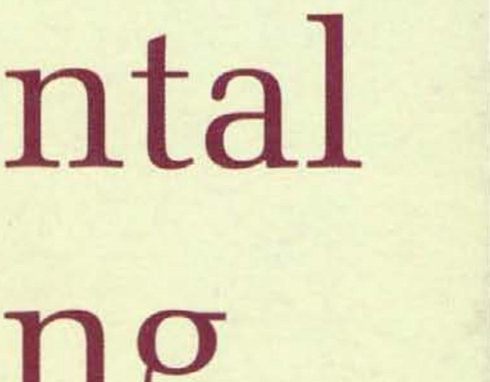
Environmental Engineering





Anil Kumar De • Arnab Kumar De

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Environmental Engineering

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Environmental Engineering

Anil Kumar De
Formerly Professor and Head
Department of Chemistry
&
Dean, Faculty of Science
Visva Bharati University
Santiniketan, West Bengal

Arnab Kumar De
Reader in Chemistry
Raja Peary Mohan College
Uttarpara, West Bengal

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Preface

While Environmental Science courses were introduced in 1980s in Indian Universities and Institutes, common courses on Environment for various disciplines had to wait till 1998 after the Hon'ble Supreme Court of India passed their landmark judgment in 1995. NEHU introduced a course on Man and Environment in 1998 for B.A., B.Sc. and B.Com. students. The authors, with their vast experience in the field, took up the project and published "Man, Nature and Environment" in 2003 as per NEHU syllabus. Now, they have launched the project on Environmental Engineering for the Polytechnic students (N-E. region). The book is designed to meet the urgent need of Polytechnic students and teachers for basic concepts on Environmental Education.

The book will serve a great purpose to generate awareness among the students about environment, environmental issues, remedial measures etc. It is presented in a logical sequence in ten chapters covering the polytechnic syllabus. Science has been kept at a low key all throughout and the subject matter is presented in a highly lucid and attractive style so as to inspire the young mind with environmental culture.

The authors cordially invite constructive suggestions from Polytechnic students and teachers for further improvement of the book in its next edition. This feedback is essential and it may be sent to the authors.

The authors place on record thanks to Mr. S. Gupta, Managing Director, and Mr. V.R. Damodaran, Chief Editor, New Age International Publishers for prompt publication. And last but not the least, the authors' sincere thanks are due to Mrs. Kalpana De, Mrs. Chandrima Datta and Mrs. Charchita Datta for their wholehearted support and encouragement.

P 27/1, C.I.T. Scheme VIIM
"Udichi"
Kolkata 700054

Anil Kumar De
Arnab Kumar De

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1 General Concepts

1.1 DEFINITION OF ENVIRONMENT

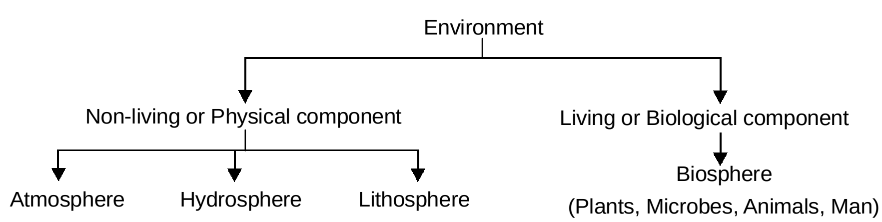
What is Environment? Why are people taking so much interest in Environment in recent years? Why are people so much concerned about the environmental issues of the day? Let us try to answer these questions.

Environment means all that environs (surrounds) us. Broadly speaking, environment is defined as the sum total of all conditions and influences which affect the development and life of all organisms on earth. The living organisms vary from the lowest micro-organisms such as bacteria, fungi etc., to the highest including man. Each organism has its own environment.

Environment has multi-dimensional aspects—the perception varies from man to man. To some, it is scenic landscape; to others, it is natural resources or vanishing forests or industrial pollution etc. Environment performs different functions in relation to man: (a) recreation and aesthetics, (b) source of natural resources, (c) sink for wastes produced by human activities. Environment loses its ability to discharge these functions properly due to stress from man-made activities.

1.2 ELEMENTS OF ENVIRONMENT

The environment consists broadly of two components—Non-living or Physical and Living or Biological.



1. Atmosphere: The atmosphere has three major constituents—major, minor and trace. Pure (i.e., pollution-free) dry air at ground level has the following components, expressed in percentage by volume (within brackets):

Major components:	Nitrogen (78.09)	Oxygen (20.94)	Water vapour (0.1)
Minor components:	Argon (0.9) (0.032)	Carbon dioxide	
Trace components:	Neon (0.0018)	Helium (0.0005)	Methane (0.0002) etc.

The properties of the atmosphere vary much with altitude. The density shows sharp decrease with increasing altitude. Pressure drops from 1 atmosphere at sea level to 3×10^{-7} atmosphere at 100 km above sea level while temperature varies from –92° to 1200°C. The total mass of the atmosphere is about 5×10^{7} tons which is roughly one millionth of the earth's total mass(5×10^{24} kg).

Structure: The atmosphere may be broadly divided into four regions as shown in Table 1.1 below. It extends up to 500 km, with temperature varying from a minimum of –92°C to a maximum of 1200°C.

Table 1.1: Major Regions of the Atmosphere

Region	***Altitude range km***	***Temperature range, °C***	***Important chemical species***
Troposphere	0 – 11	15 to –56 Water vapour, Carbon dioxide	Nitrogen, Oxygen,
Stratosphere	11 – 50	–56 to –2	Ozone
Mesosphere	50 – 85	–2 to –92	$Oxygen^{+}$, Nitric oxide
Thermosphere	85 – 500	–92 to 1200	$Oxygen^{+}$, Nitric $oxide^{+}$

$Oxygen^{+}$ = Oxygen atom with positive charge

Nitrogen $oxide^{+}$ = Nitric oxide molecule with positive charge.

These atoms/molecules pick up charge in the upper atmosphere.

The *Troposphere* contains 70 per cent of the mass of the atmosphere. Density decreases exponentially with increasing altitude. The temperature decreases uniformly with increasing altitude (*negative lapse rate*). In this region the air masses are constantly in circulation as energy flows due to imbalances in heating and cooling rates between equator and the poles.

In contrast to the Troposphere, the *Stratosphere* is the quiet layer having a *positive lapse rate* i.e., increase in temperature with increase in altitude. Here ozone is the important species which absorbs ultra-violet radiation and raises the temperature. The *ozone layer serves as a protective shield for life forms on earth* from the harmful effects of the sun's ultra-violet radiation. Because of slow mixing in the stratosphere, the molecules or particles in the region stay for a long time. If some pollutants enter this layer, they will stay for a long period and slowly come down to the Troposphere, causing long-term global hazards. Introduction of nitrogen oxides by jet planes and refrigerant gases (chloroflurocarbons) leads to thinning of ozone layer and generates ozone hole.

In the *Mesosphere* temperature decreases with increase in altitude. This is due to low levels of ultra-violet species i.e., ozone.

In the *Thermosphere* temperature rises once again giving a *positive lapse rate*. Here oxygen and nitric oxide ionize after absorption of solar radiation in the far ultra-violet region.

2. Hydrosphere: The history of human civilisation shows that water supply and civilisation are intimately linked with each other. Several cities and civilisations have vanished due to shortage of water supply.

The world's total quantum of water is 1.4 billion km^3. If all the seabeds could be filled up and brought at the level of the earth's surface, then the entire water in the seas would cover the earth's surface and make it 2.5 km. deep water mass. About 97 per cent of the earth's water supply is in the ocean which is unfit for human consumption and other uses due to high salt content. Of the remaining 3 per cent, 2.3 per cent is locked in the polar ice caps and hence out of bounds. The balance 0.7 per cent is available as fresh water but the bulk of it is ground water (0.66 per cent) and the rest 0.03 per cent is fresh water in rivers, lakes and streams. The break-up of this 0.03 per cent is: lakes and ponds, 0.01 per cent, water vapour 0.001 per cent, rivers 0.003 per cent and water confined in plants, animals and chemicals 0.0187 per cent (United Nations Water Conference Report, Argentina, 1977).

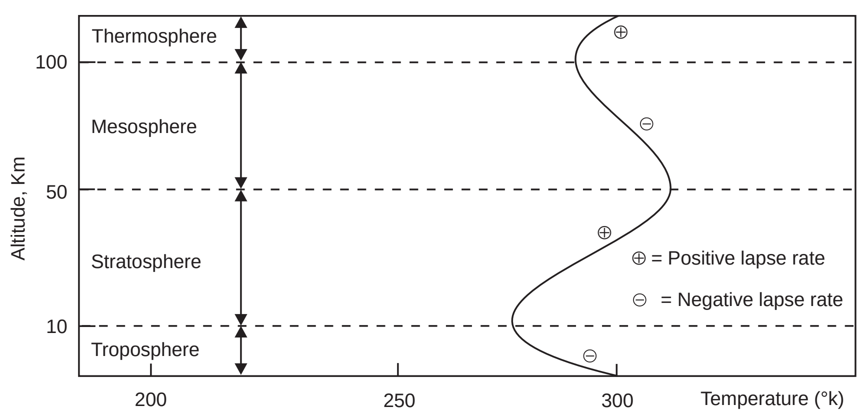


Fig. 1.1: Major regions of the atmosphere

Thus we see that we have a very limited stock of usable water, 0.03 per cent surface water (rivers, streams and ponds)and 0.66 per cent ground water. The quantity of water vapour arising from evaporation of sea water and river water returns by the same volume to the earth's surface by rainfall and back to the water sources. This natural hydrological cycle is more or less balanced in terms of charge (cloud formation) and discharge (rainfall) and is the source of fresh water supply. But we are drawing large quantities of ground water for agriculture and industries while the waste water from these is much polluted and on mixing with rivers is polluting the rivers also.

Water is essential for all life forms on earth—plants, animals and man. The *Hydrological cycle* helps in exchange of water between air, land, sea, living plants and animals. It is based on massive evaporation of water from the seas and oceans, cloud formation and condensation into rainfall. It ensures continuous circulation of water between the oceans, atmosphere and biosphere (plants, animals and man). Thus we get our supply and reserves of fresh water. Figure 1.2 illustrates the hydrological cycle (Natural Cycle —See Sec. 1.3).

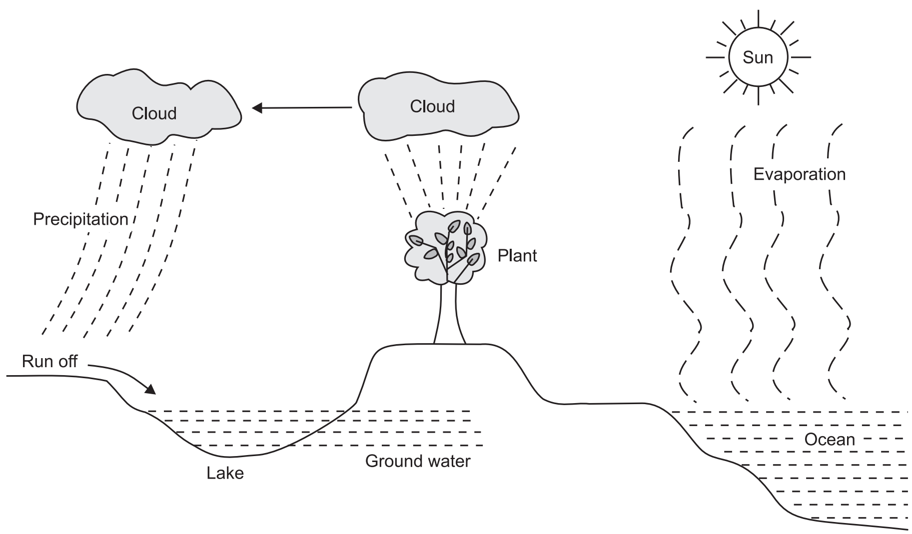


Fig. 1.2: The hydrological cycle

3. Lithosphere: It is made of the mantle of rocks. It includes the soil which covers the rock's crust in many places. Rocks are subjected to continuous weathering forces—rain, wind, chemical and biological—and suffer disintegration. The resulting primitive soil is suitable for the growth of plants—after death and decay, plant debris returns to soil. The mineral component of soil comes from the parent rocks by weathering processes while the organic component is due to plant biomass as well as populations of bacteria, fungi and insects (earthworms). A typical soil, suitable for agriculture, contains about 5 per cent organic matter and 95 per cent inorganic matter. Soil plays an important role as it produces food for man and animals. Good soil and good agriculture are valuable assets for a nation.

