glucouronides, and sulphate conjugates, and second active process secretes strong organic bases. The secretion of weak acids and bases occurs by passive mechanism and taken advantage of the fact that these compounds are lipophilic and in the unionised form diffuses out through tubule walls. The variation in the pH in tubular lumen ionises these substances. Therefore they can not diffuse back into the tabule. This mechanism is referred to as diffusion trapping. It is very sensitive to pH fluctuations.

Factors Affecting Renal Excretion

Toxicants are excreted by the same mechanism that govern the elimination of endogenous substances. The rate of renal elimination of most of xenobiotics largely dependent upon the rate of glomerular filteration, which in turn depends on blood supply to the kidney, physiological status of the animal and concentration of free xenobiotic substrates in plasma. The concentration of the xenobiotics in plasma, that are subjected to glomerular filteration is dependent upon dose, routes of administration, routes of absorption binding to plasma proteins and polarity of the compound in question. The rate of metabolism of xenobiotics may also play an important role in its rate of excretion. Highly lipophilic toxicants would not expected to be excreted by glomerular filteration since they easily diffuse back across concentration gradient generated by tubular reabsorption.

16.8.2. Hepatic Excretion

Xenobiotic substrates are also eliminated by the hepatic system in which formation and secretion of bile plays an important role and this affects enterohepatic circulation.

Bile Formation and Secretion

Elimination of xenobiotics through hepatic system has been recognised as second important mechanism next to urine. More than 200 xenobiotics have been detected in bile. Liver is interposed between intestinal tract and general blood circulation and is ideally located to effect the metabolism of endogenous and exogenous compounds. The products of metabolism may be released into circulating blood or secreted in the bile.

The liver comprising of hepatic cells are arranged into plates of two cell thickness. These plates are arranged around terminal branches of hepatic veins and exposed to venous arterial blood flowing through inter connecting spaces (hepatic sinusoids). The sinusoid walls are very permeable to relatively large molecules, particularly xenobiotics substrates, after their metabolic conversion to polar substrates. These polar xenobiotic substrates along with endogenous metabolites are transferred from hepatic cells to bile or blood.

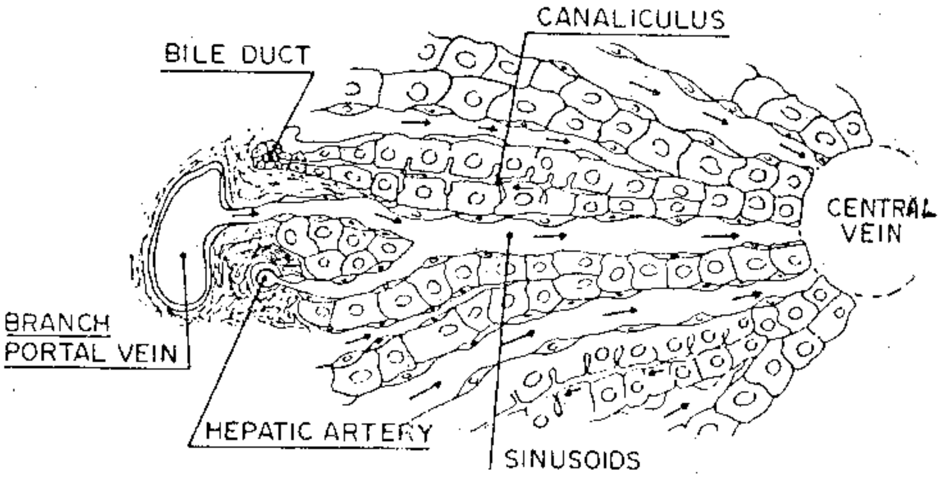

Fig. 16.4. Arrangement of Heptic Cells into Plates

Bile secretion is relatively independent of hydrostatic pressure, and bile flow may be salt dependent or salt independent. Compounds actively secreted by bile are usually amphipathic molecules, having both polar and nonpolar moieties. Bile salts are classic examples of endogenous amphipathic molecules whereas, conjugates of lipophilic xenobiotics are the classical examples of amphipathic molecules of exogenous orgin. The PKa (negative logorithm of acidic dissociation constant) values of these xenobiotic conjugates fall betwen 3-4. Therefore 99% of the conjugates are unionised at physiological pH, thus facilitating active transport.

Bile and conjugated xenobitic substrates secreted by the liver cells into the bile canaliculi flow into the fine branches of bileduct, which through hepatic duct enters the gallbladder. After meal, the hormonal secretions stimulate the gall bladder to release its content into duodenum via common bile duct. From there they enter into different parts of the intestine and some of the xenobiotic compounds are eliminated through fecal material and the rest may be subjected to enterohepatic circulation.

Enterohepatic Circulation

Dependent on the molecular weight the metabolised xenobiotic compounds are either eliminated through urine or secreted in the bile. When xenobiotic conjugates enter the intestine, they may be hydrolized by microflora or other intestinal conditions. These hydrolised products particularly less polar forms can be reabsorbed back by the intestine and returned to the liver through portal circulation. This process may be repeated several times contributing to the greater half life values to the xenobiotic compounds. A fraction of the conjugated xenobiotic metabolites in the intestinal lumen may be excreted and the remaining is reabsorbed. The process of repeated reabsorption of xenobiotic substrates can be referred to as enterohepatic circulation. The mechanism though helps in conserving bile salts, becomes a set back for toxic substances. In many xenobiotic compounds most of the compound goes into enterohepatic circulation (Fig. 16.5.).

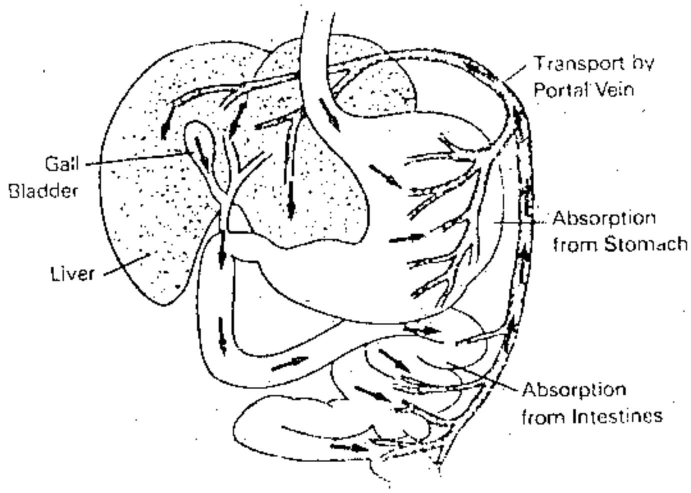

Fig. 16.5. Enterohepatic Circulation

16.8.3. Pulmonary Excretion

Many volatile toxicants such as anaesthetic gases, pesticide fumigants, volatile organic solvents and volatile metabolites of non volatile toxicants, and alcohols are significantly eliminated by lungs. Therefore, it is considered to be the third important route for the elimination of toxicants. The functional structure of lung consists of myriad, thin vascularised alveoli. The primary function of this thin specialized area is the exchange of O_2 from the air, to blood and CO_2 and from blood to air.

The exchange is primarily passive, and any toxicant metabolite with adequate volatality may pass from blood to air for elimination. The rate of elimination of volatile toxicants is influenced by solubility of toxicant in blood, rate of respiration, blood flow to the lungs. Hyperventilation adds an additional effect for the elimination of volatile toxicants. Some xenobiotic compounds, metabolised to the level of CO_2 utilizing pathways meant for endogenous pathways may be eliminated through lungs.

16.8.4. Minor Routes of Elimination

Apart from above mentioned routes of elimination, there are some minor and obscure routes of elimination. They are as follows :

Sex Linked Routes

The route of excretion of some compounds becomes linked to reproductive function of female. Considerable number of toxicants are secreted in the lactating tissue readily cross mammary cell and are reported to have been eliminated through milk. Caffeine, alcohol drugs, vitamins hormones and pesticidal and industrial chemicals stand best examples for this kind of elimination. Several reports were published about milk containing DDT and PCB samples. Another sex linked route can be seen through eggs of birds where the pesticidal chemical concentrated in white egg or yolk gets eliminated. Adverse effects on the eggs remain transient in these cases. Foetus can also be considered as another sex linked route for the elimination of xenobiotics. However, placenta acts as a barrier in preventing the passage of polar toxicants and their metabolites. But placenta cannot be considered as important barrier to the entry of lipophilic compounds.

Alimentary Elimination

Passive eliminaion in the alimentary canal usually results in the elimination of minute amounts toxicants. However, in some cases it is considered as important route. For example kepone (Pesticide) appears to be eliminated through intestine. Certain therapies, for eliminating poison consumed, through a binding substance administered, resulted in the elimination through fecal material. Elimination of chlorodecone poison by administering the cholestryramine is the best example for this kind elimination.

Obscure Routes of Elimination

Because of the possibility of diffusion of toxic metabolites across cell membrane of the body hair, feathers, oil glands, sweat glands ect., may be involved in the elimination of traceable quantities of toxicants. Such elimination is possible when components of body continuously removed.

Check Your Progress - 8, 9 & 10

8. How are xenobiotics eliminated in acellular organisms?
9. Xenobiotics are readily absorbed but not readily excreted. What is required for the elimination?
10. How ultrafittcation occurs?

Note : (a) Write the answers in the space provided below.

(b) Compare your answers with those given at the end of this unit.

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16.9. SUMMARY

The main routes of toxicant penetration are Dermal, gastro intestinal and respiratory structures. Stratum Corneum of the skin acts as primary barrier for the penetration of xenobiotics. Penetration of xenobiotics is higher in scrotal sacs followed by forehead, axillary scalp, abdomen and palm. Variation in the penetration could be attributed to variation in the thickness of the skin. Delipidization by organic solvent makes the skin more porous and non selective. Repeated use of concentrated soap and detergents damages the skin. Through oral and alveolar routes the toxicants reach gastro intestinal system. Through oral route, the contaminants or chemicals may enter through water and food. While all gaseous pollutants alongwith particulate matter enter alongwith mucous blanket.

Toxicant distribution occurs through body fluids and various biological constituents. Reversible binding capacity of toxicant forms an important route for the distribution. Blood is considered important media for the transport of toxicant when compared to lymph, because the quantity of blood is 500-700 times more to the lymph. The primary mechanism of transport and distribution occurs in association with plasma proteins.

Toxicants in course of its distribution, if stored the depot may not be available at the site of action. Therefore adverse effects may not be manifested immediately. When toxicant maintains an equilibrium between plasma and storage tissue, it leads to the constant exposure of largest tissues, resulting in the manifestation of chronic toxicosis.

Xenobiotics are passively diffused into aquatic environment. Metabolized xenobiotics are liminated through renal, hepatic and pulmonary routes. Metabolized xenobiotics substrates are subjected to ultrafilteration along with urea. Ultrafilteration occurs due to hydrostatic pressure created by the heart. Concentration of xenobiotics in plasma that are subjected to glomerular filteration, type of binding to plasma protiens, polarity of the compound and rate of metabolism of the compounds play an important role in the renal excretion of xenobiotics. Most of the toxicants are subjected to enterohepatic circulation, a process which helps in the conservation of bile salts. Excreted xenobiotics substrates through fecal matter accounts for minute quantity, therefore, elimination through hepatic systems is not appreciated in quantitative terms. Organic volatile compounds and volatile metabolites of non volatile toxicants are significantly eliminated through lung, solubility of toxicant in blood, blood flow to lungs and rate of respiration, are known to influence elimination of volatile compounds. Lactating tissue, eggs, alimentary canal, hairs, feathers and other ectodermal derivatives are some of the routes through which minute amounts of xenobiotic substrates are eliminated.