In general, soil has a loose structure consisting of solid mineral, organic matter and air space (Fig. 1.9). It shows broadly three zones as its depth increases. The top layer, up to several inches thick, is known as top soil which is an index of soil quality. This is the layer of maximum biological productivity and it contains bulk of organic matter. Hence, it is very important for vegetation cover and agricultural crops. Reckless deforestation causes loss of top soil which means loss of agricultural production. The underlying layer is the sub-soil which receives organic matter, salts and clay particles leached from the top soil. The third layer (zone) consists of weathered parent rocks from which soil was formed. Plants draw water and nutrients from soil—they transport water into the plant body (roots and leaves) and discharge excess water into the atmosphere through leaves through the process of transpiration.

The various land forms of the lithosphere are (i) mountain, (ii) plateau and (iii) plain. Mountains provide natural frontier, shelter for tribals, important flora and fauna. They contain forests which are important natural resources. Plateaus are rich in forest and mineral wealth while the plains account for maximum world population because of the convenience for cultivation, communication, transport and industrial growth.

4. Biosphere: Broadly speaking, the biosphere consists of the earth's crust, hydrosphere, atmosphere and various living species (micro-organisms to man) which exist in the zone 600 metres above earth's surface and 10,000 metres below sea level. Both biosphere and environment have close interactions with each other. Thus oxygen and carbon dioxide level of atmosphere depend on the plant world. Green plants are responsible for accumulation of oxygen in the atmosphere through photosynthesis and decay. In primitive stage the atmosphere was devoid of oxygen and there was no life form on earth. In general, the biosphere is closely related to energy flows in the environment and water chemistry.

1.3 NATURAL CYCLES

The Oxygen Cycle

Oxygen is vital for life in the biosphere. It is a major component of all living organisms. It is drawn by man and animals during aerobic respiration from air but released by plants during photosynthesis setting up the oxygen cycle. The oxygen cycle is based on exchange of oxygen among the environmental segments –atmosphere, hydrosphere, lithosphere and biosphere. It plays an important role in atmospheric chemistry, geo-chemical transformations and life processes.

Combustion Reactions

$$\underset{\text{(Fossil fuel)}}{C} + \underset{\text{(Oxygen)}}{O_2} \longrightarrow \underset{\text{(Carbon dioxide)}}{CO_2}$$

$$\underset{\text{(Methane / natural gas)}}{CH_4} + 2O_2 \longrightarrow CO_2 + \underset{\text{(Water)}}{2H_2O}$$

Weathering Processes of Minerals

$$\underset{\text{(Ferrous oxide)}}{4FeO} + \underset{\text{(Oxygen)}}{O_2} \longrightarrow \underset{\text{(Ferric oxide)}}{2Fe_2O_3}$$

$$\underset{\substack{\text{(Ferrous ion)}\\ \text{soluble}}}{4Fe^{2+}} + O_2 + \underset{\text{(Water)}}{4H_2O} \longrightarrow \underset{\text{(Ferric oxide)}}{2Fe_2O_3}$$

In the early stage of the earth, soluble ferrous iron consumed bulk of oxygen giving large deposits of ferric oxide as shown in the above reaction.

Green plants return oxygen to the atmosphere through photosynthesis:

$$\underset{\text{(Carbondioxide)}}{CO_2} + \underset{\text{(Water)}}{H_2O} + \underset{\substack{\text{(Photon}\\ \text{sunlight)}}}{h\nu} \longrightarrow \underset{\text{(Carbohydrate)}}{(CH_2O)_x} + \underset{\text{(Oxygen)}}{O_2}$$

The Nitrogen Cycle

Nitrogen and its compounds are essential for life processes in the biosphere. There is continuous exchange of nitrogen within the ecosystems operating the nitrogen cycle. Proteins produced by plants and animals in their metabolic processes are organic compounds of nitrogen. The major load of nitrogenous organic residue in soil originates from death and decay of plants and excreta of animals. These organic residues in soil are taken up by various soil micro-organisms for their metabolism which give products such as ammonia, nitrates and nitrites. Plants absorb nitrates from soil which re-enter the nitrogen cycle. Some soil micro-organisms break down soil nitrate into nitrogen by denitrification process while others transform nitrogen into soluble nitrogen compounds (*see* Fig. 1.3 The Nitrogen Cycle).

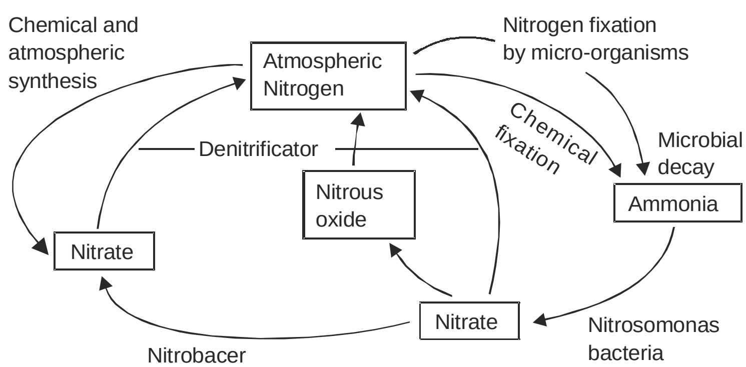


Fig. 1.3: The nitrogen cycle

The Carbon Cycle

As carbon is the backbone of biological chemistry, the carbon cycle is a very important chemical cycle. The atmosphere is the minor reservoir of carbon dioxide while the oceans are the major reservoir, containing as much as 50 times more as that of air where it is stored as bicarbonate mineral deposit on the ocean floor. The latter regulates the carbon dioxide level in the atmosphere. The cycle operates in the form of carbon dioxide exchanging among the atmosphere, biosphere and the oceans (Fig. 1.4). The Carbon dioxide balance sheet per year is given:

(i) emissions by fossil fuel 20 billion tonnes,
(ii) emissions by deforestation and changes in land use 5.5 billion tonnes,
(iii) uptake in the oceans 5.5 billion tonnes,
(iv) uptake by carbon dioxide fertilization, i.e., photo-synthesis, 7.3 billion tonnes:

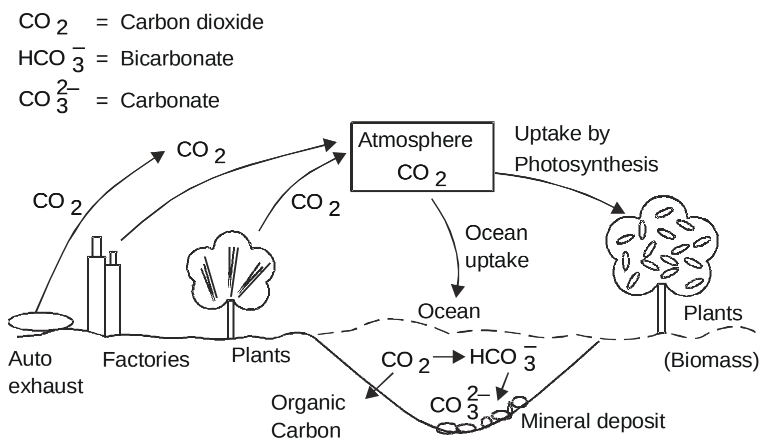


Fig. 1.4: Sources and sinks of carbon dioxide

Thus there is a net increase of carbon dioxide in the atmosphere of 11 billion tons per year. This can be reduced by 50 per cent if we can stop deforestation (Fig.1.5).

The atmosphere contains 2700 billion tonnes of carbon dioxide; biosphere, vegetation and soil about 6600 billion tonnes and the oceans about 1,36,000 billion tonnes of carbon dioxide.

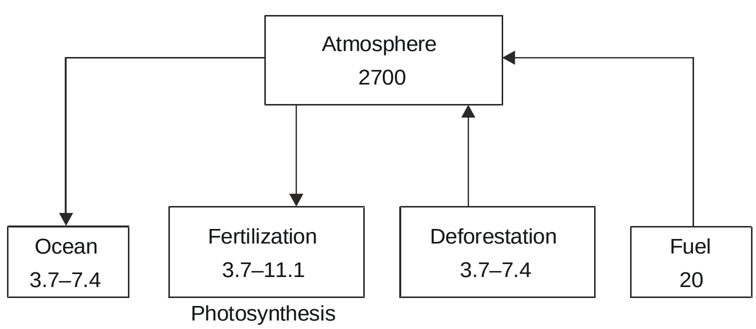


Fig. 1.5: Important fluxes of carbon dioxide (in billion tonnes)

The Phosphate Cycle

Phosphates are necessary for the growth and maintenance of animal and human bones and teeth while organo-phosphates are required for cell division involving production of nuclear DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).

Phosphate minerals exist in soluble and insoluble forms in rocks and soil. Plants absorb inorganic phosphate salts from soil and change them into organic phosphate. Animals obtain their phosphate by eating plants. After death and decay, plants and animals return phosphates to the soil. Bulk of the phosphate in soil is fixed or absorbed on soil particles but part of it is leached out into waterbodies.

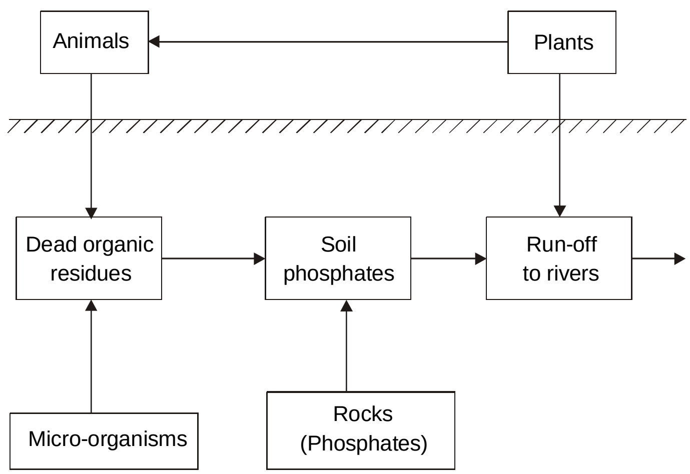


Fig. 1.6: The phosphate cycle on land

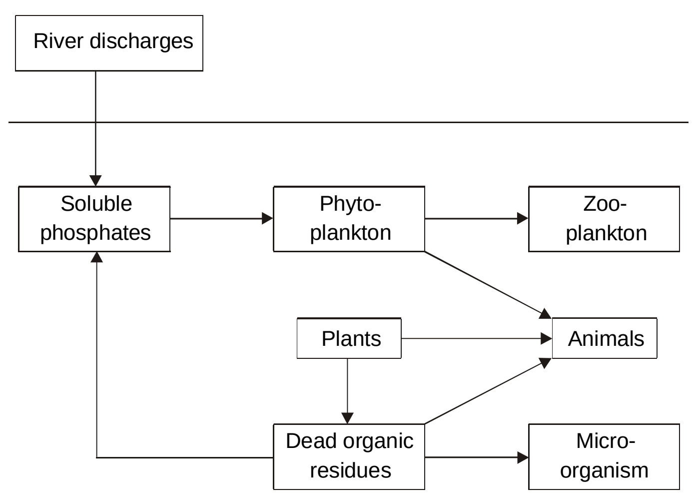


Fig. 1.7: The phosphate cycle in water

The natural phosphate cycle is affected by pollution, mainly from agricultural run-off containing superphosphate and also from domestic sewage. Phosphate pollution of rivers and lakes is the cause of algal bloom (eutrophication) which reduces dissolved oxygen in water and disrupts the food chain. The phosphate cycles on land and in water are shown in Figs. 1.6 and 1.7.

The Sulphur Cycle

Sulphur and its compounds are required by plants and animals for synthesis of some amino acids and proteins. Some sulphur bacteria act as the media for exchanges of sulphur within the ecosystems. The sulphur cycle (Fig. 1.8) illustrates the circulation of sulphur and its compounds in the environment.

The sulphur oxidation process is shown in the upper half of the cycle. The lower section shows the conversion of sulphate into plant and cellular proteins and the decay of dead plant and animal material by bacterial action. In polluted waters under anaerobic conditions hydrogen sulphide is produced by bacteria giving deposits of iron sulphide. In unpolluted waters under aerobic conditions the sulphur bacteria transform sulphides into sulphates for further production of proteins.

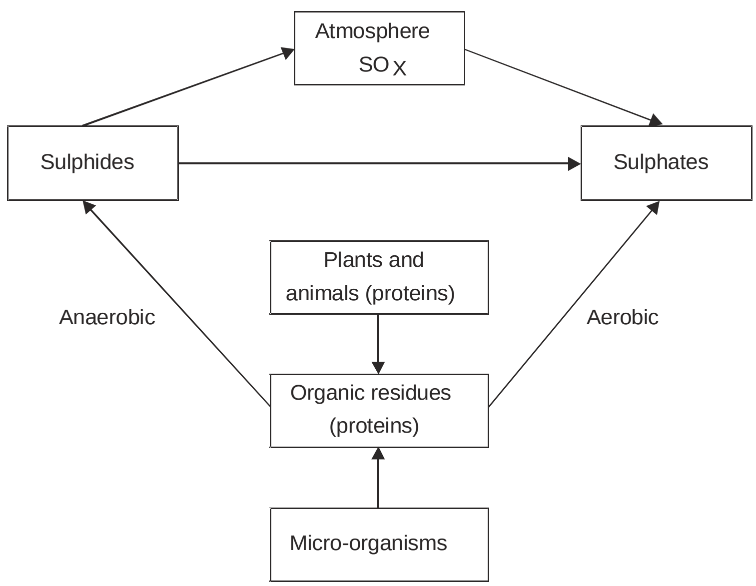


Fig. 1.8: The sulphur cycle

1.4 POLLUTION AND POLLUTANTS

Pure air is colourless and odourless while pure water is colourless, tasteless and odourless. But these properties are affected by external substances from natural or man-made sources.

This is the phenomenon of *pollution* and the external substances are known as *pollutants*. Thus air is polluted due to presence of carbon monoxide, nitrogen oxide etc. from vehicular emissions. Similarly water gets polluted by waste from domestic sewage, industrial sewage etc.

Pollutants are contributed by natural and man-made sources. Natural sources of air pollution are: volcanic activity, vegetation decay, forest fires emitting carbon monoxide, sulphur dioxide, particles of solids or liquids sprayed from the seas, and land by wind.

Man-made sources of air pollution are: gases, mists, particles and aerosols emitted by industries and other chemical and biological processes used by man.

Natural sources of water pollution are: soil erosion, particles from atmosphere, vegetation decay etc.

Man-made sources of water pollution are: domestic and industrial sewage, agricultural run-off, radioactive wastes, hot water from power plants, oil pollution, pesticides etc.

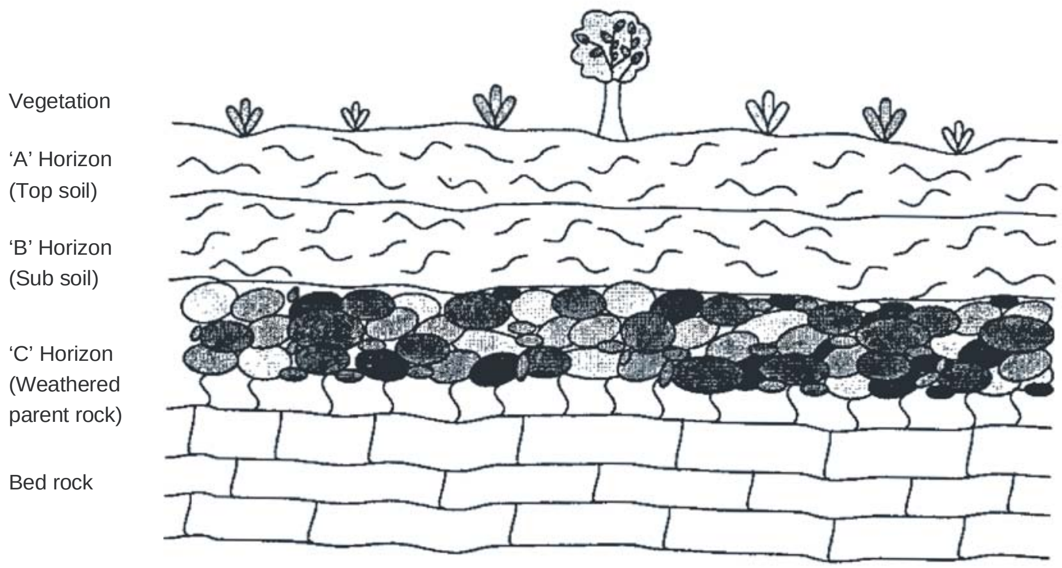


Fig. 1.9: Soil profile showing soil horizons

1.5 MAN-NATURE INTERACTION

Man is at the centre of the biosphere in dynamic equilibrium with other segments of the environment—air, water and land. His daily life is heavily dependent on his natural environment—he gets food from soil, fruits and timber from trees, medicines from plants, meat from birds and animals, fish from ponds, rivers and seas, water for daily use from springs, rivers and ground water.

Indian Tradition: India has a rich tradition in environmental ethics. Ancient Indians used to worship Nature—sun, water, air, soil, plants and animals. The ancient philosophers believed that the entire universe including earth, plants, animals and human beings is made of five essential elements viz. *kshiti* (earth), *op* (water), *teja* (fire or energy), *marut* (air) and *byom* (open space). Bodies of plants, animals and human beings are created out of these five essential elements and after death and decay, their bodies are disintegrated and converted back to these elements.

The fundamentals of conservation ethics were brilliantly formulated in the *Isho-Upanishad* during the Vedic era. *"The whole universe together with all its creatures belong to the Lord (Nature). Let no one species encroach over the rights and privileges of other species. Man can enjoy the bounties of Nature by giving up greed."* In other words, if we over-exploit Nature, we shall lose all the benefits from Nature.

In the Maurya period the emperors emphasised the awareness campaign for conservation of Nature and upholding the spirit of non-violence towards trees and animals. Compassion for animate and inanimate objects is part and parcel of Indian culture. But unfortunately we have forgotten this basic philosophy and turned to Western culture of conflict with Nature.

Scan of Human Civilisation: It is worthwhile to scan human civilisation since man's arrival on earth. Primitive man lived in mountain caves and looked at the forces of Nature with wonder and awe. He was panicky about the sun, lightning, thunder, rains and also wild animals in the forests. He was constantly busy in protecting himself and his family against the hostile elements around him. Gradually he discovered fire and made stone tools for his defence against wild animals. About 10,000 years ago agriculture was discovered and that was the starting point for human civilisation,

In course of time man devised science and technology step by step and depended on these for improving his living standard. This became prominent after the Industrial Revolution (1760-1840) which transformed England from an agricultural country into a predominantly industrial one. The invention of steam engine by James Watt (1785), mechanisation in textile industry, advancement in mining, transport and ship-building industries made Britain the most prosperous country in the world. This was promoted by British colonial exploitation.

With the help of science and technology, man overcame the natural barriers and established his supremacy over Nature. He can travel from one part of the world to the other part, in a matter of a few hours, undertake journey to outer space and planets, dive down to the bottom of seas and explore the wonders there and so on. But at the same time, the environment became more and more degraded and polluted. As a result of man-made activities (deforestation urbanisation, industrialisation, etc.) the quality of environment suffered which has threatened the survival of man himself on earth.

1.6 NATURAL AND MAN-MADE CHANGES IN ENVIRONMENT AND DISASTERS

Natural Changes in Environment

The environment is always subject to changes and these changes will continue in future. When life first appeared, there was no oxygen in the atmosphere which was full of carbon dioxide and other gases including water vapour. This primitive climate changed very slowly; it took over 2 billion years to accumulate enough oxygen in the atmosphere which helped in the evolutions of life forms (aerobic organisms). Most of the oxygen in the atmosphere today has come from water through the photosynthetic activities of green plants. Such change is natural (non-anthropogenic) but it altered the chemical composition of air which led to other changes in the environment. From oxygen of the atmosphere ozone was formed which slowly passed into the stratosphere where it served as a protective umbrella of ozone layer. The latter protects life on earth by absorbing the harmful ultraviolet radiator from the sun.

Continental drifting is an important part of natural changes. The continents were not stationary but they were slowly drifting apart. The entire outer shell of the earth is made up of huge tectonic plates[1] which float on the molten fluid core of the earth. Initially the continents were all joined together forming a single landmass - later on they drifted very slowly. This movement is the phenomenon of *continental drift.*

The continents have drifted for about 2500 million years and the annual rate of drifting is 20 to 75 mm. Such movement can cause splitting of part of a continent forming oceans such as the Atlantic Ocean, seas such as the Red Sea and lakes such as Lake Baikal. Collision of one tectonic plate with another can cause earthquakes, volcanic explosions and formation of mountains. Collision of Indian plate with Asian plate gave rise to the world's highest mountain, our Himalayas some 50 million years ago.

The earth's environment also passed through drastic changes in average temperature of the earth's surface creating the Ice Ages. During the earth's history the temperature fluctuated between relatively stable states about 30 times due to earth's rotation on its axis and changes in the sun's activity. The last Ice Age was about 18,000 years ago when a vast sheet of ice advanced from the North Pole covering Canada, Greenland and up to U.K. including the North Sea. As the ice moved back, vast quantities of cold water flooded the Atlantic disturbing the ocean currents. The Ice Age was over by 3000 B.C. and normal temperature slowly restored.

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1. *Tectonic plates:* Continental land mass is a large segment of the earth's crust. It is like a huge plate which moves slowly and carries the continents along. The plates are called tectonic plates and the processes, tectonic processes which lead to earthquakes, volcanic explosions, formation of oceans and mountains.

Natural Disasters

The environment has undergone sweeping changes by natural disasters viz. cyclone, typhoon, hurricane, tornado, earthquake, volcanic eruptions etc. The latter have caused enormous damages on lives and properties.

Cyclone, typhoon and hurricane, are the same weather phenomenon occurring in different regions of the world. Cyclones are storms that originate in the Indian Ocean and bring about extensive flood and damage in the Indian sub-continent including Sri Lanka and Mynamar. Typhoons are storms in the Pacific Ocean which cause havoc in South-East Asia while those in the North Atlantic Ocean that destroy South East USA are hurricanes. Hurricanes arise from tropical seas when the latter are warmed by the solar heat. They are powered by the heat released when the rising water vapour condenses. Most of the hurricane's energy is used to lift the airmass at the centre of the storm. Hurricanes, typhoons are in the form of spiralling air column which can have a speed of over 250 km/hr., uprooting big trees, tearing off house roofs, lifting people, cattle, cars and sucking almost anything on their path. They can whip up high waves on the surface of seas, oceans as sea level is raised as high as 8 m or 25 ft. This can cause flash floods along the coastal region. They are also accompanied by torrential rains in the region.

The earthquakes have a rather high frequency, about 100 earthquakes/hr all over the world. But most of them are of low magnitudes. The earthquake-prone zones in the world encircle the Pacific Ocean (Zone1) and on the other side, stretch from Spain, Turkey, Northern Mediterranean to Japan, Himalayas and Indonesia (Zone 2). These two zones meet near New Guinea (North of Australia). The earth's outer crust is divided into seven large tectonic plates and in between them there are more than 20 smaller plates. The plates move slowly over a partially molten mass of metals and minerals–they often converge, collide and sometimes one plate slips below another plate releasing tremendous energy in the form of seismic waves that shake the ground violently. This causes earthquake.

The intensity of an earthquake is measured on Richter scale (1 Richter is the minimum intensity detectable on the instrument, Seismograph). The earthquake at Bhuj, Gujarat (2000 A.D.) measured 6.0 on the Richter scale. It destroyed the entire city of Bhuj and killed most of its population–its destructive force was equivalent to more than 100 Hiroshima-type atomic bombs.

Volcanoes sometimes erupt with devastating power, throwing molten lava, silicate dust and sulphuric acid into the atmosphere. When Mt. Pinatubo in the Philippines erupted in 1991, it increased the dust content of the atmosphere to more than 50 times its normal level. As a result, Indonesia, Malayasia missed summer in 1991.

Man-Made (Anthropogenic) Changes in Environment and Disasters

Primitive man looked at Nature with wonder and awe because of its terrible forces as manifested from time to time as lightning, thunder, cyclone, volcanic eruption, flash flood, landslides, etc.

In his constant efforts for better living standards, man developed science and technology over the years. The Industrial Revolution of 1780 was a landmark in the history of human civilization. It started with the invention of steam engine (James Watt) in England. By 1840 England was transformed from an agricultural country into a predominantly industrial one. Textile, mining, transport and ship-building industries were developed. Manchester, Newcastle, Birmingham and Glasgow became major industrial cities of Britain. The Industrial Revolution along with colonial rule made Britain the most prosperous country in the world in the 19th century.