16.10. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The main routes of toxicant penetration are : Dermal, gastro intestinal and respiratory structures.

2. Penetration of xenobiotics is higher in scrotal sacs followed by forehead, axillary scalp, abdomen and palm. Variation in the penetration could be attributed to variation in the thickness of the skin.

3. The factors like monionic state, molecular size, temperature, relative, humidity, concentration of toxicant, partition co-efficient, duration of exposure, physiological status and structural variation of the skin influence toxicant penetration.

4. The surface area of intestine is very large i.e. 2000 feet. Therefore the penetration is greater.

5. Toxicant distribution occurs through body fluids and various biological constituents.

6. Reversible binding capacity of toxicant forms an important route for the distribution.

7. Blood is considered important media for the transport of toxicant when compared to lymph because the quantity of blood is 500-700 times more to lymph.

8. Xenobiotics passively diffuse into aquatic environment.

9. Metabolic conversion to more polar compounds are required for the elimination of xenobiotics.

16.11. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write about different routes of penetration of xenobiotic compounds into the body.
2. Write an essay on "Distribution of Toxicants"
3. Describe different processes of elimination of xenobiotics.

II. Answer the following questions in about 10 lines each.

1. Write about gastrointestinal penetration.
2. Write briefly about rate of penetration or dispersion of toxicants.

Prof. S.L.N. Reddy

UNIT - 17 : BIOTRANSFORMATION OF POLLUTANTS OR XENOBIOTICS

Contents

17.1. OBJECTIVES

After going through this unit, you will be able to:

* define xenobiotics,
* describe the handling of xenobiotics in the body,
* explain whether xenobiotics remain unaltered or subjected to biotransformation.
* list out the enzymes responsible for biotransformation,
* mention the location of enzymes concerning with biotransformation.
* explain the meaning of Microsomal oxidation and the way these help in biotransformation.
* explain whether biotransformation enhances or reduces the toxic potentialities of a xenobiotic compounds,
* describe the significance of phase I & Phase II reactions,

17.2. INTRODUCTION

Modern world is dependant on industrial and Agricultural activity to meet the demands of growing population. Both these activities requires enormous quantities of chemicals as raw materials, fertilizers, pesticides etc. A rough estimate reveals that about 60,000 chemicals are in common use, which pose serious threat of environmental pollution. Table 17.1 shows approximate number of different chemicals in common use.

Table 17.1. Various commonly used chemicals.

S.No.	Type of Chemicals	Approximate Number
1.	Industrial chemicals	48000
2.	Drugs	1815
3.	Food additives	8625
4.	Cosmetics	3410
5.	Pesticides	3350

These chemicals, particularly, indiscriminate use of organochlorine pesticides, such as DDT, BHC, endosulfan etc., remain persistant in nature for a longer periods, transported by various means and finally enter into living organisms through food webs. These pesticides induce toxicity in the organisms by manifesting alterations at physiological and molecular levels consequently causing mortality of animal species. Pests have been co-existing with human society from times immemorial but in recent times man's attempt to eradicate the pest species, resulted in the enormous release of persistant pesticides into the nature during agricultural activity. Pesticides have considerably disturbed an ecological balance between plants and animals. Today it is alarming to note, that toxic chemicals are reported in Antarctic snow, blubber of polar whales, tissues of seals, penguin and polar bears. The pervading nature of pesticides can be assessed from the fact that they are found in human milk.

17.3. XENOBIOTICS AND ENZYMES

Conventional dictionaries have not provided a meaning for the word xenobiotics. Xeno is derived from greek which means stranger or foreign i.e., which is stranger to living system or foreign to the organism. Therefore, it can be said that the xenobiotic compounds means foreign compounds i.e., the compounds that are not found or synthesized in the organism. The compounds that occur in living systems, broadly classified into proteins, carbohydrates, lipids, nucleic acids, vitamins and minerals are called as endogenous substrates. There is distinct enzymatic machinery to catabolize or synthesize some other essential compounds from these endogenous substrates. Xenobiotic substrates are structurally and chemically different from endogenous substrate, therefore, they can't be handled by the normal metabolic machinery.

Majority of the xenobiotics are lipophillic in nature, therefore, this property enables them to penetrate the lipid membrane easily. Mechanisms of penetration, distribution or transportation and the factors influencing these functions have been discussed at length Unit 16. Metabolism of xenobiotics, carried out by a complex of relatively non specific enzymes, through microsomal oxidations, and these reactions modify the chemical nature of toxicant. Such modification is referred as Biotransformation. Metabolism of xenobiotics occurs in two phases. In phase one, a polar reactive group is introduced into the molecule, rendering it a suitable subtrate for phase II enzymes. Phase II reactions bring about conjugation to various endogenous substrates such as sugars, amino acids, etc. Conjugated products are exceedingly water soluble and are readily excreted. Phase I reaction products containing reactive intermediates may be more toxic than the parent compound. However, phase II reactions conduct the conjugation with endogenous substrates increase water sulubility and becomes fit to be eliminated from the body there by decreasing its bioavailability.

Therefore, the sequences of reaction events are generally referred as detoxication mechanism. In some cases the end products are more toxic than orginal compound and therefore the sequence of events is referred as intoxication.

Check Your Progress - 1

What is the meaning of Xenobiotic compounds and why they are called so?

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

17.4. BIOTRANSFORMATION

By now, you are aware that, a group of nonspecific enzymes conduct microsomal oxidations in two different stages. i.e., phase I and phase II, which, biotransform the xenobiotic compound and renders it fit for elimination through any one of eliminatary route (Unit 16). Now let us look into various aspects of phase I and II reactions and where these reactions are conducted?

17.4.1. Phase I Reactions

Phase I reactions are microsomal mixed function. Oxidation reactions are catalyzed by a non specific multienzyme system of microsomal particles derived from endoplasmic reticulum. The multi enzyme system has cytochrome P 450 as the terminal oxidase. Apart from microsomal oxidation the phase-I reaction include: cytosolic, mitochondrial oxidation, co-oxidation, in the prostaglandin synthetase reaction, hydrolysis, and epoxide hydration. All these reactions introduce polar group which in most cases can be conjugated during phase II reactions.

Microsomal Mixed Function Oxidations

Mixed function oxidations (MFO) are also known as mono oxygenations. In these oxidations, one atom of a molecular oxygen is incorporated into the substrate, while other is reduced to water. Monooxygenation of xenobiotics are catalysed by cytochrome P-450 dependent monooxygenase system or FAD containing monooxygenase located in the microsomes. Microsomes are the derivatives of endoplasmic reticulum. These microsomes can be obtained by the homogenization and centrifugation. Ultracentrifugation of post mitochondrial supernatant gives a microsomal sediment. Like endoplasmic reticulum the microsomes are also devided into rough (studded with ribosomes) and smooth types. Though both the microsomes possess all the components of cytochrome P-450 dependent monooxygenae system, the specific activity in smooth type is usually higher.

Cytochrome P-450 Dependent Monooxygenase System

Cytochrome P-450 is hemoprotein of the cytochrome b type. This is a carbon monoxide binding pigment. The absorption maxima of carbon monoxide reduced form is 450 nm. Therefore, it is named as cytochrome P-450. The role of cytochrome P-450 as the terminal oxidase in monooxygenation reaction is supported by considerable evidence. The initial proof was derived from the demonstration of concomitant light reversibility of carbon monoxide binding cytochrome P-450 complex and inhibition by CO-of C_{21} hydroxylation of a - hydroxy progesterone by adrenal microsomes. Direct proof was provided by the demonstration of monooxygenase systems, that is reconstituated from apparently homogenous cytochrome. P-450, NADPH cytochrome P-450, reductase, and phosphatidyl-choline, can catalize many monooxygenation reactions. The electrons involved in the reduction of cytochrome P-450 in monoxygenations or MFO are derived from NADPH.

Cytochrome P-450 is found in higher quantities in liver, where monooxygenation reactions are actively conducted. It is also reported in appreciable quantities in skin, nasal mucosa, lung, and gastrointestinal tract (GT), indicating the evolution of defence mechanisms at portals of entry. In addition to these, P-450 has been demonstrated in kidney, adrenal cortex and medulla, placenta, testes, ovaries, fetal and embryonic liver, corpus luteum, aorta, blood platelets and nervous system etc.

Cytochrome P-450 dependent microsomal mixed function oxidations are basically similar with regard to the role played by molecular oxygen, supply of electrons and non specific nature of enzyme action. But the substrates and reaction products fall into different categories. Therefore we can classify chemical reactions, basing on the type of products formed. They are as follows.

Epoxidation and Aromatic Hydroxylation

Epoxidation is very important microsomal reaction. It produces environmentally persistant epoxides, and highly reactive intermediates of aromatic hydroxylations. These reactive intermediates are reported to be involved in chemical carcinogenesis.

Benzo(a)pyrene with MFO reaction becomes 7,8 epoxide benzo(a)pyrene which subsequently by expoxide hydrolase gets converted into Benzo(a)pyrene 7,8, dihydrodiol. This is further metabolised by cytochrome p-450 monooxygenase system and converted into 7,8 diol -9 -10 epoxide isomers. These isomers are mutagenic and carcinogenic in nature.

Aliphatic Hydroxylation

Xenobiotic compounds of aliphatic nature, such as n-butane, n-pentane, hexane etc and alicyclic compounds such as cyclohexane are reported to be oxidised to alcohols. Similarly aliphatic side chains of aromatic compounds are more readily oxidised and this oxidation occurs at more than one position. For example n-propyl benzene is oxidised thrice to give following: alcohols and oxidation of these alchols are also possible.

Aliphatic Epoxidation

Many aliphatic and alicyclic compounds having unsaturated carbon atoms are known to be metabolized to epoxides by microsomal oxidations. Aldrin, a pesticide is oxidised to Aldrin epoxide or Dieldrin. This residue is reported in animals exposed to Aldrin. Epoxide formation is also known to occur in aflatoxin. The aflatoxin epoxide formation through MFO is considered as activation reaction since this product expresses carcinogenicity.

Dealkylations

Several xenobiotics including insecticides and drugs through monooxygenation reaction catalized by MFO undergo dealkylation. These dealkylations include O-dealkylations, N-dealkylation and S-dealkylation.

O-dealkylation : The best example for o-dealkylations is the demethylation of P-nitroanisole, which is converted into p-nitrophenol through unstable methylol intermediate D-nitro phenol is measured for demostrating the cytochrome P-450 dependent mono oxygenase activity.

Chlorfenvinphos an organophosphate insecticide undergoes o-dealkylations and this involves dealkylation of ester rather than ether. Similar dealkylation occur in a variety of vinyl, phenyl. phenylvinyl and napthyl phosphate and thiophosphate triesters.

N-dealkylation : Carbamate insecticide undergo N-dealkylation during monooxygenase activity. Both N-alkyl and NN-dialkyl carbamates are readily dealkylated. In some cases methylol intermediates formed are stable enough to be isolated. The insecticide carbaryl undergoes several monooxygenations, including attach on the N-methyl group.