With development of science and technology, man continued to plunder natural resources and pollute the environment. He destroyed forests, degraded lands, threw toxic wastes into rivers and seas and also harmful gases into the atmosphere. The continuous load of pollutants into the environment brought about changes in it which ultimately backfired into series of disasters from time to time. Several man-made disasters may be mentioned below. All these killed people and made generations to suffer from genetic and other disorders.

London Smog

Heavy smog (smoke + fog) conditions due to high sulphur dioxide (1.3 parts per million) content prevailed in London (December 5-9, 1952) and killed about 4,000 people in one week. The causes of death, particularly among the aged people, were bronchitis, pneumonia, etc. Similar but less severe smog recurred in 1962 when 700 people died.

Mediterranean—A Dead Sea

The Mediterranean sea has a coastline of 48,000 km. where about 100 million people live. It is surrounded on all sides by Europe with a Gibraltar strait connecting to the Atlantic. Here the famous luxury tourist hotels and numerous industries are located. The industries dump their wastes into the Mediterranean which also receives sewage from the European countries. As a result, the sea is heavily polluted with high levels of lead, chromium, mercury, etc. The seashore emits offensive odour due to pollution which forces closure of the tourist hotels for some six months every year. The sea became so heavily polluted since 1950 that it was declared a dead sea, unable to support any aquatic life (fish, plants, etc.).

Nuclear Explosions

The two atom bombs were dropped by USA during World War II (August 6, 9, 1945) on Hiroshima and Nagasaki in Japan. These instantly killed about 6 lakhs people, destroyed the two cities and unleashed radioactive fallout which has caused generations to suffer from various diseases including genetic disorder. Radioactive radiation continues to damage plants, soil and biosphere in the region.

Minamata Disease

At Minamata Bay in Japan (1953-60) about 100 people lost their lives and thousands were paralysed after eating mercury-contaminated fish from the Bay. A chemical company, (Minamata Chemical Company) discharged their wastes containing mercury into the Bay where sea fish picked up mercury and concentrated it in their body as the methyl derivative. The latter was highly toxic and caused deaths of the Japanese who consumed such fish. This case of mercury-poisoning is known as the Minamata Disease.

Bhopal Disaster (December 3, 1984)

This is the worst environmental disaster in human history. A pesticide factory, Union Carbide Corporation, leaked large volumes of methyl isocyanate (raw material for production of the pesticide, Carbaryl) into the atmosphere of Bhopal on December 3, 1984 at around midnight. Very soon the city was transformed into a gas chamber. Within a week 10,000 people died, 1000 people turned blind and lakhs of people continue to suffer from various diseases. This was mass murder in recent history and the victims/survivors are yet to receive their compensation from the Union Carbide Corporation or the government. It was the end result of negligence on the parts of the Central and State governments and factory management on one hand and lack of awareness among the public and hospital doctors on the other hand.

Chernobyl Disaster (1986)

The worst nuclear reactor accident occurred at Chernobyl, USSR (now CIS) on 28th April, 1986. The reactor exploded as a result of uncontrolled nuclear reactions-radioactive fuel and debris shot up into air like a volcanic explosion and spread out in the surrounding areas. The accident killed at least 2000 people and damaged soil, water and vegetation in an area of 60 sq. km. around Chernobyl. Several generations in the region suffer from radiation-induced diseases including cancer.

Gulf War Hazards

The Gulf War was of six weeks duration (1991) fought between Iraq and USA-led multi-national coalition forces under the banner of the United Nations. The issue was annexation of a neighbouring state, Kuwait by Iraq in utter violation of international law and order. The war was fought for liberation of Kuwait and provides the latest example of how war destroyed the environment for several years.

The Gulf War destroyed Iraq and Kuwait. Cities and roads can be rebuilt but environment cannot be rebuilt. It will take several decades for the environment to be recovered.

About one lakh one-ton bombs were dropped on Iraq raising clouds of dust and black smoke. About 700 oil wells were set ablaze in Kuwait for over 10 months whereby black smoke and soot were shot up at high altitudes of the atmosphere. They moved with winds encircling the earth, warmed up the upper atmosphere causing temperature inversion (warm air overcool air mass). They disrupted monsoon circulation in the region and caused acid rain and crop damage in South-East Asia. The global temperature dropped by about 0.5 °C. Besides these, a total of 200 million gallons of oil were dumped into the Persian Gulf which destroyed the marine ecosystem.

At the end of the war, the world witnessed a scene of “hell on Earth”-chaos of oil fire, smoke, oil spill and a landscape of mines. It was the toughest challenge to handle such environmental disaster. But this almost impossible task was handled by a number United Nations Agencies and several national and international agencies with the coordination of UNEP (United Nations Environment Programme) working hard for about one year.

Gulf War II: USA and Britain attacked Iraq again in 2003 and the war was of three weeks, duration (March-April). As before, several thousand Iraqis were killed while there was widespread devastation of environment.

1.7 NEED OF ENVIRONMENTAL EDUCATION*

The Stockholm Conference (UN) on Human Environment (1972) initiated efforts to establish programmes of environmental education at all levels—primary, secondary and tertiary levels—of our educational system and also to motivate the general public in rural and urban areas about environmental awareness. This was followed by Belgrade (1975) and Tibilsi (1977) Conferences on Environmental Education. These laid stress on developing basic concepts of quality of life plus environmental knowledge, awareness, attitudes, skills and participation. In India the First International Conference on Environmental Education was held at New Delhi in 1981 and the Second Conference also at New Delhi in 1985. These showed keen interest taken by India in Environmental Education. The Bhopal Disaster of 1984 sounded the wake-up call for India to take note of the crisis situation and realise the need of environmental awareness and education at all levels of the society.

The perception about education has a glaring example in the Chinese proverb:

"If you plan for one year, plant rice;
If you plan for ten years, plant trees;
But if you plan for 100 years, educate the people."

It is the people's education which holds the key to environmental management and good quality of life. Equal priorities should be given to formal and non-formal education in order to broaden the base of environmental awareness—non-formal education is important for reaching out to the common masses, who constitute about 50 per cent of our population living outside our educational system.

Environmental Education/Studies in Indian Perspective

In spite of its urgent need, the study of Environment i.e., Environmental Education in India remains largely neglected. Only 25 out of 250 Universities including Jawaharlal Nehru University (JNU), Cochin University, Pondicherry University etc., offer courses (M.Sc.) in Environmental Sciences. In view of the environmental crisis all over the country, the Supreme Court of India issued in 1991 directive to the Central Government for introduction of common course on Environment at under-graduate level for various streams (Arts, Commerce and Science) in all colleges of the Universities. But the Universities were slow to respond. In absence of proper background of the subject and suitable textbooks, the teachers and students presented a scenario of confusion in all colleges. Prior orientation programmes are essential for developing motivation in the subject.

* See also heading 11.4.

The Supreme Court again came into the picture after a gap of 12 years: displeased with the non-compliance of their earlier order, the Supreme Court issued fresh directive in 2003 to all States and educational institutions to introduce the course on Environmental Studies at under-graduate and higher secondary levels from 2004-2005 academic session.

30-year Episode (1974-2004)

1974 — Central Board of Prevention and Control of Pollution Act was constituted. (CPCB Act).

JNU established School of Environmental Sciences and offers M.Sc. and M.Phil courses in Environmental Sciences.

1983 — Cochin University established School of Environmental Studies and started M.Sc. programmes in Environmental Technology.

1987 — Salim Ali School of Ecological and Environmental Sciences, Pondicherry University offers M.Sc., PG Diploma and Ph.D. programmes in biodiversity and applied ecology.

1991 — Supreme Court of India orders the Ministry of Human Resources to enforce compulsory education on Environment from 1992-93 in college and school courses – universities were called upon to introduce common paper for Arts, Science and Commerce streams at under-graduate levels.

2003 — Failure to implement earlier order (1991) in 12 years provoked a Public Interest Litigation case filed by the Environment lawyer, M.C. Mehta in 2003.

Displeased with non-compliance of the earlier order, the Supreme Court directs all States and Educational Institutions to introduce Environmental Studies as a compulsory subject at higher secondary level and colleges from 2004-2005 academic session. The Supreme Court warns that failure to implement this order will evoke penal measures.

Questions

1. What is meant by Environment?
2. What are the functions of Environment in relation to Man?
3. Name and describe the Environmental Elements/Segments.
4. What are the major and minor components of atmosphere?
5. Give an account of the water resources of the world and write their percentages.
6. Illustrate and explain the Hydrological Cycle.
7. Show the soil profile with the various zones.
8. Write notes on:
   (a) Biosphere
   (b) Pollution and Pollutants
   (c) Importance of Environmental Education

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2 Ecology and Ecosystem

2.1 DEFINITION

The word *'Ecology'* was coined by a German biologist, Haans Reiter in 1865 and defined by another renowned biologist, Ernst Haeckel in 1870: "*Scientific study of the relationships of living organisms with each other and with their environment.*" The term is derived from the Greek roots '*Oikos*' (meaning home) and '*logos*' (meaning study or discourse). The living organisms and their physical environment are closely related with each other so that any change in the environment has an effect on the living organisms and vice versa.

Any unit or biosystem that includes all the organisms which function together (*biotic community*) in a given area where they interact with the physical environment is known as *Ecosystem*. The ecosystem is the functional unit in ecology as it consists of both the biotic community (living organisms) and abiotic environment. The latter have close interaction, essential for maintenance of life processes. The interaction is conducted by energy flow (solar energy) in the system and cycling of materials (natural cycles).

From biological point of view, the ecosystem has the following constituents:

(i) inorganic substances (carbon, nitrogen, carbon dioxide, water etc.) involved in natural cycles;

(ii) organic compounds (proteins, carbohydrates, humic substances etc.);

(iii) air, water and substrate environment (i.e., biological base for growth) including the climatic regimes and other physical factors;

(iv) producers, autotrophic (i.e., self-sustaining organisms) green plants that can manufacture food from simple inorganic substances;

(v) heterotrophic (i.e., depending on others for nourishment) organisms, mainly animals which live on other organisms or particulate organic matter;

(vi) micro-consumers, decomposers, mainly bacteria, fungi which obtain their energy by breaking down dead tissues or by absorbing dissolved organic matter; extracted from plants or other organisms. The decomposers release inorganic nutrients that are utilised by producers. They also supply food for macro-consumers or heterotrophic organisms (animals) and often excrete hormone-like substances that inhibit or stimulate other biotic components of the ecosystem.

Typical profiles of a grassland ecosystem and of a pond ecosystem are shown in Fig. 2.1.

The common features of all ecosystems—terrestrial, freshwater, marine and agricultural—are the interactions of the autotrophic and heterotrophic components. The major autotrophic metabolism occurs in the upper 'green belt' stratum where solar energy is available while the intense heterotrophic metabolism occur in the lower 'brown belt' where organic matter accumulates in soils and sediments.

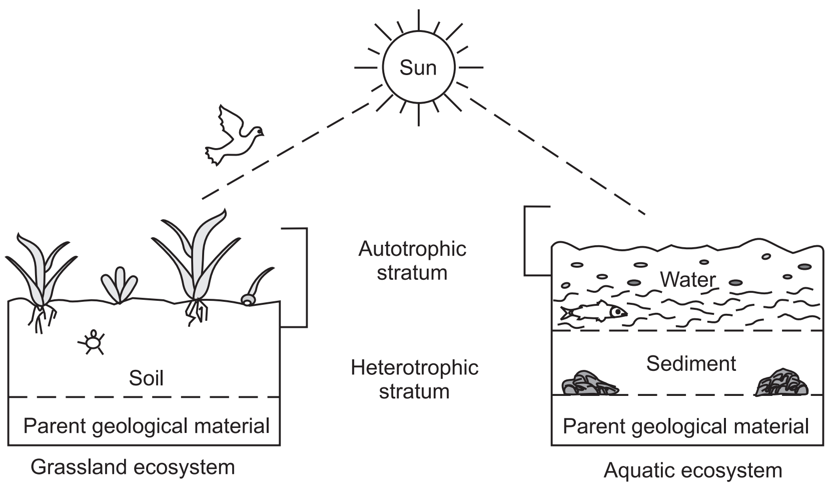

Fig. 2.1: Grassland and pond ecosystem

2.1.1 Forest Ecology

Plants have been dominating the earth for about 3.0 billion years. They have the unique art of manufacturing their own food by photo-synthesis from nature and the rest of the living world depends on them for their food and sustenance. Plants constitute 99 per cent of earth's living species while the rest 1 per cent includes animals and man who depend on the plant world for their food. If this ratio (99 : l) is disturbed by elimination of plants (i.e., deforestation), then the natural balance will be lost and the entire living world will suffer. The dynamic balance is among plants (*producers*), bacteria and micro-organisms (*decomposers*) which decompose mineral salts in soil into elements which are cycled back into plants and animals and man (*consumers*). Once this dynamic balance is upset, there is ecological crisis whereby the entire biosphere is in danger.