S-dealkylation : S-dealkylation occurs in the xenobiotics containing thioethers. Methyl mercaptan, 6-Methyl thiopurine etc are the best examples for this.

N-Oxidation

N-Oxidation occurs in many ways. This oxidation results in the formation of hydroxylamine, oxime, and N-oxide. Hydroxylamine formation occurs in number of amines such as anilines and their subsituted derivatives.

Oximes can be formed by the N-hydroxylation of amines and primary amines. Further amines were considered as intermediates in the formation of oximes from primary amines.

Oxidative Deamination

Oxidative deamination is a common reaction in the cellular systems, through which amino acids are converted into ketoacids. This reaction occurs in cytosolic and mitochondrial fractions. But MFO of microsomes conduct oxidative deamination of xenobiotics and drugs. Oxidative deamination of amphetamine occurs in the Rabbit liver. However this reaction in dog or rat tend to hydroxylate aromatic ring. A close examination of the reaction indicates that it is probably not an attack on the nitrogen but rather on the adjacent carbon atom, giving rise to carbinol amine, which, subsequently produces a ketone by the elimination of ammonia.

S-Oxidation

This reaction is found common to insecticides belonging to several chemical classes including Carbamates (Methiocarb), Organophosphates (Phorate and demeton) and Chlorinated hydrocarbons (endosulfan and methiochlor). Thioethers in this reaction are oxidized to sulfoxides and sulfones by microsomal mono-oxygenations. S-oxidation is also common among drugs (e.g., chloropromazine).

P-Oxidation

Xenobiotics like trisubstituted phosphines through cytochrome P-450 dependent mixed function oxidase is converted into phosphine oxide.

Desulfuration and Ester Clevage

Insecticides such as phosphothionate and phosphorodithioate exhibit their insecticidal activity due to oxidative reaction in which P=S is converted P=O, there by the compound acts as cholinesterase inhibitors. This type of reaction, though, known in many organophosphate compounds, but most intensively studied in case of Parathion which is converted to Paraxon.

Phosphate ester bond in organophosphorous insecticide was believed to be hydrolysed. But now it is known to be due to oxidative dearylation. This is typical P-450 dependent oxidation, requires NADPH and inhibited by carbon monoxide. The reaction whether it is desulfuration or dearylation, involving ester clevage, occurs independently or catalized by two different P-450 is not clearly understood.

17.4.2. Other Microsomal Oxidations

Tertiary amines such as trimethyl amine and dimethyl aniline are metablized to N - oxides (CH3) N -------- > (CH3)3NO by amine oxidase which is not dependent on cytochrome P-450. This enzyme presently known as microsomal FAD containing mooxygenase and is dependent on NADPH and O_2. This enzyme exhibit wider substrate specificity. It handles variety of xenobiotics which includes tertiary and secondary amines, sulfur compounds such as sulfides, thioethers, thiols, thiocarbomates and organophosphorus compounds like phosphines. These compounds are also known to be the substrates of cytochrome P-450.

17.4.3. Non Microsomal Oxidations

So far we have considered metabolism of xenobiotics through microsomal oxidations and how the substrates of different chemical classes are handled by these non specific multienzyme complex containing cytochrome P-450.

In addition to the microsomal enzymes, several other enzymes located in mitochondrial and cylosolic system also known to handle the metabolism of xenobiotic compounds. The following enzymes distributed in different organs handle the xenobiotics whenever these compounds or possibly a portion of the compound structurally resemble endogenous substrates. These enzymes include, Alcohol dehydrogenase, Aldehyde dehydrogenase etc.

1. **Alcohol dehydrogenase :** The enzyme catalizes the conversion of alchohols to aldehydes or ketones, probably involve in the metabolism of foreign alcohols. Aldehydes formed in this reaction are highly toxic therefore considered as an activation reaction. Because of the lipophilicity, it is not readily excreted. Rate of alcohol oxidation varies between different alcohols. Primary alcohols are oxidized at higher rate in comparision to secondary and tertiary alcohols. Further oxidation of aldehyde is handled by aldehyde dehydrogenase.

2. **Aldehyde dehydrogenase :** This enzyme catalizes the aliphatic, aromatic aldehydes to acids which are subsequently eliminated after conjugation reactions. Aldehyde dehydrogenase, isolated from the mammalian liver is known to handle wide variety of aldehydes.

3. **Amine oxidase :** These enzymes help in oxidation of amines. There are two types of amine oxidases viz. Monoamine oxidases and Diamine oxidases.

Monoamine oxidases are flavoprotein containing enzymes located in the mitochondria and these enzymes are found in variety of tissues like liver, kidney, brain, intestine, blood platelets etc. In normal function this enzyme helps in the neurotransmittor turnover. In liver it is known to deaminate primary, secondary and tertiary aliphatic amines. The reaction rate is more with primary amines and also reaction rate appear faster when these are attached to aromatic rings.

Diamine oxidases, the soluble pyridoxal phosphate containing proteins have also contain copper. This enzyme is reported in liver, intestine, kidney and placenta. The aliphatic diamines with carbon skeleton numbering four (Putrecine) or five (cadeverine) are oxidized to aldehydes.

4. **Reduction reactions :** There are number of enzymes, which conduct reduction reactions in the cellular system. Xenobiotics containing Nitro, diazo, carbonyls disulfides, sulfoxides alkenes etc. are susceptible to reduction. In many cases it is very difficult to say that, whether these reduction reactions are nonenzymatic that proceed through various reduced nucleotides

such as NADPH, NADH or $FADH_2$ or through mediation of specific enzymes by utilizing reduced nucleotides. However, the enzymes like Nitroreductase, Azoreductase, Aldehyde and alcohol dehydragenases were reported to handle xenobiotic reduction in mammalian liver. Reduction of disulfides, sulfoxide, N-oxide, double bonds, and pentavalent arsenic compounds were reported to be conducted by the relatively non specific reductases in the liver.

5. Hydrolysis : There are many xenobiotics, which contain esters, amides, or substituted phosphates, and ester type of bonds, are subjected to hydrolysis by utilizing the hydrolytic enzymes meant for the hydrolysis of endogenous substrates. Hydrolases are distributed in most of the tissues, blood plasma. These enzymes are also found in soluble and microsomal fractions.

Esterases found in the tissues are divided into two types. Type A esterases include aryl esterases and where as type B esterases include cholinesterase of plasma acetyl cholinesterases of erythrocytes and nervous tissue, carboxylesterase and lipose etc., which are sensitive to inhibition by organophosphate xenobiotics.

Arylesterases are nonspecific enzymes which can hydrolyze short chain aromatic esters, these enzymes are activated by Ca^{+2} ions.

Warfare agents such as nerve gases, tabun, sarin and DFP are detoxified by utilizing hydrolytic enzymes present in the plasma and tissues

Similarly xenobiotics such as phthalic acid esters (Plasticizers), phenoxyacetic acid and Piclonic acid esters (herbicides) and pyrethroids and their derivatives (insecticides) and wide variety of drugs having ester and amide derivatives are detoxified by utilizing the hydrolizing enzymes present in aminal, plant and bacterial systems. Hydrolytic reactions are considered as part of phase I reactions and they do not utilize energy. The products of hydrolysis may be directly eliminated or after conjugation by phase II reaction.

6. Epoxide hydration : MFO (Mixed function oxidases) conduct epoxidation reactions in the aromatic and aliphatic fragments of xenobiotics. These expoxides proved, carcinogenic, but become polar by nonenzymatic rearrangement, which subsequently elimianted after getting conjugated with glutathione. Apart from this the epoxides are also deactivated by expoxide hydrase as well as glutathione epoxide-S-transferases. The enzymes concerning with hydration are located in microsomal fraction of mammalian liver. There is also an evidence that hepatic microsomal fraction contain more than one epoxide hydrases.

Check Your Progress - 2

What are Phase I reactions and Where do they occur?

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

17.4.4. Phase II Reactions

Phase II reactions are the biosynthetic reactions or conjugation reactions, in which, biochemical conjugation or union or coupling of a natural or foreign compound or its phase I metabolite takes place with endogenous substrate. The endogenous conjugating substrate may be derived from carbohydrate, a protein or a sulfur component. Conjugated products are more soluble. more polar and less lipid soluble, therefore, easily eliminated from the organism and hence considered less toxic. Conjugation reactions involve by some high energy intermediates and have been classfied into two types basing on activated conjugating agent or activated substrate as shown below.

Type - I

[Activated Conjugting Agent] + [Substrate] ———> [Conjugated Product]

Type - II

[Activated Substrate] + [Amino Acid] ——— > [Conjugated Product]

Type I reactions include formation of glycosides and sulfates and as well as methylated and acylated conjugates. Type II reaction result in peptide conjugates.

Glycoside Conjugation

For glycoside conjugation to occur, either uridine diphosphate glucose (UDPG) or uridine diphosphate glucuronic acid is required. These are formed by the enzymatic reactions [illegible]

Many phase I metabolites which are formed gets conjugated with UDPGA. This conjugation is mediated by glucuronosyl transferases, the enzymes located in microsomal membrane

Sulphate Conjugation

Sulphate conjugation renders fit for the elimination of several xenobiotics having alcohol, phenol, aryl amines etc. This process requires prior activation of sulfate, therefore, requires energy rich molecules, ATP

For the activation of sulphate it not only requires two ATP molecules but also the participation of ATP sulfurylase and APS kinase. The activation results in the production of PAPs. The PAPS (Phosphoadenosine phosphosulphate) conjugates with phase I xenobiotic metabolites and this reaction is catalized by sulfotransferases.

Sulfotransferases are several types. But steroid sulfotransferase is known to play a role in detoxication of xenobiotics and these enzymes, distributed in liver, kidney, intestinal mucosa, etc.

Methyl Transferases

Many endogenous and exogenous compounds subjected methylation reactions, which involve transfer of methyl group from three major co-enzymes to amines, phenols and thiols to form N-

O-and S-methyl conjugates. The co-enzymes that provide methyl groups includes: S-adenoxylmethionine (SAM), N^5 methyl tetrahydrofolate (H_4 folate) and vitamin B_{12} (Methylcorrinoid) derivatives. However, SAM is the most important for the methylation of xenobiotics. SAM is synthesized from L-methionine (sulfur containing essential amino acid) and ATP. Methylated products are less soluble in water in comparision to the parent compound, even this reaction is considered as detoxication reaction, as conjugated product is less toxic.

Some elements like mercury lead, tin, thallium, selenium, tellurium etc are also subjected to biomethylation.

The enzymes involved in biomethylation of elements are known to use SAM or vitamin B_{12} as methyl donors. Methyl mercury and other heavy metals pose a problem to higher animals as they absorbed through membranes of intestinal villi, cross blood brain barrier, and placental barriers.

Glutathione S-transferases

A large number of xenobiotics, particularly metabolites of phase I reactions, metabolised into mercapturic acids, and are eliminated either through bile or through renal route. Though formation of mercapturic acid was known about 75 years, the role of glutathione was appreciated only 25 years back for contributing cysteine moiety in the mechanism of formation of mercapturic acid.

Though Mercapturic acid formation involves participation of several enzymes such as, glutathione - S - transferase, - glutamyl transpeptidase, cysteinyl glycinase and acetyltransferase. the initial step catalized by glutathione - S - transferase is more important for the pathway. The entrie pathway is not elaborated here.