Forests are renewable resources and play a key role in improving the quality of environment by exerting beneficial effect on the life support system. Moreover, forests also contribute much to the development of the country by providing goods and services to people and industry. They are the treasure house of valuable plants and animal genes and medicinal plants, most of which are yet to be discovered. Hence tropical forests, in particular, are regarded as bioreserves. Our ancient civilisation flourished in forests where Indian philosophy was built up by our 'rishis' (seers).

It is well-known that forests play a vital role in the life and economy of all forest-dwelling tribes. They supply food (tuber, roots, leaves, fruits from plants; meat from birds and animals), medicinal herbs and other forest products for commercial use which provides for forest-based subsistence.

Around 3000 B.C. India had about 80 per cent forest cover. But waves of migrants came to India from middle-east countries which were deserts and tree-less and they changed the whole landscape. During the Maurya period of history emperor Chandra Gupta and later his grandson, Ashoka adopted the policy of tree-plantation. Emperor Ashoka also ordered the establishment of the first wildlife sanctuaries (abhayaranya). Engraved scriptures on stone walls, pillars in this era show how wild animals were treated with medicine and care while trees and plants were given special attention and their destruction prohibited.

During the Moghul period the picture was in sharp contrast as the Moghuls came from desert areas—they transformed forests into agricultural lands. During the British period the rate of conversion into agricultural land continued. They also exploited forests for timber for laying communication system (e.g., railway lines, roads) particularly after 1867 (India's First War of Independence/Sepoy Mutiny). After our Independence in 1947 the situation did not improve, rather the trend continued for drawing revenue from forests. The net result is that the forest cover has dwindled from 80 per cent to about 12 per cent in 5000 years. India has been losing 1.3 million hectares (1 ha = 2.5 acres) of forests each year.

The main causes for forest destruction are human population and livestock population explosion (livestock means cattle, goats, buffaloes, sheep). The latter puts tremendous pressure on forests for meeting their demands for timber and fuel wood (for man) and grazing land (for livestock). At the global level wood consumption is 46 per cent for industrial and 54 per cent for firewood purposes. The present requirements in India (2000 A.D.) are 78 per cent for fuel wood, 16 per cent for timber and 6 per cent for pulpwood (for paper industry).

2.1.2 Forest Conservation

The Forest Policy of the Government of India (1952) laid down that one third i.e., 33 per cent of our land should be under forest cover. However, this has not been seriously followed with the result that at present the forest cover is barely 12 per cent. We have almost reached a critical state which must be remedied now before it is too late for our own survival. The remedial measures have been suggested as follows:

(i) *Conservation of Reserve Forests:* These are areas where our major water resources are located viz. the Himalayas, Eastern and Western Ghats and also areas such as reservoirs, National Parks, Sanctuaries, Biosphere Reserves etc. These must be protected and commercial exploitation not allowed in these areas. This is an important conservation strategy.

(ii) *Limited Production Forests:* These are less fertile areas at high altitude (more than 1000 metres) with hilly environment. Here the health of the forests should not be damaged and only limited harvesting with utmost care be allowed.

(iii) *Production Forests:* These are forests on the plains and their productivity can be enhanced by proper management. These should be maintained to make up for the losing forest cover.

(iv) *Social/commercial Forestry:* Such forestry is meant for supplying goods and services to meet the very increasing demand for firewood, fodder, food, fertiliser, fibre, timber, medicine etc., or for industrial purposes such as timber, plywood, matchwood, fibre board, paper and pulp, rayon etc. The main idea is to remove pressure on natural forests for these requirements.

Social forestry is based on public and common (private) land to produce firewood, fodder, fruit and small timber for rural people. The programme should be conducted by a co-operative system including farmers, tribals, panchayats and NGOs (non-government organisations). Degraded lands should be utilised for social forestry for firewood whereby the quality of land improves in course of time.

Massive afforestation should be done involving multi-purpose species of plants/shrubs so that every village/town/city is able to meet its requirements for firewood, fodder and small timber. Production/commercial forestry is intended entirely for commercial purposes to meet the needs of the forest-based industry. Fallow lands, not used for agriculture, grazing lands etc., can be used for raising plantations for commercial purposes.

2.1.3 Biodiversity

There are about 10 million species of plants, micro-organisms and animals on earth while only about 1.5 million species are on record i.e., identified so far. Among these the majority are insects (7,50,000) while 41,000 are vertebrates (i.e., those having backbones or spinal columns), 2,50,000 are plants and the rest are invertebrates, fungi and micro-organisms.

Biological diversity or biodiversity involves genetic variation among individuals as also between species in a community of organisms. The existing species of plants and animals are the product of 3 billion years of evolution involving mutation, recombination and natural selection. Changes in environment e.g., warm and cool periods exerted selection pressures and have been responsible for evolution of new species and extinction of others who could not survive in the struggle for survival. The dinosaur era is an example. These giant-sized animals dominated the earth for 100 million years and became extinct before the Ice Age (18,000 years ago).

Natural extinction, part of evolutionary process, has been accelerated by man-made extinction wave due to constant need and greed of man. By this time, now out of ten million species has become extinct and each day we are losing one plant and one animal species. At this rate of extinction, the survival of man himself is threatened. The *specide* (extinction of species) in which man is involved as serious a crime as genocide (mass murder) during war. In this context we may note our 3000 year old history—Charaka, the well-known ancient physician, was asked by his teacher to get a plant that was useless. He returned after a few days and reported that there was no such plant. One cannot imagine a situation if *Penicillium* was extinct before man could make use of it as an antibiotic or if *Cinchona* became extinct before quinine was discovered as a cure for malaria. It is, therefore, in our own interest that we should conserve our plant wealth as well as animal and micro-organism (fungus and bacteria) wealth. There is a growing realisation all over the world about the urgent need to conserve the *biodiversity*.

The United Nations Earth Summits (Rio de Janeiro, 1992 and Johannesburg, 2002) adopted the Treaty on Biodiversity whereby all the countries agreed to conserve the Biodiversity—the living natural resources (plants, animals, microbes) for the welfare of mankind.

2.1.4 Sustainable Ecosystem

The developing countries face today the critical situation on economic and environmental fronts. For economic growth they have to give priority to agricultural and industrial bases but at the cost of environment. The resource base, once depleted, sets in a chain of environmental degradation which finally weakens the economy. Our population explosion remains the core issue. Our development policy should be such that the ecosystem is sustainable i.e., it contains the element of renewability. This requires sound management strategy which ensures the continuation of socio-economic development in the long run.

The important components of sustainable development/ecosystem are:

- Population stabilisation
- Integrated land use planning
- Conservation of biodiversity
- Air and water pollution control
- Renewable energy resources
- Recycling of wastes and residues and
- Environmental education and awareness at all levels.

2.2 ENERGY PATH

The green plants absorb solar radiation and transform it into potential of food energy through the process of photosynthesis.

$$\underset{\text{Carbon dioxide}}{6\,CO_2} + \underset{\text{Water}}{12\,H_2O} \xrightarrow[\text{chlorophyll}]{\text{sunlight }(h\nu)} \underset{\text{Carbohydrate}}{C_6H_{12}O_6} + 6\,H_2O + \underset{\text{Oxygen}}{6\,O_2}$$

The rest of the biological world other than chlorophyll bearing plants and chemosynthetic bacteria derives its potential chemical energy from organic matters produced either by plant photosynthesis or chemosynthesis. An animal takes in chemical potential energy of food from the plant source, most of which is converted into heat to enable a small part of the energy to be re-established as the chemical potential energy of new protoplasm. During the transfer of energy from one organism to another, a large portion (about 80 per cent) is degraded into heat at each step of the transfer. The transfer and dispersal of energy is guided by the *Stability Principle* which in turn follows from the Second Law of Thermodynamics. According to the Stability Principle, any natural closed enclosed system with energy flowing through it tends to change until a stable adjustment is developed through self-regulating or homoeostasis mechanism. While matter in the natural cycles (nitrogen cycle, oxygen cycle, phosphorus cycle etc.) moves in a cyclic path, energy moves in a unidirectional way in the ecosystem and then passes to the biosphere.

2.3 ENERGY FLOW/ENERGY BUDGET

The movement of energy through ecosystem is called *energy flow*. It is an essential part of the ecological process of life support in nature. As stated earlier, green plants transform solar energy with the help of carbon dioxide and water into food energy (chemical energy) by photosynthesis. This food energy goes on transforming when food is taken as energy by other organisms of different trophic levels. Thus energy flow is related with Food Chain. Almost all the solar energy is trapped by autotrophic organisms of the first trophic level (green plants). Because much energy is dissipated, about 90 per cent of available chemical energy (food energy) is lost at each stage of transfer from one trophic level to the next higher level.

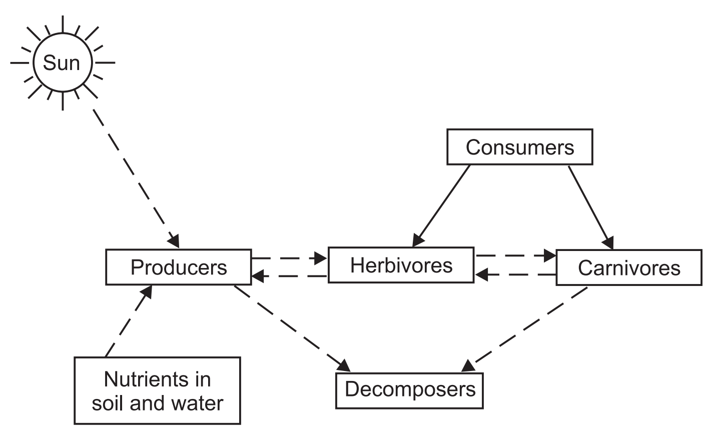

Fig. 2.2: Energy flow in ecosystem

2.4 ENERGY BUDGET

Energy Budget shows a record of the flow of energy through an ecosystem in each step from one organism to another.

The *primary productivity* of an ecosystem is defined as the rate at which radiant energy is converted by photosynthetic and chemosynthetic activity or producer organisms (green plants, for example) to organic substances.

In coastal waters of seas primary production in relation to biomass shows vertical distribution. It is concentrated in the upper 30 meters or so—in the clearer but less fertile waters of the open seas the primary production zone may extend down to 100 metres or more. This is why coastal water appears dark greenish and the ocean waters blue.

2.5 TROPHIC LEVELS

The transfer of food energy takes place in some hierarchical order in the ecosystem. The food energy passes from one group of organisms to other groups at different levels. These levels are called *Trophic levels* which mean feeding level of a group of organisms.

Trophic Level I: Here we find primary producers or autotrophs which produce their own food by converting solar energy into chemical energy in the form of organic substances such as carbohydrates. The green plants belong to this category.

Trophic Level II: Here we find primary producers who do not produce their own food but use plants as their food. Examples are grazing animals—cow, sheep, goat, deer, rabbit etc., who are called herbivores.

Trophic Level III: At this level we find animals who depend upon other animals for their food. They are carnivores (tiger, lion etc.) who eat mainly herbivores. This is the secondary consumer level.

Trophic Level IV: It is the tertiary trophic level to which belong all groups of animals including man who obtain their food from the other three levels. They are carnivores who eat both plants and animals.

It may be pointed out that organisms deriving their food energy, from the same producer level belong to the same trophic level. Thus grasshopper, cattle and grain-eating birds are all primary consumers and occur at the second trophic level since they derive their energy from plants.