Glutathine - S - transferase helps in the conjugation of toxic electrophilic xenobiotics with endogenous glutathione (GSH) there by offers protection to many proteins and nucleic acids. Glutathione - S - transferase is widely distributed in all living organisms. These enzymes have been demonstrated in microsomes. Sufficient amount of glutathione (GSH) appears to be present in various mammalian tissues. Depletion in GSH enhances the toxicity of electrophilic xenobiotic metabolites. Glutathione S-transferase catalizes, reactions which includes the following : alkyltransferase, aryltransferase aralkyl transferase, alkenetransferase; apoxidetransferase.

Acylations

Acylation reactions require conjugating agent CoA, and N-acetyl-transferase, which is distributed in soluble fraction of liver reticulo endothelial cells, spleen, lung and intestinal mucosa. Foreign compounds having carboxylic acids and amides undergo biological acylation. This reaction makes the compound less water soluble than parent compound, but conjugated product is less toxic.

Amino Acid Conjugation

The first reaction in the amino acid conjugation is acylation reaction of type II. In this foreign carboxylic acids are activated in the presence of ATP and CoA to form acylo CoA derivatives, which inturn acylates the amino group of certain amino acids to form a peptide conjugates. The sequence of reaction occurs is follows:

Peptide conjugation has been reported to occur in several mammals, reptiles and fishes, different types of aminoacids were utilized in peptide conjugation. They are glutamine in mammals, ornithine in reptiles and birds, argenine and glutamine in ticks, alanine, glycine serine in insects etc.

Deacetylations

N-acetylated xenobiotics are subjected to deacetylation and this reaction is catalized deacetylation which is catalized by deacetylase.

Deacetylation occurs in several species. Acetylation and deacetylation are independent of one another and act in opposite directions. Deacetylated products may be excreted as such or may be in a modified form.

Phosphate Conjugation

Phosphate conjugation is very important reaction in the biosynthesis of phosphate esters. Phosphate conjugates of xenobiotics are rarely seen. However, insects have been found to utilize this mechanism as phase II reactions. Phosphate conjugation require ATP and an enzyme phosphotransferase.

Check Your Progress - 3 & 4

3. What is the signigicance of Phase II reactions ?

4. List out the important conjugation reactions.

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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17.5. SUMMARY

Organochlorine pesticides such as DDT, BHC, Aldrin and endosulfan etc are persistant in nature. Xenobiotics means foreign compounds i.e. they are not found in the organism nor synthesized in the organism and they can't be handled by normal metabolic machinery of the animal. Lipophillic property of the xenobiotic chemicals enables them to enter the lipid membranes easily. Proteins, Carbohydrates, lipids, nucleic acid and their metabolities and also vitamins are known as endogenous substrates. FAD containing monooxygenases catalizes the other microsomal oxidations. It handles variety of xenobiotics, such as tertiary, secondary amines, sulphides, thioethers, niocarbonates etc.

Alcohol dehydrogenases, aldehyde dehydrogenases amine oxidases and reductases participate or conduct non-microsomal oxidation. Hydrolytic reactions and hydration reaction help in the detoxication of xenobiotic substrates. Phase II reactions are conjugation reactions. Phase I metabolites, which are highly reactive are the substrates for phase II reactions. Conjugation mostly deactivates the reactant metabolites and makes it fit for the elimination. By doing so all important functional molecules like enzymes, proteins and nucleic acids are protected from the attack by phase I reactive metabolites.

Glycoside conjugation, sulphate conjugation, methylations, Acylations, peptide conjugation amino acid conjugation, glutathione conjugation and phospate conjugation are the phase II reactions which help in the detoxication.

17.6. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Xenobiotics means foreign compounds i.e., they are not found in the organism nor synthesized in the organism. They can't handled by normal metabolic machinery of the animal.

2. Phase I reactions are Microsomal Oxidations catalized by a nonspecific group of enzyme systems collectively known as mixed function oxidases (MFO) and these reactions occur in microsomal particles.

3. Phase II reactions are conjugation reactions. Phase I metabolites, which are highly reactive are the substrates for Phase-II reactions. Conjugation mostly deactivates the reactant metabolites and makes it fit for the elimination. By doing so all important functional molecules like, enzymes, proteins and nucleic acids are pretected from the attack by Phase - I reactive metabolities.

4. Glycoside conjugation, sulphate conjugation, methylations, Acylations, Peptide conjugation aminoacid conjugation, glutathione conjugation and phosphate conjugation are the Phase II reactions which help in the detoxication.

17.7. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Mention the important reactions that help in the biotransformation of xenobiotic compounds.

2. Write about Epoxidation and Aromatic hydroxylation.

II. **Answer the following question in about 10 lines each.**

1. What is the meaning of xenobiotic compounds and why they are called so?
2. Name the various components of MFO. When nature of MFO reaction is same, what is the basis for the classification of reactions?

Prof. S.L.N. Reddy

UNIT - 18 : METABOLIC EFFECTS OF POLLUTANTS

Contents

18.1. OBJECTIVES

By the end of this unit you will be able to :

* list out and describe the metabolic processes that liberate energy,
* mention the sites of oxidative phosphorylation,
* explain the mechanism of A.T.P. generation through electron transport system,
* list out various biochemical sites that are influenced by the toxicants,
* describe the influence of toxicants on the process of A.T.P. generation,
* mention various biochemical sites where toxicants can act and interfere with protein synthesis and breakdown.

18.2. INTRODUCTION

Metabolism is defined as the sum total of all chemical changes, which go on in a living organism for performing various anabolic and catabolic reactions. For the metabolic functions, the most essential things that are required in a cell includes availability of energy, and factors that promote or catalize various catabolic and anabolic reactions. Energy is obtained by a specific process called, oxidative pohsphorylation and the catalyst that accelerate various reactions in the body are known as enzymes. Therefore, in a cell, amongst various metabolic processes, oxidative phsphorylation and protein synthesis are considered to be very important metabolic events. Therefore, in this chapter the metabolic effects of pollutants on oxidative phsphorylation and protein synthesis are discussed.

18.3 METABOLIC EFFECTS ON OXIDATIVE PHOSPHORYLATION

Before we go into the effects of toxicants on oxidative phosphorylations, let us try to answer a question - What is meant by oxidative phsphorylation? The answer to this question is very simple, phosphate esterification accompanied by oxidation of food stuffs and nutrient metabolites yeilding energy rich terminal pyrophosphates of ATP. This was first demonstrated by Kalkar and Belitzer (1939). Though mechanism of this most fundamental energy conservation reaction is not clearly understood, the phosphorylation coupled with oxidation and electron transport system in the mitochondrial system is well knwon. Therefore at this stage let us also know some structural details of mitochondria, so that we can know where exactly this oxidative phsphorylation occurs? What are the biochemical events involved in this process? and where actually toxicant can act to disrupt the formation of ATP molecules.

18.3.1. Site of Oxidative Phosphorylation

Oxidative phosphorylation is primary process that occurs in mitochondria, where by aerobic cells produce ATP by the esterification of adenosine diphosphate with inorganic phosphate. It is well known that mitochondria, a shoe shaped organelle measuring about 3µm long and 1µm in diameter found in aerobic eukaryotic cells. The number of mitochondria varies markedly in different animals and tissues indicating metabolic state of the cells. The number of mitochondria in Euglena is about 15-20 where as Liver contains about 1,000-2,500. Mitochondria is a double membraned organelle. Both membranes, run parallel to each other but the inner membrane forms several invaginations which are called cristae. There may be considerable variation in the number, size, and shape of the cristae among mitochondria of different cells, indicating differences in metabolic status. The space within cristae and between two membranes is called the intractristal space. The space in the interior of the mitochondria is called the matrix space. The inner surface of cristal membrane consists of tripartite structures with short basepiece, stalk and rounded head

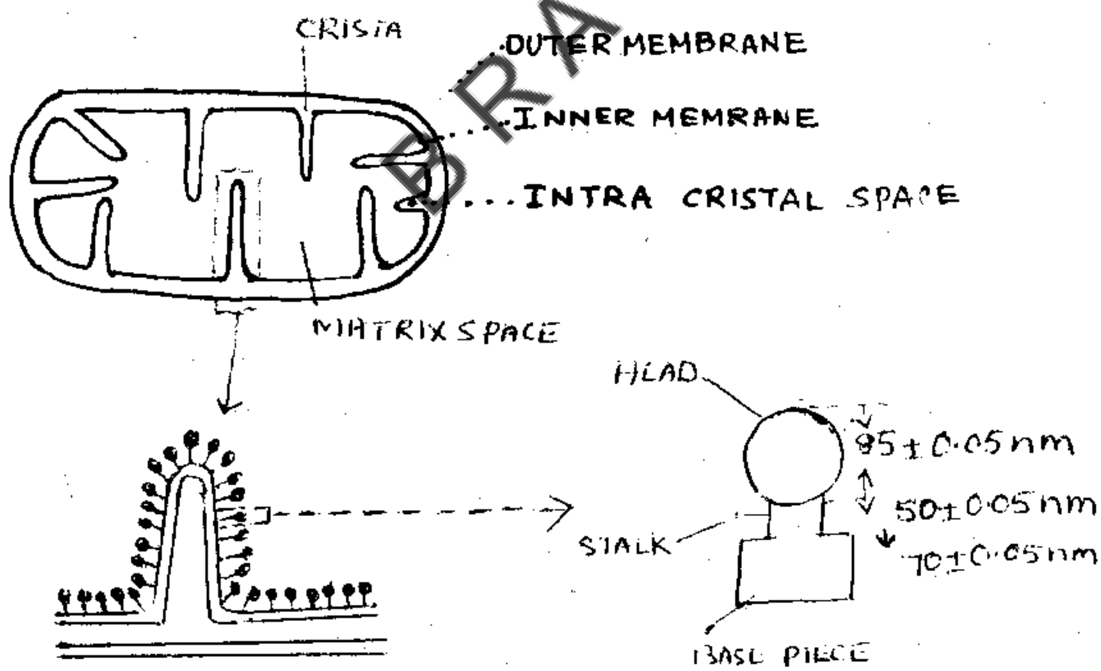

Fig. 18.1. Structural details of mitochondria.

Mitochordria contains, enzymes of Krebs cycle, electron transport system, oxidative phsphorylation, phospholipid synthesis, fatty acid oxidation and synthesis and also DNA. The enzymes responsible for electron transport system are located in basepiece of tripartite repeating Unit. The coupled synthesis of ATP by ADP and inorganic phsphate is catalized by the enzymes located in head piece and stalk sector.

18.3.2. Electron Transport and Phosphorylation

The inner membrane of basepiece of tripartite stalked particles have been fractionated into four complexes, each of which contains several components of electron transport chain. The details of these complexes are not discussed here.

You are aware that various dehydrogenases of Krebs cycle located in mitochondrial matrix produces the reduced equivalents like NADH + H^+ and $FADH_2$ during cellular oxidations. Electrons from these reduced equivalents enter electron transport series and when these electrons are passed on from one carrier to the other at three different stages, the liberated energy is utilized in the phosphorylation of ADP with inorganic phosphate. It is also known that whenever electrons are transferred from carrier complex I, it results in three phsphorylations and if electrons pass through carrier complex II. It results in two phosphorylations.