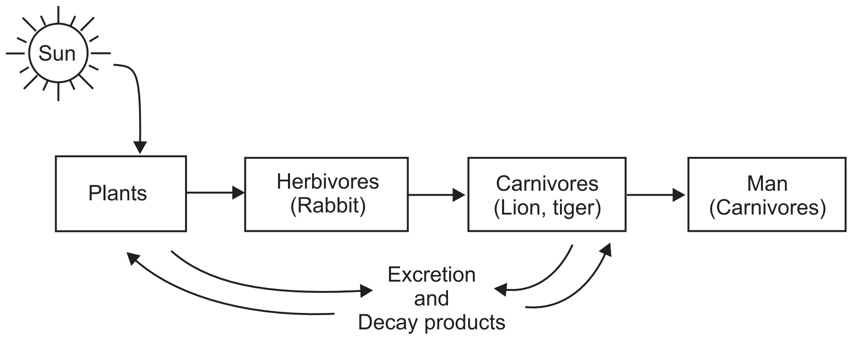

Fig. 2.3: Relationship among different biotic components of an ecosystem

2.6 FOOD CHAIN AND FOOD WEB

Food chain means the transfer of food energy from the source in plants through a series of organisms with the repeated process of eating and being eaten. In a grassland, grass is eaten by rabbits while rabbits in turn are eaten by foxes. This is an example of a simple food chain. This food chain implies the sequence in which food energy is transferred from producer to consumer or higher trophic level. It has been observed that at each level of transfer a large proportion, 80-90 per cent, of the potential energy is lost as heat. Hence the number of steps or links in a sequence is restricted, usually to four or five. The shorter the food chain or the nearer is the organism to the beginning of the chain, the available energy intake is greater.

Basically, food chains are of two types: (i) *Grazing food chain* and (ii) *Detritus food chain*. The grazing food chain starts from green plants and passes through harbivores to carnivores. On the other hand, the detritus food chain starts from dead organisms and goes into the micro-organisms and then to detritus feeding organisms and their predators. The term 'detritus' refers to all organic matter involved in the decomposition of dead organisms.

The energy from the sun is transferred in the form of food from one organism to another in the ecosystem.

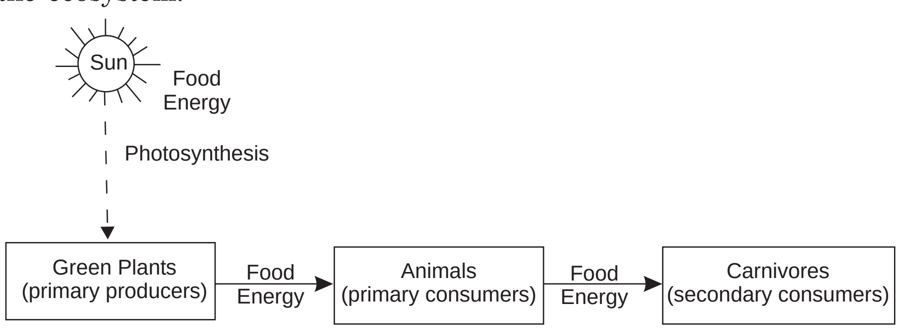

Fig. 2.4: Food chain

Food Web: In complex natural communities the food chains are not found in isolation. They are all inter-connected with each other since most consumers have multiple food sources and many species are prey to several predators and parasites. Such inter-locking food chain is called *food web*.

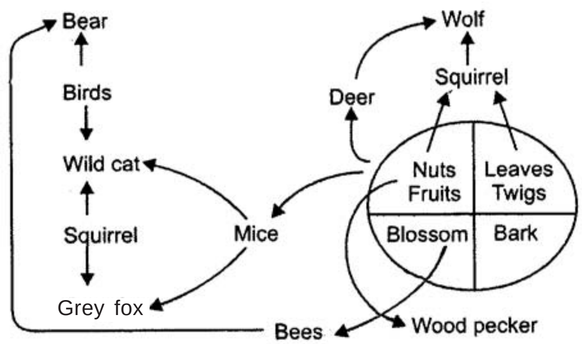

Fig. 2.5: Food web in terrestrial ecosystem

Questions

1. Distinguish between Photosynthesis and Chemosynthesis.
2. How do green plants produce their own food?
3. How does the flow of energy in an ecosystem conform to the Stability Principle?
4. Illustrate the Food Chain and show how energy passes from one group of organisms to another.
5. Illustrate Food Web in an ecosystem.
6. Define Ecology and Ecosystem.
7. What is Biodiversity? Explain the need of biodiversity conservation.

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3 Population and Environment

3.1 HUMAN POPULATION AND DISTRIBUTION

Population is intimately related to environment. The human population has grown faster in the 20th century than ever before. World population doubled in 40 years between 1950 and 1990 to cross 5 billion. The developed countries account for 1.5 billion while developing countries 3.5 billion population. By 2000 A.D. the population has touched 6.3 billion and by 2010 it will grow to 7 billion (one in every seven will be an Indian). World population is growing by 92 million every year, roughly adding population of Mexico.

It is interesting to note that it took about 2 million years for the world population to become 1 billion (1830), l00 years for 2 billion (1930), 30 years for 3 billion (1960), 25 years for 4 billion (1985) and 12 years for 5 billion (1997). The population stands at 6.3 billion (2000) and is estimated to be about four times around 22.5 billion in 2100. In developed countries the population is likely to be less than double while in developing countries like India, about four times (2100).

The statistics for India is of serious concern. Between 1901 and 1951 India's population grew from 238 million to 361 million, an increase of 52 per cent in 50 years. Between 1951 and 1981 it expanded from 361 to 685 million. Post-Independent India in 35 years (1947-1981) literally added a second India i.e., doubled its population. At present, it has exceeded 1 billion mark (2000 May), close to China. We have been overwhelmed by population explosion since 1980.

Distribution

For historical and other reasons, world population is not uniformly distributed. USA and Canada have a population of 250 million; South America and the Soviet Union (CIS) have the same population. Africa and Western Europe have about 500 million people; East Asia, i.e., China, Japan and Korea have more than 1 billion while South Asia is the most populous region with 1.5 billion population (India, Pakistan, Bangladesh). India is adding every year the population of Australia (16 million).

3.2 POPULATION DENSITY

The density of population within a country gives a rough idea of the effect of population on natural resources. In general, lightly populated countries retain more of their original vegetation and wild animal populations than those with dense human population. Thus Australia (4 people/sq.km) is not likely to face wood or water shortage compared to Bangladesh (1800 people/sq. km). *Population density* is defined as *the number of persons per sq. km*. It should be noted that the total population size or population density cannot accurately predict the impact of environmental damage on the economy of a country. Some of the most crowded countries in East and South Asia are the most prosperous e.g., Taiwan, South Korea, Hong Kong and Singapore where the population density is 1000 people/sq. km.

Some crowded countries can even manage to produce all their own food. Thus U.K. (600 people/sq. km) exports food while Brazil (44 people/sq. km) has acute shortage of food and has to import it. Again, Europe has all the timber and fresh water it needs but Africa (95 people/sq. km) has acute shortage of both these items. Such inequalities among countries are due to difference in their economic status—sustainable and non-sustainable. The countries with stable population (e.g., U.K.) enjoy sustainable economy and are prosperous. But countries with fast population growth suffer from non-sustainable economy and consequent problems of poverty, diseases etc.

3.3 AGE STRUCTURE

In contrast to the developed countries, India has a pyramidal distribution of age-wise population. Children constitute 40 per cent, youth 33 per cent, middle aged persons 21.5 per cent and old 6.2 per cent. Such a structure with predominantly young people up to 34 years favours fast population growth. While India has a youthful age structure (reproductive group), in the Western countries the population has much less youthful age structure which slows the population growth.

The ratio of people over 65 and under 15 to the rest of the population is known as *dependency ratio*. This gives a measure of the economic impact of the age structure. People above 65 and below 15 contribute little to the economy and must be supported by the working population. Dependency ratios are rising in the developing countries.

High dependency ratios as in India, have adverse effect on the economy. This explains why working Indians have lower standard of living compared to developed countries.

Fertility Rate

The general fertility rate of a population is the number of babies born to 1000 women of the reproductive age. The rate of population growth, however, is based on the average age of reproduction. Thus whether a population is increasing, decreasing or stationary is more correctly estimated from the age-specific fertility rate. The fertility rate for India and other developing countries is about 3.0 while that for the Western countries is below 1.5.

Doubling Time

The period within which the population of a country doubles is known as its *doubling time*. This gives an idea of the population growth rate. Most developed countries have doubling times of more than 100 years while in the developing countries as in India, the doubling time is less than 25 years. It is absurd to double our resources viz. water, food and energy in 25 years and hence we fail to tackle the pressure on schools, hospitals, police protection and other vital services.

3.4 INFANT MORTALITY/LIFE EXPECTANCY

The death rate is generally expressed as the number of deaths per year for every 100 people. Modern medical science has helped to reduce the death rate but not the birth rate. Death control without birth control has led to population explosion.

Infant mortality is one of the most tragic indicators of poverty of a country. It also sets the parameter of *life expectancy* i.e., the average number of years that a new-born baby is expected to survive. Progress in medical science has in general increased the life expectancy. In 1900 life expectancy was 46 years in the developed countries because the infant mortality was high i.e., 40 per 1000. The situation improved much in 1984 in these countries when the life expectancy rose to more than 70 years as the infant mortality dropped to about 10 per 1000. The world's highest life expectancy is that of Japan (79 years) which enjoys high literacy and high standard of living. In the developing countries high infant mortality is responsible for low life expectancy. Furthermore, lack of basic amenities of life viz., access to clean water, nutritious food and elementary education explains why life expectancy in most of Africa is 45 years while in East Africa and South America life expectancy is 65 years.

It is on record that in developing countries 1 in 3 children is malnourished and about 3 million children die annually from diseases that could be avoided by immunisation. And moreover, 1 million women die each year from preventable reproductive health problems.

3.5 CARRYING CAPACITY

The maximum population size that an ecosystem can support under particular environmental conditions is known as the *carrying capacity*. In natural ecosystem with unlimited resources and ideal environment, species can multiply at a maximum rate. However, in actual practice, the population of a species remains in check due to interaction of the inhabiting species as also finite nature of resources.

It is an established fact that while foodgrain production can under optimum conditions increase arithmetically (1, 2, 3, 4,...), population increases geometrically (2^2, 3^2, 4^2,...).

Rate of population growth, $\frac{dN}{dt} = r\,N$

where N = popualtion size

and r = specific growth rate

With doubling of population, resources do not double and hence set in a critical situation. If the population size far exceeds the carrying capacity by a wide margin, it leads to *population crash* or *expiosion* when environmental conditions get degraded lower the carrying capacity.

The earth weighs about 5.97×10^{24} kg. If the present population growth continues for the next 5000 years, then the weight of human population itself will match the earth's weight. In other words, another earth will have to be accommodated within this earth, which is totally absurd. This implies man will run out of space and resources. Thus the present population growth will get more and more unfavourable for human survival as it will destroy the carrying capacity in the long run.

The concept of carrying capacity, as stated above, implies that only a limited number of people can be supported by the resource base of a country. The population growth must be linked to the resource base in order to have sustainable development. The developed countries follow the policy of *Population Stabilisation* i.e., keep the population growth level below 0.5 per cent and thereby hold the key to economic development and resource management. This is the success story of all developed countries.

For India, population explosion is a time bomb, which must be diffused sooner the better. It is the major crisis facing the country. *We have to break the vicious P-triangle: Population-Poverty-Pollution on an emergency basis for our own survival*.

3.6 POPULATION GROWTH PATTERN (INDIAN CONTEXT)

During the British rule in India the population growth rate was insignificant. Agriculture was neglected and peasants were tortured as a matter of the colonial policy which led to poverty, malnutrition, famine, epidemics and death. The birth rate and death rate were almost balanced and this caused population drop by 1.1 per cent during 1911-1921. Slow increase in population was noticed from 1931 onwards which got a boost after Independence in 1947.

The population of 340 million in 1947 more than doubled to 683 million in 1981 within a period of 34 years and to over 1 billion in 2000. In other words, India added a second India within 34 years and a third India within 53 years since Independence. The population increased by 160.6 million during 1981-91 and after touching the 1-billion mark by May 2000, India became the second most populous country in the world, next to China. At present, India has been adding a population of 18 million every year roughly equal to the population of Australia. At this rate it is expected to overtake China by 2025 A.D. and earn the distinction of becoming the most populous country in the world.

The population growth rate in India is shown in Table 3.1.

Table 3.1: Population Growth in India (1901-2000)

Year	*Population (in million)*	*Decade growth rate (%)*
1901	238.1	–
1911	252.1	+ 5.75
1921	251.3	– 0.31
1931	279.0	+ 11.00
1941	318.9	+ 14.22
1951	361.1	+ 13.31
1961	439.2	+ 21.51
1971	548.2	+ 24.80
1981	683.8	+ 24.75
1991	846.3	+ 23.51
2000 (May 11)	1000 (1 billion)	

Such fast growth rate of population (2.4%) has led to population explosion. This is responsible for rapid environmental degradation and poor economy of the country.