18.3.3. A.T.P. Generation

It is clearly known that coupling reactions for the formation of ATP from ADP and inorganic phosphates are located in the mitochondrial system. Coupling involves inter digitation of Electron transport chain and ATP generating system. In an uncoupled system, oxidation of substrates takes place and electrons are also subjected to transfer from one carrier to the other. Oxygen is utilized but ATP is not generated. Though this explains us that ATP formation is linked to coupling reactions, but the exact mechanism through which ATP is synthesized is not known. Several hypothesis have been proposed to explain mechanism of oxidative phosphorylations, which are not being discussed here. Sum of the aggregate events explained above will result in the production of ATP through oxidative phosphorylations.

18.3.4. Effect of Different Toxicants on Oxidative Phosphorylation

Wide variety of chemical compounds are known to affect the oxidative phosphorylation in different ways. This would depend upon nature and intensity of toxicosis. Impairment in the oxidative phosphorylations could be attributed to the mitochondrial disorganization or specific interaction toxicant with components that help in oxidation reactions, electron transport system, and subsequently coupling reaction of oxidative phosphorylation. Basing on the effect of toxicants on the mechanisms concerned with oxidative phosphorylations, the toxicants are classfied into several types. These include Electron transport inhibitors, uncouplers, energy transfer inhibitors and multiple types of inhibitors. Studying these different inhibitors will help us to know the metabolic effects of toxicants on oxidative phosphorylation.

Electron Transport Inhibitors

Agents that are able to interrupt electron flow at some point in the respiratory chain by acting on anyone of the four complexes stop electron flow, will inhibit oxidative phosphorylations. The chemicals that are found to interfere with the electron carriers include amytal pieridicin, and rotenone interfere with complex I, therefore prevent NADH linked oxidations. Malonate acts as competitive inhibitor of succinate and interferes with complex II and oxidation of succinate. Similarly carrier complex III is affected by Antimycin A and 2-heptyl 4 hydroxyquinoline N oxide (HOQNO). Carbon monoxide, Azide and Cyanide interfere with complex IV

Uncouplers

Some toxicants prevent the phosphorylation of ADP without interfering with electron transport. These compounds promote the dissipation of energy released during the electron transport, and prevent the production of ATP Therefore these compounds are regarded as uncouplers. Several pesticides such as, pentachlorophenol (PCP). Dinitrophenol (DNP) are considered as classical examples of uncouplers. Halogenated nitrophenols exhibiting, acaricidal, ovicidal, fungicidal and herbicidal activity possess uncoupling activity. The uncoupling activities vary depending upon substituents present in the benzene ring. Apart from these, carbonyl cyanides, phenyl hydrazones, salicylanilides, atebrin (Antimalarial drug) and dicoumarin (anticoagulant) are identified as uncouplers. Detoxification mechanism by microsomal enzymes render phenyl rings of xenobiotics to hydroxylated products Several hydroxylated products are also identified as potential uncouplers, if they are not cleared by phase II reactions.

Energy Transfer Inhibitors

Usually uncoupling takes place when energy dissipated during electron transport, preventing the production of ATP. The energy transfer inhibition also does the same function as uncoupling of ADP with inorganic phosphate. The difference between these two is that, the energy is not dissipated as energy conserving apparatus if mitochondria is intact. The energy combine with an intermediate in the energy coupling chain and hence block phosphorylation sequence that lead to the production of ATP. Oligomycin Aurovertin, Organotins and some pesticides known to affect ATP generation by acting at a locus closed to ATP formation.

Multiple Types of Inhibitions

Some xenobiotics exhibit specific toxic action, while in some cases toxic action is more complex. Overlapping occurs in the toxic action of some xenobiotic compounds and this could be attributed to variations in the concentration of a toxicant. Many herbicides (N-phenyl carbomates, 2.6, dinitroanilines and phenylamides) and some insecticides (cyclodienes) act as uncouplers at low concentration and inhibitors of electron transport at higher concentrations. The action of many herbicides, insecticides pharmaceuticals and anaesthetics may be different from that of classical chemicals, that exhibit ucoupling, and electron transport inhibition etc. These compounds because of their lipophilic nature can be partitioned into non polar regions of inner membrane of mitochondria. Partitioning may result in the alterations in the fluidity and permeability properties of the membrane. Changes in the permeability characterstics of the membrane might result in multiple types of inhibitions.

Check Your Progress - 1, 2 & 3

1. What is specific process that results in the formation of ATP.
2. Where does oxidative phosphorylation occur ?
3. Which structural features of mitochondria indicate metabolic status of animal?

Note : (a) Write the answer in the space provided below.

(b) Compare your answer with the one given at the end of this unit.

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18.4. EFFECT OF TOXICANTS ON PROTEIN SYNTHESIS AND BREAKDOWN

Protein synthesis and breakdown are very important metabolic processes of the cell. Cells maintain an equilibrium between rate of protein synthesis and rate of protein breakdown at any given point of time in order to regulate body functions. Protein synthesis is an essential biochemical process as it not only provides structure to the cell (Plasma membrane) but also provides various functional molecules such as enzymes, hormones, chromoproteins, immunoproteins, anticoagulants etc. At the same time protein breakdown is also another important process by which it abolishes the old proteins. Amino acids formed during protein degradation are useful in maintaining osmolarity, nitrogen regulation and also provide various amphibolic intermediates through transaminations and deamination reactions. These amphibolic intermediates are useful in the synthesis of some other essential cellular products and also act as alternate substances for the energy production. Thus we can go on appreciating the importance of proteins in cellular activities. This information is available in many basic text books of physiology and biochemistry. Therefore, elaboration on functional importance of proteins is avoided here

We have discussed the patterns of absorption, distribution and elemination of xenobiotics at length in Unit 16. Toxicants after they gain entry into the cellular system either it must initiate toxic action, or subjected to biotransformation or it may be stored in a particular tissue by binding to cellular components. Toxicant action depends on the biological half life values. Toxicants after their entry into the cell exert primary or secondary effects on various aspects of metabolism including protein synthesis and breakdown.

Possible Biochemical Sites of Toxicant Action on Protein Synthesis and Break Down

Toxicants may exert primary or secondary effects on nucleic acid and protein metabolism. Therefore, let us examine, and identify direct and indirect effects of toxicants on specific biochemical processes. We can locate the possible sites of toxicant action in the biochemical processes. These possible sites include: precursor incorporation into macromolecular synthesis i.e. synthesis of a complimentary strand of polynucleotide during DNA replication, synthesis of different kinds of RNAs and protein synthesis. Precursor incorporations are catalized by respective DNA and RNA polymerases. Therefore, toxicant induced inhibition of precursor incorporation by acting on DNA and RNA polymerases reflects direct effects of toxicants. Toxicant induced impairment in the sequential steps of amino acid assemblage i.e. initiation and elongation and termination steps also reflect direct effect of toxicants on protein synthesis.

It is well known that DNA, RNA and protein synthesis are energy requiring processess. At the same time precursor update by cell is also energy requiring process. Agents that disturb mitochondrial structure, also disturbs the production of ATP (Section 18.3.4.) by impairing the oxidative phosphorylation mechanism. Therefore, reduced levels of ATP indirectly affects the DNA, RNA and protein synthesis. Now let us examine the specific examples of toxicant action on the aforesaid biochemical sites.

Thymidine Incorporation into DNA and Modification of DNA Metabolism

Precursor incorporation studies have provided valuable information on the toxicant effects on DNA replication. Short term or acute effects are resulted in an inhibition of incorporation of thymidine and other precursors into DNA. But such inhibitory effects were found during early stages of toxicosis (i.e. upto 12 hours). Dimethyl benzanthracene intoxication in young rats inhibited an incorporation of thymidine. About 75% inhibition was found 6 hours after intoxication. Thymidine incorporation returned to normal level after 24 hours. Several hepatoxicants like carbon tetrachloride, thioacetamide, diethylnitrosamine galactosamine caused cellular necrosis and for few hours, thymidine incorporation was also found inhibited. However, thymidine incorporation markedly increases between 1-3 days after intoxication. Impairment of thymidine incorporation in synthesis of complementary strand during DNA replication could be attributed to the possible toxicant action on DNA polymerase. The increased incorporation after several hours indicates the detoxification of toxicant or it could be attributed to increased DNA replication preparatory to the replacement of cells lost by cell lethality and necrosis or due to DNA polymerization during the repair of DNA in the surviving cells.

Toxicant Effect on Precursor Incorporation in RNA and Modification of RNA Metabolism

It is well known that RNA synthesis is one of the essential factors to promote the protein synthesis. Different types of RNA synthesis is catalized by RNA polymerases I, II and III. Precursor incorporation indicates the synthesis of RNA. Inhibition in the incorporation suggests the impairment in the respective RNA polymerases. Inhibition of precursor incorporation in RNA is reflected in reduced levels of protein synthesis. Amantin is known to inhibit all types of RNA polymerases. The most commonly used radio active precursor for labelling RNA are orate, uridine, and orthophosphate. Many toxicants such as 4-dimethyl amino azobenzene, dimethyl nitrosamine and tannic acid inhibited the uridine precursor incorporation in nuclear RNA. Around 50% of inhibition was recorded for each toxicant between 6-48 hrs after intoxication. However recovery was witnessed after 72 hours. Recoveries in the precursor incorporation may be due to metabolic conversion of toxicant to less toxic metabolites by microsomal enzymes may be necessitated to replace the killed cells by promoting protein synthesis and mitotic activity.

Effect of Toxicants on Protein Synthesis and Modification of Protein Metabolism

There are two aspects of protein synthesis. The first aspect is preparation for the protein synthesis i.e. transcription DNA by polymerase and synthesis of different kinds of RNA by RNA polymerases I, II and III. The second aspect is the sequential steps of protein synthesis i.e. initiation, elongation and termination. It is known that many toxicants bring about the cessation of protein synthesis. Toxic action on protein synthesis may be due to secondary effects of toxicants in many other processes such as: alteration in the membrane permeability impairs the precursor uptake; energy production, and synthesis of m-RNA. Therefore, it is very difficult to pinpoint whether inhibition of protein synthesis is primary or secondary.

Carbon tetrachloride induces cellular necrosis, and the sequence of events and the possible role of protein synthesis in necrosis is still debated. In CCl_4 intoxicated rats, disaggregation of polyribosomes to monoribosomes or ribsomal subunits were found in the liver. The disaggregation was noticed in both free and membrane bound polyribosomes. Such disaggregation was attributed to the alterations in the structural component of m-RNA, and r RNA. Aminoacid incorporation is reduced in toxicant induced polyribosomal disaggregation causing reduction in the protein synthesis. On some occasions toxicants can induce synthesis of specific protein, while inhibiting synthesis of other proteins. Synthesis of metal binding proteins metallothionenin (which binds to Zn, Cd, and Hg and other ions) and Copper chelatin (which binds to copper ion) stands as good examples for the selective protein synthesis during toxic action. similarly induction of MFO in animal, intoxicated with certain aromatic xenobiotics can be taken as another example for toxicant induced protein synthesis. Induction of synthesis of specific proteins may be due to induced synthesis of appropriate m-RNA. Synthesis of specific proteins during the toxicosis forms a biochemical strategy of the animal to withstand the toxicosis, or to minimize toxic actions or to detoxify the toxicant. However, the synthetic activity be operated within reasonable limits of toxicosis.

There are certain toxicants which proved highly specific inhibitors of protein synthesis. Cyclohexamide inhibits peptidal transferase activity which catalizes formation of peptide bond between two aminoacids at 60S ribosomal sub unit. Inhibition stops the movement of ribosome along with m-RNA, and polyribosomes remain intact, even when it is treated with carbon tetrachloride which normally causes disaggregation. Another inhibitor puromycin which is structurally similar to aminoacyladenosine moiety of amino acyl t-RNA occupies the site of ribosome and an amide bond formed enzymatically between amino acid at peptidal t-RNA and puromycin, puromycin blocks the further elongtion of peptide and get dissociated from ribosome resulting with termination of premature peptide chain. Diphtheria toxicant inactivates elongation factor 2 (EF_2) which translocates the Amino acyl t-RNA along with polypeptidal chain to p site, therefore, stops the elongation process. Chloramphenical exclusively inhibits protein synthesis in prokaryotic cells and also protein synthesis in mitochondria.

18.5. SUMMARY

The process of oxidative phosphorylation results in the formation of ATP. Oxidative phosphorylation reactions occur in the stalked particle of mitochondria. Number, shape and size of the cristae indicate metabolic status of animal. Enzymes of Krebs cycle, electron transport system, oxidative phosphorylation, phospholipid synthesis, fattyacid oxidation and fattyacid synthesis are present in mitochondria. There are four electron carrier complexes, located in the base piece of stalked particle. Krebs cycle reactions occur in mitochondrial matrix. Oxidative phosphorylation is coupling reaction. Impairment in the oxidative phosphorylation could be attributed to inhibition in the electron transport, or uncoupling process due to dissipation of energy or both. Some toxicants like amytal, Antimycin azide, etc. stop the flow of electrons at one of the carriers, while some toxicants Dinitrophenol, pentachlorophenol, impairs coupling process, oligomycin and aurovertin prevent formation of ATP by inhibiting energy transfer. Some herbicides inhibit oxidative phoshorylation by multiple ways (i.e. by checking electron flow, transfering energy and preventing coupling reactions). Abertin antimalrial drug and dicoumarin anticoagulant are identified as uncouplers. Oligomycin, Aurovertin and Organotins are known to affect ATP generation by acting at a locus nearer to ATP formation. N-phenylcarbamate and 2,6 dinitroaniline (herbicides) and some cyclodiene insecticides promote multiple inhibitions. Amphibolic intermedates are ketoacids formed by the transamination and deamination of aminoacids. These are useful in the synthesis of essential molecules and act as substitutes for the krebs cycle intermediates.

18.6. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The process of oxidative phosphorylation results in the formation of ATP.
2. Oxidative pohosphorylation reactions occur in the stalked particles of Mitochondria.
3. Number, shape and size of the cristae indicate metabolic status of animal.

18.7. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write about the possible biochemical sites of toxicant action on protein synthesis and break down.
2. Describe the effect of toxicants on protein synthesis and modification of protein metabolism.

II. Answer the following questions in about 10 lines each.

1. Write about ATP Generation.
2. Write about effect of different toxicants on oxidative phosphorylation.
3. What are electron transport Inhibitors.
4. Write briefly about energy transfer inhibitors
5. Write about multiple types of inhibitions.

Prof. S.L.N. Reddy

BLOCK - 5

WILD LIFE MANAGEMENT

UNIT - 19 : WILD LIFE MANAGEMENT & CONSERVATION

Contents

19.1. OBJECTIVES

After going through this unit you will be able to:

* define the wild life,
* describe the wild life management and conservation,
* describe the causes for wild life depletion,
* list out the endangered species national parks and sanctuaries.
* explain the biosphere reserves,
* explain man and biosphere programmes,
* describe the present day need for wild life management and conservation.

19.2. INTRODUCTION

Wild life means the wild undomesticated animals living in their natural habitats as forests, deserts, grasslands etc., In the ecologist point of view wild life includes both the naturally occuring animals (fauna) as well as plants (flora). Wild life is a renewable resource like soils, water and forests as it can be used time and again without being destroyed. Habitat can be defined as an area where the occurrence of an animal is more and the basic needs of the animal like food, cover and shelter are provided. Depending upon its social behaviour the animal has its home range and territory within the habitat. Therefore the relation between the animal and habitat is complex and variety of parameters which make it prefered or dependent The increased anthropogenic pressure in the form of extraction of food, fodder and poaching for skins, hide, musk, tusk, etc., has caused habitat fragmentation, shrinkage and finally resulting in the loss of valuable animal species. Therefore the wild life conservation started with protecting the wild fauna in the areas where animal population had dwindled from near abundance to near extinction.

Conservation means the utilisation of renewable national resources in such a way that they are not destroyed but are not to be used later. Wild life management is a part of conservation which is concerned with assuring the maximum possible populations of wild animals consistent with other land uses in the same area and with the number that the given habitat will support.

The major objective of the study of wild life is to impart knowledge to the students about ths status of wild life, its management and conservation for the protection of wild species (both flora and fauna) As per projections of the world conservation strategy. The picture in 2000 AD in IUCN (International Union for the Conservation of Nature) and associated organisations likely to be as follows.

1. Half the tropical forests and all the low land rain forests (except parts of Amazon) would be lost.
2. Vegetation cover over vast areas will get eroded and about 20,000,000 sq km of land will get at the brink of becoming desert.
3. About one-third of the worlds crop lands will get eroded due to bad irrigation, desertification growing urbanisation and Industrialisation.
4. With the reduction in the tropical forests 15-20% of the forest species of plants and animals will get extinct as over 1000 vertebrates and 25,000 plants have already been threatened
5. Near-shore damage and over fishing will collapse major world fisheries.
6. With the world populations reaching 6,000,000,000 will be facing food crisis as the above factors will tend to reduce production specially in South Asia, the food per capita will be reduced.
7. The burning of fossil fuel and the loss of forests may start affecting the global climate, which may lead to the floods and famines in less developed nations.

19.3. NATIONAL CONSERVATION STRATEGY (NCS)

The development of an effective National Conservation Strategy is formidable task as both conservation and development aspect have to be entertained. We have spent the first 2000 years of our continent in headless exploitation of natural resources with little or no thought for the consequences. Our NCS has now to find a way of living in hormony with nature for the next 2000 year. As a matter of policy, all native mammals, birds and reptiles need to be protected. Laws protecting wild life and covering their habitats need to be propagated as preservation of habitat is basic to the preservation of any species.

19.4. AIMS OF WILD LIFE MANAGEMENT

Wild life management aims at:

1. Protecting natural habitats through controlled limited exploitation of species.
2. Maintenance of the viable number of species in protected areas like National Parks sanctuaries, biosphere reserves etc.
3. Establishment of biosphere reserves for plants and animal species.

4. Protection through legislation.
5. Improving the existing protected areas as sanctuaries National Parks etc.
6. Imposing restrictions on export of rare plant and animal species and their products.
7. Educating public for environmental protection at all levels.

19.5. REASONS FOR DEPLETION OF WILD ANIMALS

Many wild animals become extinct due to the following human and natural activities

1. Absence of cover or shelter to wild animals.
2. Due to deforestation for cultivation, road building, railway routes, dam construction, urbanisation, reduction in the area for free movement of wild animals which retard reproductive capacity of certain wild animals.
3. Destruction of wild plants and forests for timber, charcoal and firewood often deprive wild animals their most palatable food and affects their survival.
4. Noise pollution by different transporting media and polluting the river water have adversely affected wild animals.
5. Various natural calamities such as floods, droughts, fires, epidemics etc., have also caused great destruction of wild life.
6. Hunting methods of all kinds for any purpose like food, recreation, hide, fur, plumage, musk, tusk, horn etc., have caused destruction of wild life.
7. Destruction of their natural habitats due to expanding agriculture, urbanisation and industrialisation.
8. Over grazing by domestic animals that convert the area into deserts.

19.6. ENDANGERED SPECIES

Amphibians and Reptiles

1. Agra monitor lizard (*Varanus griseus*)
2. Atlantic ridley turtle or Kemp's ridley turtle (*Lepidochelys kempii*)
3. Barred, oval or yellow monitor lizard (*Varanus flavescens*)
4. Estuarine crocodile (Crocodylus proosus) Salt water crocodile (*Crocodylus palustris*)
5. Gharial (*Gavialis gangeticus*)
6. Gangas soft-shelled turtle (*Trionyx gangeticus*)
7. Green sea turtle (*Chelonia mydas*)
8. Hawksbill turtle (*Eretmochelys imbricata inlscata*)
9. Himalayan net or salamander (*Trylototriton verrucosus*)
10. Indian egg-eating snake (*Elachistodon westermanni*)
11. Indian sift-shelled turtle (*Lissemys punctata punctata*)

12. Indian tent turtle (*Kachuga tecta tecta*)
13. Large Bengal monitor lizard (*Varanus bengalensis*)
14. Leathery turtle (*Dermochelys coriacea*)
15. Loggerhead turtle (*Caratta caretta*)
16. Olive-Back loggerhead turtle (*Lepidochelys olivacea*)
17. Pythons (*Genus Python*)
18. Three keeled turtle (*Geoemyda tricarinata*)
19. Tortoise (*Testudinidae, Trionvchidae*)
20. Viviparous toads (*Nectophylynoides spp.*)
21. Water lizard (*Varanus salvator*)

Birds

1. Andaman teal (*Anas gibberifrons albogularis*)
2. Assam bamboo partridge (*Bambusicola fytechii*)
3. Bazas (*Aviceda jeordoni and Aviceda leuphotes*)
4. Bengal florican (*Eupodotis bengalensis*)
5. Black necked crane (*Grus nigricollis*)
6. Blood pheasants (*Ithaginis cruentatus tibetanus, Ithaginis cruentatus kuseri*)
7. Brown headed gull (*Larus brunnicephalus*)
8. Cheer pheasant (*Catreus wallichii*)
9. Combduck (*Sarkiaiornis melanotos*)
10. Forest spotted owlet (*Athene blweitti*)
11. Great Indian bustard (*Choriotis nigriceps*)
12. Great Indian hornbill (*Buceros bicronis*)
13. Hooded crane (*Grus monacha*)
14. Hornbills (*Ptilotaemus tickelli. asteni, Aceros nepalensis, Rhyticeros undulatus ticehursti*)
15. Houbara bustard (*Chlamydotis undulata*)
16. Humes bar-backed pheasant (*Syrmaticus humiae*)
17. Indian pied hornbill (*Anthracoceros malabaricus*)
18. Jerdon's courser (*Cursoius bitorquatus*)
19. Lammergier (*Gypaetus barbatus*)
20. Large falcons (*Falco peregrinus, Falco biarmicus and Falco chicquera*)
21. Large Whistling teal (*Anatidae*)