3.7 URBANISATION

Industrial progress along with job opportunities led to growth and mushrooming of cities all over the world as centres of commerce and production and of art and culture. These also encouraged migration of rural population to cities. At the time of Independence the share of urban population did not exceed 8 per cent of total population but by 1991 it rose to 36.2 per cent (217 million). The number of million-plus cities increased from 3 (pre-1947) to 23 by 1991. The top ten such cities are listed in Table 3.2.

Unplanned growth of urbanisation has led to collapse of infrastructure particularly in the metropolitan cities and also miserable living conditions in slums with the net result that the citizens have poor quality of life.

Table 3.2: Top Ten Cities (1-Million-plus) of India (1991)

	Cities	*Population (in million)*
1.	Greater Mumbai	12.57
2.	Kolkata	10.92
3.	Delhi	8.38
4.	Chennai	5.36
5.	Hyderabad	4.28
6.	Bangalore	4.09
7.	Ahmedabad	3.30
8.	Pune	2.49
9.	Kanpur	2.11
10.	Nagpur	1.66

The world scenario of megacities (population exceeding 10 million) is presented in Table 3.3.

Table 3.3: World's Megacities (2000)

Cities	*Population (in million)*
Tokyo	28.0
Sao Paulo	22.6
New York	16.6
Mexico	16.2
Sanghai	17.4
Mumbai	14.2
Los Angeles	13.2
Buenos Aiyres	13.8
Seuol	13.0
Beijing	14.4
Kolkata	10.9

It is intriguing that whereas London, once a megacity till 1950s, moved out of the list with its stabilised population, Kolkata moved in since the 1980s. Originally built for a population of 1 million, the infrastructure of Kolkata is on the point of collapsing under the pressure of the megacity population for their basic civic amenities viz. housing, transport, roads, water supply, sanitation etc.

3.8 IMPACT OF POPULATION PRESSURE ON INDIA'S ENVIRONMENT—FOOD AND NATURAL RESOURCES

India occupies 2.4% of world's land area but it accounts for 16% of world population. Also the hard fact remains that among 1-billion plus population, about 400 million are illiterate and an equal number live below poverty line. Such huge population has enormous demands for food, shelter, water, fuel, sanitation etc. which in turn have impact on the natural resources.

Food: Rice is the principal crop which mainly grows in the monsoon-dominated regions of West Bengal, Assam, Bihar, Orissa, eastern U.P. and southern states of Andhra Pradesh, Tamil Nadu, Kerala and Karnataka. The second and most important crop is wheat which grows in Punjab, Haryana, U.P., M.P. and in the plains of Gujarat and Rajasthan. The Green Revolution of the sixties boosted wheat production in Punjab and Haryana, which are known as the bread baskets of India. Use of high input, high output technology viz. high-yielding variety of wheat (Mexican), intensive irrigation, chemical fertilisers and pesticides showed record production of wheat in Punjab and Haryana. This was reflected in increased overall food production. From 50 million tons in 1950, the foodgrain production jumped to 100 million tons in 1970, 180 million tons in 1993 and 200 million tons in 1998. But since the nineties, they reached the plateau. The foodgrain production cannot keep pace with our population explosion. It is well-known that while agricultural production increases arithmetically, population increases geometrically. The cultivated land (about 143 million hectares) has already reached the saturation carrying capacity since it is subjected to soil erosion, loss of soil fertility due to intensive cultivation, excessive use of fertilisers and pesticides.

Water: The water front presents another gloomy scenario. Heavy withdrawal of ground water for intensive cultivation, for more than two decades caused water tables to sink thereby threatening food production and food scarcity of the country. According to the estimate of the International Water Management Institute (IWMI) withdrawals of ground water are double the rate of aquifier recharge from rainfall. As a result, water tables all over the country are falling. This is likely to reduce India's grain harvest by one fourth.

On the other hand, population explosion has, in general, exerted tremendous pressure on water resources. Our available water resource is 690 cubic km (km^3) surface water and 452 km^3 ground water. This is not adequate to meet the growing demand for water and is likely to result in water scarcity in near future all over the country.

Soil: Fast growth of human and livestock population has led to continuous degradation of soil due to human activities such as intensive cultivation, over utilisation of grazing land, reckless deforestation, fuel and fodder collection, road construction, surface mining etc. It is estimated that every year we are losing 6000 tons of top soil resulting in soil erosion, loss in soil fertility, drought and flood.

Forest: Population explosion exerts tremendous pressure on forest resources to meet the ever-increasing needs for land, timber, fuel etc. This has resulted in random deforestation with annual loss of 1.3 million hectares of forests, Deforestation brings in its trail extinction of valuable species of plants including medicinal plants, animals causing loss of biodiversity and hence national calamity.

Fuel: Population pressure has imposed severe strain on non-renewable and conventional energy resources like fossil fuel (coal, petroleum, natural gas) and also mineral resources such as iron, copper, lead, silver and gold. The increasing consumption of fossil fuel for domestic and industrial needs and transport has generated air pollution and health hazards particularly in cities and industrial areas.

It may be concluded that population, food, natural resources and environment are closely inter-related. As a matter of policy, the population growth has to be reduced from 2.4 per cent to 1 per cent (China, 1 per cent; western countries, 0.5 per cent), in order to protect the environment and save the next generation. We have to pull ourselves out of the vicious P-Triangle in which we are trapped: *Population-Poverty-Pollution*.

3.9 WOMEN AND ENVIRONMENT

Women, particularly poor village women, are the worst victims of environmental degradation. Their day starts with a *long march* in search for fuel, fodder and water. Many such women spend up to 10 hours a day fetching fuel, fodder and water. An average family in Karnataka village walks about 5km. daily on average for collecting fuelwood only, equivalent to walking from Delhi to Bombay every year. In deforested hill and forests the treks are longer and more difficult. By lighting firewood in chullahs, they turn their kitchens into gas chambers where they spend 2-3 hours daily for cooking food. They are exposed to heavy fumes and smoke and suffer as much as a chain smoker smoking 20 packets of cigarettes a day.

Biomass plays a crucial role in meeting daily needs of the vast majority of rural households. The different forms of biomass are food, fish, fuel (firewood, crop wastes and cowdung); fodder, fertiliser for agricultural fields (cowdung, organic manure, forest wastes); building materials (timber and thatch) and medicines (herbs). The country's biomass base is affected by deforestation and loss of vegetation cover. It is the village women who are worst hit by deforestation and divagetion (loss of vegetation cover). Similarly, the forest dwellers, viz. tribals and nomads those who wander from one place to another and have no fixed location, face total social destruction –they are converted into the uprooted lot of *"environmental refugees."*

Woman Power

In the 18th century some 350 Bishnoi men and women from the Bishnoi community in Rajasthan were determined to protect their forest. They clasped the trees when the Maharaja of Marwar sent some wood-cutters along with soldiers to cut down those trees which were required for a brick kiln (furnace) to make slabs for his palace. But the group of men and women resisted by continuing to clasp the trees and finally they were hacked to death. This was the precursor (fore-runner) of the Chipko Movement two centuries later (1983).

The women of the Garhwal hill region of Uttarakhand were at the vanguard of the Chipko Movement *(see* Chapter 10). They organised and executed the movement with utmost sincerity and spread their base all over the Garhwal region. Thus organised woman power prevented further ecological crisis in the Himalayan region.

Another shining example of woman power was the case of Khirakot women in Almora district of Uttarakhand Himalayas. A Kanpur contractor was setting up soapstone mines in the hills thereby destroying the ecology of the region. The Khirakot women sprang into action–they got organised, stopped the work of the mines and also fought legal case against the contractor. Finally they won the battle, both legal and environmental and got the contractor's license cancelled.

3.10 HUMAN DEVELOPMENT

The economic status of a country is normally judged by its Gross Domestic Product-GDP (consumerism i.e., commodities purchased per year, consumer durables, financial status). But since the nineties the United Nations introduced the concept of *Human Development Index–* HDI replacing GDP. This is an estimate of human resources development as measured by three parameters– life span, literacy and standard of living. It determines the quality of life in a country. All the countries in the world have been listed in terms of HDI.

The latest United Nations Report (2000) on Human Development and HDI list (Human Development Index) reveals some interesting facts and figures regarding the status of India in the world perspective.

India has moved down by four places from 132 to 134 in the HDI list while Pakistan ranks 135, Bangladesh 146, and Sri Lanka has moved up to position 84. *Canada retains the top position (number one)* for the seventh consecutive year while Japan has moved down from position number one to eighth during a span of 10 years. The HDI rankings of other countries in the high category are: Norway (number 2), USA (number 3), Australia (number 4), Sweden (number 5), Belgium (number 6), the Netherlands (number 7), Japan (number 8), Britain (number 9) and Finland (number 10).

According to the Report, even in the richest nations relative prosperity in some countries like USA has failed to improve lives. Although USA has the second highest per capita income among 18 richest nations (OECD i.e., Overseas Economic Cooperation and Development countries), it has a fairly high poverty rate. The main reason is the prevalence of functional illiteracy (20 per cent).

In general, however, the deprivations cast their dark shadow over most of the world. Some *1.2 billion people live below poverty line, with income less than one dollar a day; more than 1 billion people in the developing countries lack access to safe water and more than 2.4 billion people lack adequate sanitation.*

In the HDI list, *India occupies l34th position.* Per capita GDP (Gross Domestic Product) values for India ($ 300) are less than 1.5 per cent of those of Japan ($, 24,000) and USA ($20,000). Inspite of remarkable progress in science and technology, India remains one of the poorest countries in the world, with 40 per cent population living below the poverty line, 44 per cent below literacy line and 25 per cent without access to proper health care.

Questions

1. Trace the world population growth up to 2000 A.D.
2. What is population explosion? How does it affect the economy of India?
3. Comment on the doubling time of population with reference to India and compare it with that of the world.
4. How is infant mortality related to life expectancy?
5. Explain carrying capacity of the Earth. How is it affected by population explosion at the present rate?
6. Illustrate the population growth pattern in India from 1901 to 2000 A.D.
7. Name the top ten million-plus cities of India.
8. Discuss how population pressure affects: (a) Food, (b) Water and (c) Forest Resources.
9. What is P-Triangle? How can we get out of this Triangle?

4 Air Pollution

Pure air is colourless and odourless. But various pollutants from natural and man-made sources are entering the atmosphere daily and these disturb the dynamic equilibrium in the atmosphere. This leads to air pollution when the normal properties of air are upset and both man and environment suffer.

Natural sources of air pollution are:

- Volcanic activity, vegetation decay, forest fires emitting carbon monoxide, sulphur dioxide and hydrogen sulphide and tiny particles of solids or liquids sprayed from the seas and land by wind.

Man-made sources are:

- Gases, mists, particulates and aerosols emitted by industries and other chemical and biological processes used by man.

4.1 AIR POLLUTANTS

In general, air pollutants, emitted from natural and anthropogenic sources, can be broadly classified under two categories —Primary and Secondary pollutants. The primary pollutants are those that are emitted directly from the sources. These are:

Inorganic gases – SO_2, NO, CO, CO_2, H_2S. HF.

Olefinic and Aromatic hydrocarbons; Radioactive compounds.

The Secondary pollutants are those that are formed in the atmosphere by chemical reactions among primary pollutants and atmospheric constituents. Examples are: SO_3, NO_2, PAN (Peroxyacyl nitrate), O_3, aldehydes, ketones, various nitrate and sulphate salts.

The five major primary pollutants are:

Carbon monoxide CO

Nitrogen Oxides, NO_x

Sulphur dioxide, SO_2

Hydrocarbons, HC and

Particulate matter.

Emission Sources in India

Air pollution originates from our fuel combustion policy. Table 4.1 gives the emissions of the five primary pollutants from fuels alone on all India basis (1976-77). Air pollution resulting from combustion of non-commercial fuels (fire wood, cowdung etc.), far surpasses that from combustion of commercial fuels (Coal, petroleum etc.) However, the latter is the major source of air pollution in urban areas.