22. Monal pheasants (*Lophorus impejanus*)

23. Mountain quail (*Ophyrysia superciliosa*)

24. Narcondom hornbill (*Rhyticeros undulatus narcondami*)

25. Nicobar megapode (*Megapodius freycinet*)

26. Nicobar pigon (*Caloenas nicobarica pelewensis*)

27. Peacock pheasant (*Polyplectron bicalcaratum*)

28. Peafowl (*Pavo cristatus*)

29. Pinkheaded duck (*Rhodonessa caryophyllacea*)

30. Solater's monal (*Lophophorus sclateri*)

31. Siberian white crane (*Grus leucogeranus*)

32. Spurfowl (*Gallaperdix spp.*)

33. Tibetan snow-cock (*Tetragallus tibetanus*)

34. Tagopan pheasants (*Tragopan melanocephalus, Tragopan blythii, Tragopan satyra, Tragopan temmincki*)

35. Whitebellied sea eagle (*Haltaetus leucogaster*)

36. White-eared pheasant (*Crossoptilon crossoptilon*)

37. White spoonbill (*Platalea leucorodia*)

38. White-winged wood duck (*Cairina scutulata*)

Mammals

39. Hooklock gibbon (*Hylobaes hooklock*)

40. Himalayan brown bean (*Ursus aretos*)

41. Sloth bear (*Melursus ursinus*)

42. Malabar civet (*Viverra megaspila*)

43. Tiger-civet (*Prionodon pardicolor*)

44. Striped hyaena (*Hyaena hyaena*)

45. Tiger (*Panthera tigris*)

46. Indian lion (*Panthera leo*)

47. Leopard (*Panthera pardus*)

48. Snow leopard (*Panthera uncia*)

49. Desert cat (*Felis silverstris*)

50. Hunting leopard (*Acinoryx jubatus*)

51. Dugong (*Dugons dugong*)

52. One horned Rhinoceros (*Rhinoceros unicornis*)

53. Indian wild ass (*Asinus hemionous*)

54. Kashmir stag (*Cervus elaphus henglu*)

55. Swamp deer (*Cervus duvaucelli*)

56. Tibetan antelope (*Pantholaps hodgri*)

57. Wild buffalo (*Bubalus bubais*)

58. Wooly flying squirrel (*Eupetaurus cinereus*)

59. Whales and dolphin species (*Kogia* species, *Stenella* species, *Sotalia* species, *Steno* species, *Tursiops* species, *Langenorhynchus* species, *Ziphius* species, *Neomris* species, *Delphinus* species etc.

60. Himalayan marnmot (*Marmota bobak*)

19.7. NECESSITY FOR WILD LIFE CONSERVATION

The conservation of wild life is required because of the following reasons.

1. The wild life helps us in maintaining the balance of nature. Once this equilibrium is disturbed it leads to many problems. The destruction of carnivores or insectivores often leads to the increase in herbivores which inturn affects the forest vegetation or crops.
2. The wild life can be used commercially to earn more money. It can increase our foreign exchange earnings if linked with tourism.
3. The preservation of wild life helps many naturalists and behaviour biologists to study morphology, anatomy, physiology, ecology, behaviour biology of the wild animals under their natural surroundings.
4. The wild life provides best means of sports and recreation.
5. The wild life of India is our cultural asset and has deep-rooted effects on Indian art, sculpture, literature and religion.

19.8. NATIONAL PARKS AND WILDLIFE SANCTUARIES IN INDIA

State	District	Name of national parks/sanctuaries	Area	Fauna
1	2	3	4	5
Andhra Pradesh	Warangal	Pakhal Wildlife Sanctuary	54400 ha.	Tiger, panther, hyaena, fox jungle cat, chawsingha, etc.
	Medak	Pocharam Wildlife Sanctuary	2950 ha.	Horned games, aquatic birds, including spot bill
	Adilabad	Kawal Wildlife Sanctuary	89096 ha.	Horned game and carnivores.
	West Godavari	Kolleru Pelicanary	67340	Pelicans

Arunachal Pradesh	Tirap	Namidapha wildlife Sactuary	807.82 sq.km	Tiger, leopard, snow leopard, clouded leopard several species of cats, elephant, gaur, jakin, swamp, deer, hog deer, sloth bear, himalayan black bear, slow loris, hoclock, Malabar squirrel, etc.
Assam	Kaziranga	Kaziranga National Park	430 sq.km	Great Indian one-horned rhinoceros, wild buffalo, gaur, swamp deer, hog deer, sambar, elephent, tiger, leopard cat, wild boar, langur, pelican, florican, patridge, python, etc.
	Kamrup	Manas wildlife Sanctuary	580 sq.km	Same as in Kaziranga, also golden langur, pigmy hog, water montor; bird life is rich and interesting.
		Sonai-Rupa Wildlife Sanctuary	195 sq.km	One-horned rhinoceros, elephant, wild buffalo, wild boar, sambar, swamp deer, barking deer, tiger, leopard, wild dog, sloth bear, hornbill imper
Bihar	Hazaribagh	Hazaribagh National Sanctuary	184 sq.km	Tiger, leopard, sloth bear, wild dog, hyaena, samber harking deer, chital, chaw Singha, neelghai, civet cat, wild boar, etc.
	Palamau	Betla National Park	345 sq.km	Tiger, leopard, jungle cat, chital, gaur, elephant sambar wild boar, langur, rhesus, etc.
	Bettiah	Ganauli Sanctuary	132 sq.km	Leopard, wild board, sloth bear, chital, langur, rhesus, etc.
Goa	Goa	Mollen wildlife Sanctuary	240 sq.km	Panther, gaur, samber, barking deer, mouse deer, malabar squirrel, flying squirrel, ant eatter, porcupine, slender loris, grey jungle fowl and number of other birds, python, king cobra, etc.
		Cotgao wildlife Sanctuary	105 sq.km	Same as above

Gujarat	Junagarh	Gir National Park	140.40 sq.km	Indian lion, panther, hyaena, sambar, chital, neelgai, chaw singha, chinkara, wild boar, langur, crocodile
		Gir Wildlife Sanctuary	1412.13 sq.km	Same as above
	Bhavanagar	Velavadar National Park	17.83 sq.km	Black-buck, wolf, etc.
	Surendra nagar	Wild Ass Sanctury in little Rann of Kutch	4840.83 sq.km	Wild ass, neelgai, wolf, Chinkara
	Ahmedabad	Nal Sarovar Bird Sanctuary	115 sq.km	Water birds
Harayana	Gaurgaon	Sultanpur lake Bird Sanctuary	28.87 sq.km	Most of the birds are migratory
Himachal	Chamba	Sechu-tun-Nalah Sanctuary	414.40 sq.km	Goral, serow, ibex, Himalayan Tahr, musk deer, Himalayan
	Chamba	Gamgul-Siya Behli Sanctuary	900.75 sq.km	brown bear, Himalayan black bear, snow fox, martin, weasal, monal, tragopa,
	Chamba	Kugti Sanctuary	11828.70 ha.	snow cock, koklash, kalij, chakor.
	Kinnaur	Daranghati Sanctuary	16740 ha.	Same as above
	Mandi	Nargu and Winch Camo Sanctuary	27837 ha.	Same as above
	Dilaspur	Gobindsagar	10034 ha.	Water birds
Jammu & Kashmir	Srinagar	Dachigam Wildlife Sanctuary	55 sq.km	Hangul, serow, musk deer, Himalayan black bear, brown bear, Pine martin, other avian fauna
Karnataka	Mysore	Bandipur National Park	874.20 sq.km	Elephant, gaur, sambar, chital barking deer, chawsinha, wild boar, tiger, leopard, sloth bear, jungle cat, langur, wild dog, bird life quite rich
	Coorg	Nagarhole National Park	571.5 sq.km	Same as Bandipur
	Mysore	Ranganthitto Bird Sanctuary	26.70 sq.km	Open bill, stork, white ibis, little erget, cattle egret, darter, cormorants, river tern, spoon bill, crocodile

Kerala	Periyar Wildlife	777 sq.km	Elephant, tiger, leopard. sloth bear, wild dog, gaur, neelgai, sambar, barking deer, wild boar
	Wynad wildlife Sanctuary	344 sq.km	Similar as Perilyar
	Neyyar Wildlife Sanctuary	128 sq.km	Elephant, sambar, chital neelgai, wild boar.
Madhya Pradesh	Kanha National Park	446.6 sq.km	Tiger, leopard, gaur, swamp, deer of hard ground, sambar, chital, black duck etc.
	Shivpuri National	155.55 sq.km	Tiger, leopard, neelgai, chewsingha, sambar, chital, etc.
	Bandhavgarh National Park	267.75 sq.km	Tiger, leopard, gaur, sambar, chital, barking deer, chinkara, wild board, neelgai, sloth bear.
Maharashtra	Tadoda National Park	116.5 sq. km.	Tiger, Panther, Sloth bear, gaur, sambar, chital, neelgai, chinkara
	Dhakna-Kilkaz Wildlife Sanctuary (now under project tiger)	381.5 sq.km.	Tiger, Panther, gaur, sambar barking deer, chawsinghs, sloth bear, wild board and chital confined to flat tracts, Bird life rich
	Yawal Wildlife Sanctuary	177.5 sq.km.	As in Dhakha-Kolkar and also jungle cat, bonnet macaque, langur, neelgai, wild dog, etc.
	Karnala Bird Sanctuary	4.48 sq.km.	140 species of birds seen during October to April: other wildlife are panther, chawinghs and common langur.
Manipur	Keibul Wildlife Sanctuary	25 sq.km.	Brown-antered deer and also some water birds
Meghalaya	Balpakram (proposed) Sanctuary	221 sq.km.	Elephant, gaur, wild boar sambar, chital, etc.
Mizoram	Dampa Wildlife	180 sq.km	Tiger, leopard, elephant gaur, sambar, barking deer, wild board, wild dog, Himalayan black bear, leopard, cat, etc.
Nagaland	Intangki Wildlife Sanctuary	202.02 sq.km.	Tiger, panther, clouded leopard, elephant, gaur, barking deer, etc.

Orissa		Simplipal National park (proposed)		Elephant, sambar, barking deer, leopard, tiger, etc.
		Khalasuni Wildlife	115 sq.km.	Tiger, leopard, sloth bear, elephant, gaur, neelgai, sambar, barking deer, chital
Punjab		Abohar Wildlife Sanctuary	228 sq.km	Black buck and several species of birds
Rajasthan	Jaipur	Ranthambore (Tiger project)	392 sq.km.	Tiger, leopard, jungle cat, sloth bear, neelgai, sambar, chital, wild boar, etc.
	Alwar	Sariska Wildlife Sanctuary	195 sq.km	Tiger, leopard, hyaena jungle cat, sambar, neelgai chawsingha, etc.
	Bharatpur	Ghana Bird Sanctuary	29 sq.km.	About 300 migratory and resident birds. Also black buck, wild boar, sambar, chital etc.
Sikkim		Kanchenjunga National Park	800 sq.km.	Musk deer, goral, bharal, Himalayan black bear, show, leopard, tibetan wolf
Tamil Nadu		Mudumalai Wildlife Sanctuary	321 sq.km.	Tiger, leopard, elephant guar, sambar, chital, sloth bear, wild dog
		Vedanthangal Water bird Sanctuary	30 sq.km.	Several species of water birds
Uttar Pradesh		Corbett National Park	525 sq.km.	Tiger, leopard, sloth bear, elephant, sambar, chital, hog deer, barking deer, chawshingha, wild boar, crocodile, rich bird life.
		Dudwa National Park	500 sq.km	Tiger, leopard, sloth bear, swamp deer, sambar, Chital, hog deer, barking deer, neelgai
West Bengal		Sunderban Tiger Reserve	2585 sq.km	Tiger, sambar, Chital wild board, several species of birds and crocodiles
		Jaidapara Wildlife Sanctuary	115.5 sq.km	Rhino, elephant, tiger, leopard, wild board, gaur, sambar, barking deer.
		Senchal Wildlife Sanctuary	38.88 sq.km	Serow, Himalayan black bear, goral, etc.

19.9. SPECIAL PROJECTS FOR WILD LIFE CONSERVATION

Some special projects to protect selected wild life species are also undertaken in India.

1 **Project Tiger:** Eleven tiger reserves located in different kinds of habitats in 10 states covering an area of 15,800 sq.km constituting 0.49% of the total geographic area of the country is under wild life management.

2. **Gir Lion Project:** In Gujarat Gir forest is the only surviving habitat of Asian lion clearing of forest for agriculture, excessive cattle grazing and other factors led to decline in the lion population. As a result of declaring the Gir forest area as National Park in view of the wild life management, there has been an increase in the lion population.

3. **Crocodile Breeding Project:** This project was initiated in 1975 to manage and conserve the declined crocodile population

4. **Rhinos Conservation:** In Assam this was introduced in 1987 for effective and intensive management of Rhino habitats.

5. **Snow Leopard Project:** Throughout Himalayas this project is being taken to create 12 snow leopard reserves.

19.10. BIOSPHERE RESERVES

Biosphere Reserve Net Work Programme was launched by UNESCO in 1971 under its "Man's and the Biosphere Programme" (MAB) The objectives that combines the four major groups conservation, research, education and local involvement are:

1. Conserve representative samples of ecosystems
2. Provide long term in situ conservation of genetic diversity
3. Promote and facilitate basic and applied research and monitoring
4. Provide opportunities for education and training
5. Promote appropriate sustainable managements of the living resource
6. Disseminate the experience so as to promote sustainable development elsewhare and
7. Promote International Cooperation

Biosphere Reserves include natural minimally disturbed, man modified and degraded ecosystem. In India nearly 13 representative ecosystems are identified for protection.

Biosphere Reserves are given below

Sl.No.	Biosphere Reserve	States where located
1.	Namdapha	Arunachal Pradesh
2.	Uttarakhand	Uttar Pradesh
3.	Gulf of Mannar	Tamil Nadu
4.	Sunderbans	West Bengal
5.	Thar desert	Rajasthan
6.	Manas	Assam

7.	Little Ran of Kutch	Gujarat
8.	North Islands of Andamans	Andaman & Nicobar
9.	Nanda Devi	Uttar Pradesh
10.	Khaziranga	Assam
11.	Kanha	Madhya Pradesh
12.	Nokrek	Meghalaya
13.	Nilgiries	Karnataka, Kerala, Thamilnadu

19.11. PRESENT NEED

In view of what has been indicated, systematic studies of all the endangered species, their habitats and biology need to be made, so that they could be effectively protected and conserved. Techniques allowing conservation of wild life need to be so developed that they have minimum or no disturbance to agricultural production. Special sanctuaries and wild life research centres need to be developed at the critical locations to give protection to the native animals and birds. Forests have to play a significant role in this venture. Shooting and killing of wild life is to be strictly prohibited, provided there is no significant damage to agricultural crops or domestic livestock. It is to be permitted only a situation of self defence.

19.12. WILD-LIFE PROTECTION ACT

In the wild life (protection) Act 1972 there is no legal provision for identification of core areas to promote sacro-sanct conditions, where wild life can feed, procreate, and develop undisturbed. In any sanctuary or National Park, there should be three zones.

1. A core zone where all foresty and harvesting operations are prohibited and even entry is restricted except for population studies and scientific investigations.
2. A transitory or intermediate zone, where wild life come out for browsing and grazing and where visitors are allowed to go and see wild life. In this zone harvesting and collection operations are controlled by the order of chief wild life warden under Act 33 of Indian wild life (Protection) Act.
3. A buffer zone or surround where facilities for camping of tourists are provided.

The concept of preparation of management - plans for management of wild life to take care of the protection of the environment and conservation of nature and natural resources is gaining ground. Efforts to study the population dynamics, their seasonal movements, availability of food, water, shelter, salt-licks, wallows, interaction of plants and animals etc. are being made. Identification of core areas should be immediately done in all sanctuaries before it is too late to preserve the natural habitats. The concept of alienation of core-areas (upto 20 to 30% of total area) and included in them the "Natural Biosphere Reserves" and "Ecotype forests" is the result of the growing concern of environmentalists and wildlife enthusiasts to preserve the natural ecosystems and the virgin environments covering our indigenous flora and fauna in totality. Habitat preservation is as important as wild-life conservation but the wave of environmentalism should not undetermine the basis role of forests and their productivity.

The preamble to Indian Wild Life Bill seeks to:

a) Constitute a wild life Advisory Board for each state

b) Regulate hunting of wild animals and birds

c) Laydown the procedure for declaring areas as sanctuaries and national parks etc.

d) Regulate possession, acquisition or transfer of, or trade in wild animals, animal articles and trophies and taxidermy thereof.

e) Provide penalties for controvention of the act.

In short the basic idea of all sanctuaries, National Biosphere Reserves, and Ecotype forests would be to preserve the ecosystem of forests available in the sanctuary and work in such a manner that the habitat improves and become more congenial for wild-life (both flora and fauna). Uncontrolled exploitation has been the prime cause for the decline of wild life throughout the world, because of the enormous profits made from this trade. To control thriving global and illegal trade of our endangered species, India became a party in 1976 to the "International Convention on Trade in the Endangered Species of Wild Fauna and Flora"

India further demonstrated its committment to the cause of conservation by participating in an International conference.

Check Your Progress - 1

1 What is wild life Protection Act.?

Note: a) Write the answer in the space given below.

b) Compare your answer with the one given at the end of this unit.

19.13. SUMMARY

Wilf Life means the wild undomesticated animals living in their natural habitats and is renewable resource. Conservation means the utilisation of renewable natural resources in such a way that they are not destroyed but are to used later. Wild life conservation started with protecting the wild fauna in the areas where animal population is declining from near abundance to near extinction. Wild life management is a part of conservation which is concerned with ensuring the maximum possible populations of wild animals consistent with other land uses in the same area and with the number that the given habitat will support, Wild life management aims at protection of natural habitats. maintaining the species, establishing the biosphere reserves, improving the existing areas as sanctuaries and national parks, imposing restrictions on export of rare plant and animal products and educating the public. The reasons for depletion of wild animals are the absence of shelter to wild animals due to deforestation, noice pollution, natural calamities, hunting, natural habitat destruction, over grazing by domestic animals etc., The necessity for wild life conservation is to maintain the balance of nature and to preserve the cultural assets. For this many special projects like Tiger Project, Gir Lion Project, Crocodile breeding project, Snowleapard Project, Rhino Conservation Project etc., are taken up to protect selected wild life species, Biosphere Reserve net work programmes were also launched by UNESCO under man and the Biosphere Programmes (MAB). A list of endangered species of various groups of animals and list of important National Parks and sanctuaries are given.

19.14. CHECK YOUR PROGRESS: MODEL ANSWERS

1. In 1972, the Wild Life Protection Act was promulgated. The Act prohibits hunting, killing, capturing, tapping, injuring wild animals in the forest, and in the public or private lands. The act has provision for setting up national parks and sanctuaries where wild life can be protected.

19.15. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. What is wild life? Enumerate the reasons for wild life depletion?
2. Write about the National Parks and Sanctuaries of India?
3. Write notes on Biosphere Reserves?
4. What are the aims and objectives of wild life management?

II. Answer the following questions in about 10 lines each.

1. Write about the wild life Protection Act.?
2. If wild life management steps are not taken in the present situation what will be the fate of nature and global environment. Think in scientific lines?
3. What are the special projects for wild life?
4. What is the necessity for wild life conservation?

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FACULTY OF SCIENCE
P.G. DIPLOMA IN ENVIRONMENTAL STUDIES
Course-III:Contemporary Environmental Issues
Model Examination Paper

Time: 3 Hours. Max. Marks:100

Section-A

4x15 = 60

Answer any four of the following questions
each question carries equal marks.
Answer the following questions in about 30 lines each.

1. Describe the different components of ecosystem.
2. Write a brief note on inland waters and their ecosystem.
3. Write briefly on nitrogen fixation.
4. What is ecological sucession? What are its three major aspects?
5. Write an essay on water pollution in urban India.
6. Describe in detail about the forest management.
7. Describe behavioural adaptations in desert reptiles.
8. Write an essay on non-carcinogenic disorders of liver.

Section - B

5x8 = 40

Answer any five of the following questions.
Each question carries 8 marks.
Answer the following questions in about 10 lines each.

9. Describe different components of ecosystem.
10. Briefly write on detritus food chain.
11. Write briefly on nitrogen fixation.
12. What are the effects of chlorobluorocarbons on ozone layer?
13. How can the solid wastes be utilised.
14. Write a brief account on thermal pollution.
15. What are the biochemical reactions associated with CO_2?
16. Write briefly about rate of penetration of toxicants
17. What are electron transport inhibitors?
18. What is the necessity for wild life conservation?

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Course IV B: Environmental Biology

ASSIGNMENT - I

Time : 2 Hours

Note:

1. *Do not copy the answer directly from any of the books.*
2. *As far as possible, try to answer the questions independently in your own words.*
3. *If it is necessary to quote from any source, give the correct reference.*
4. *Use your own foolscap pages for writing the assignment.*
5. *Leave sufficient margin for the comments of the evaluator.*
6. *Completion of this assignment normally should not take more than 2 hours time.*

I. Answer the following questions in about 30 lines each.

1. Describe different components of ecosystem.
2. Write a brief note on inland waters and their ecosystem.
3. Write briefly on nitrogen fixation.

II. Answer the following questions in about 10 lines each.

1. What are Savannas? Write brief account on them.
2. Briefly write on detritus food chain.
3. Write about the pyramid of energy.

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ASSIGNMENT - II

Time : 2 Hours

Note:

1. *Do not copy the answer directly from any of the books.*
2. *As far as possible, try to answer the questions independently in your own words.*
3. *If it is necessary to quote from any source, give the correct reference.*
4. *Use your own foolscap pages for writing the assignment.*
5. *Leave sufficient margin for the comments of the evaluator.*
6. *Completion of this assignment normally should not take more than 2 hours time.*

I. Answer the following questions in about 30 lines each.

1. What is ecological succession? What are its three major aspects?
2. Write an essay on water pollution in urban India.
3. Describe in detail about the forest management.

II. Answer the following questions in about 10 lines each.

1. What are the effects of Chlorofluorocarbons on ozone layer.
2. How can the solid wastes be utilised.
3. Write a brief account on thermal pollution.

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ASSIGNMENT - III

Time : 2 Hours

Note:

1. *Do not copy the answer directly from any of the books.*
2. *As far as possible, try to answer the questions independently in your own words.*
3. *If it is necessary to quote from any source, give the correct reference.*
4. *Use your own foolscap pages for writing the assignment.*
5. *Leave sufficient margin for the comments of the evaluator.*
6. *Completion of this assignment normally should not take more than 2 hours time.*

I. Answer the following questions in about 30 lines each.

1. Describe behavioural adaptations in desert reptiles.
2. Write an essay on non-carcinogenic disorders of liver.
3. Write about epoxidation and aromatic hydroxylation.

II. Answer the following questions in about 10 lines each.

1. What are the biochemical reactions associated with CO_2?
2. Write briefly about rate of penetration of toxicants.
3. What are electron transport inhibitors.

Notes