Table 4.1: Nationwide Air Pollutant Emission from Fuel Sources in India* (1976–77)

	Particulate matter	*SO_2*	*NO_x*	*CO*	*Organics including HC*
			(millions of tonnes)		
Commercial (coal, petroleum, natural gas)	3.21	2.15	0.62	1.29	2.80
Non-commercial (firewood, dry cattle dung, vegetable wastes, refuse burning)	7.54	4.67	1.97	2.05	6.19

In addition to burning of fuels, major industries like steel, paper and pulp, textiles, cement, and sulphuric and nitric acid plants contribute relatively small but significant amounts of air pollutants to the nation's atmosphere. Since most of the industries are located in major cities, these significantly add to the pollution burden of the metropolitan areas. Table 4.2 lists the various sources and their contributions to the pollution of a typical metropolitan city like Mumbai.

* Recent data (2006-07) are much higher (>50%) than those in Table 4.1 and Table 4.2.

Table 4.2: Major Pollutant Emissions in Greater Mumbai Area (1976-77)

Source	***Particulate matter***	***SO_2***	***NO_x***	***CO***	***HC***
		(Tonnes per day)			
Domestic	19.0	2.7	3.3	7.0	2.0
Commercial & institutional	2.2	1.7	1.0	—	—
Industrial	14.0	236.0	35.7	111.0	11.6
Power generation	28.0	62.0	30.0	2.0	—
Transportation	30.0	40.6	27.7	263.0	37.4
Total	93.2	343.0	97.7	383.0	81.0

As seen from the table, industry is the major source of pollution on a tonnage basis, followed by transportation and generation of electrical power. These three sources are responsible for the emission of about 77 per cent of particulate matter, 98 percent of SO_2 and 94 per cent of NO_x.

Air pollution status of Indian metropolitan cities may be compared in this context.

According to UN Report in 1994 Kolkata, Mumbai and Delhi were among the most polluted cities in the world. During winter temperature inversion occurs when pollutants are trapped near the ground level.

Kolkata

Total vehicular emissions 300 tonnes/day; suspended particulate matter (SPM) *2000-3000* μg/m^3 (WHO limit 150-250 μg/m^3); Polynuclear aromatic hydrocarbons (due to automotive emissions and smoke from chullahs) 150- 500 μg/m^3; SO_x 100-250 μg/m^3; NO_x 150-250 μg/m^3.

Delhi

SPM 150-700 μg/m^3

SO_x 10-35 μg/m^3

NO_x 70-180 μg/m^3

This shows that Kolkata air is more polluted than Delhi air.

In USA air pollution pattern (as on 1976 and valid even in 1995) shows that transportation accounts for more than 46% of total pollutants produced per year and hence remains the principal source of air pollution. Carbon monoxide is the major individual pollutant with a tonnage matching that of all the pollutants taken together.

Table 4.3: Primary Air Pollutant Sources and their Quantities (Million Tonnes per Year)

Sources	***CO***	***Weight of pollutants produced*** NO_x	***HC***	SO_x	***Particulates*** <20μ>	***30μ***	***Total weight of pollutant produced***
Transportation	70	10	10.8	0.8	1.2	1.0	94
Fuel combustion (stationary sources)	1.2	11.8	1.4	21.9	4.6	1.3	42.2
Industrial processes	7.8	0.7	9.4	4.1	6.3	2.7	31.0
Solid waste disposal	7.8	0.8	1.6	0.1	1.1	—	11.2
Miscellaneous	8.5	0.4	6.3	0.1	1.3	—	16.6
Total weight of pollutant produced (in million tonnes)	95.0	23.6	29.5	27.0	—	19.5	194.6

1μ $=10^{-6}$ metre (1 part in 1 million parts of 1 metre)

4.2 PRIMARY POLLUTANTS

4.2.1 Carbon Monoxide, CO

It is a colourless, odourless and tasteless gas which is injurious to our health. Each year 350 million tonnes of CO (275 million tonnes from human sources and 75 million tonnes from natural sources) are emitted all over the world in which USA alone shares 100 million tonnes. Transportation accounts for 70 per cent of CO emission. That is to say, diesel and petroleum engines in automobiles are primarily responsible for about 70 per cent of CO emissions.

The sources of carbon monoxide, CO are the chemical reactions:

(i) incomplete combustion of fuel or carbon containing compounds:

$$\underset{\text{(carbon)}}{2C} + \underset{\text{(oxygen)}}{O_2} \longrightarrow \underset{\text{(carbon monoxide)}}{2CO}$$

(ii) reaction of carbon dioxide and carbon-containing materials at elevated temperatures in industries e.g., in blast furnaces:

$$\underset{\text{(carbon dioxide)}}{CO_2} + \underset{\text{(carbon)}}{C} \longrightarrow 2CO$$

(iii) dissociation of carbon dioxide at high temperatures:

$$\underset{\text{(carbon dioxide)}}{CO_2} \rightleftharpoons \underset{\text{(carbon monoxide)}}{CO} + \underset{\text{(oxygen)}}{O}$$

Sinks

Part of carbon monoxide is lost in the upper atmosphere. The major sink is soil micro-organisms. A potting soil sample weighing 28 kg completely removed in 3 hours 120 ppm carbon monoxide from ambient air. The same soil sample on sterilization failed to remove carbon monoxide from air.

Control of CO Pollution

The petroleum and diesel-fed automobiles account for major share of carbon monoxide emission. Hence efforts for carbon monoxide pollution control are mainly aimed at automobiles. Use of catalytic converters in the internal combustion engines of automobiles helps in cleaning up the exhaust emissions. Such converters built into the automobile engines promote oxidation-reduction cycles and ensure complete combustion of carbon monoxide, nitrogen oxides and hydrocarbons. The following figure and flow-sheet illustrate the action of catalytic converters: Use of catalytic converters in two stages helps in elimination of pollutants from exhaust gases before they are discharged into the atmosphere.

In the first converter nitrogen oxides are reduced to nitrogen (+ ammonia) in presence of finely divided catalyst platinum, and the reducing gases, carbon monoxide and hydrocarbons. The production of ammonia is kept at a minimum under carefully controlled conditions. In the second converter, air is introduced to provide an oxidizing atmosphere for complete oxidation of carbon monoxide and hydrocarbon into carbon dioxide and water in presence of finely divided platinum catalyst.

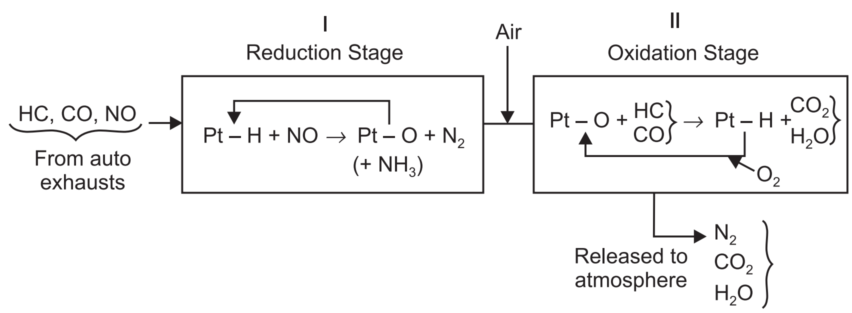


Fig. 4.1: Catalytic converters for treating auto emissions

Thus by means of platinum catalytic converters, auto exhaust emissions are cleaned up through reduction-oxidation reactions. In all developed countries it is mandatory by law for all automobiles to fit their engines with catalytic converters. In India some automobile companies have plans to fix their automobile engines with catalytic converters.

4.2.2 Nitrogen Oxides, NO_x

It consists of mixed oxides, nitric oxide and nitrogen dioxide (NO and NO_2 respectively)—the former is a colourless and odourless gas but the latter (NO_2) has a reddish brown colour and pungent smell.

The formation of NO and NO_2 is based on the chemical reactions:

$$\underset{\text{(nitrogen)}}{N_2} + \underset{\text{(oxygen)}}{O_2} \xrightleftharpoons{1210° - 1765°C} \underset{\text{(nitric oxide)}}{2NO}$$

$$2NO + O_2 \rightleftharpoons 2NO_2$$

These reactions occur inside the automobile engines so that the exhaust gases consist of NO_x. The latter concentration in rural air is much less than in urban air.

In air NO_x is converted into nitric acid, HNO_3 by natural processes:

$$\underset{\text{(Nitrogen dioxide)}}{NO_2} + \underset{\text{(Ozone)}}{O_3} \longrightarrow \underset{\text{(Nitrogen trioxide)}}{NO_3} + O_2$$

$$NO_3 + NO_2 \longrightarrow \underset{\text{(Nitrogen pentoxide)}}{N_2O_5}$$

$$N_2O_5 + \underset{\text{(Water vapour)}}{H_2O} \longrightarrow \underset{\text{(Nitric acid)}}{2HNO_3}$$

This nitric acid is one of the constituents of acid rain discussed in a subsequent section. From auto exhaust emissions NO_x is removed as discussed above by means of catalytic converters.

4.2.3 Hydrocarbons and Photochemical Smog

Natural processes, particularly trees emit large quantities of hydrocarbons in air. Methane, CH_4 is a major hydrocarbon. It is generated in large quantities by bacteria formed by anaerobic decomposition of organic matter in water sediments and soil.

$$\underset{\text{(Organic matter)}}{2\{CH_2O\}} \xrightarrow{\text{bacteria}} \underset{\text{(Carbon dioxide)}}{CO_2 \uparrow} + \underset{\text{(Methane)}}{CH_4 \uparrow}$$

Domestic animals (cattle, buffaloes, etc.) contribute about 85 million tonnes of methane to the atmosphere each year. Automobiles are significant sources of hydrocarbons.

In presence of ozone, carbon monoxide, nitrogen oxides and hydrocarbon participate in photochemical reactions (in presence of sunlight). A chain reaction proceeds in which the free radical R $\dot{C}H_2$ is generated in the first step. Other free radicals which are formed are: R $CH_2\dot{O}_2$ in the second step by reaction with oxygen, R CH_2 O; R $CH_2\dot{O}$ in the third step by reaction with nitric oxide; $H\dot{O}_2$ in the fourth step by reaction with oxygen; a stable aldehyde R CHO is another product at this stage; $H\dot{O}$ is formed in fifth step by reaction with nitric oxide (nitrogen dioxide is another product here); and finally, the starting free radical R $\dot{C}H_2$ is regenerated by reaction with hydrocarbon, R CH_3 thereby sustaining the chain reaction.

The harmful products in the chain reaction are NO_2 and aldehyde, R CHO. A side reaction also follows by another route through the aldehyde, R CHO; it gives an injurious end product, peroxy acyl nitrate (PAN) which is a strong eye irritant. These reactions lead to photochemical smog formation, which is characterized by brown hazy fumes which irritate the eyes and lungs and also cause serious damage to plants.

Photochemical smog occurs in coastal cities in winter climate e.g., in Los Angeles, USA which have the heaviest vehicular traffic.

4.2.4 Sulphur Dioxide, SO_2

Sulphur dioxide is a colourless gas with a pungent odour. It is produced from the combustion of any sulphur-bearing material.

Sulphur dioxide, SO_2 is always associated with a little of sulphur trioxide, SO_3.

$$\underset{\text{(sulphur)}}{S} + \underset{\text{(oxygen)}}{O_2} \longrightarrow \underset{\text{(sulphur dioxide)}}{SO_2}$$

$$2SO_2 + O_2 \longrightarrow \underset{\text{(sulphur trioxide)}}{2SO_3}$$

Man-made sources—coal-fired power stations and other industries contribute about 33 per cent of SO_x pollution while natural sources, viz. volcanoes provide about 67 per cent of SO_x pollution.

Soot particles containing metal oxides, catalyze the oxidation of sulphur dioxide to trioxide.

$$\underset{\text{(sulphur dioxide)}}{SO_2} + \underset{\text{(ozone)}}{O_3} \longrightarrow \underset{\text{(sulphur trioxide)}}{SO_3} + O_2 \xrightarrow{H_2O} \underset{\text{(sulphuric acid)}}{H_2SO_4} \longrightarrow \underset{\text{(aerosol droplet)}}{(H_2SO_4)_n}$$

$$SO_2 + \tfrac{1}{2}O_2 \xrightarrow{\text{soot}} SO_3 \longrightarrow H_2SO_4 \longrightarrow \underset{\text{aerosol droplet}}{(H_2SO_4)_n}$$

The first reaction above occurs in presence of ozone and water vapour. The product, sulphuric acid is formed on aerosol (fine particle suspended in air as in smoke, fog, mist, etc.) droplet. Sulphuric acid is one of the constituents of acid rain.

In winter climate sulphur oxides from thermal power plants along with other gases leads to *smog* formation e.g. *London smog.* This is known as reducing smog in contrast with photochemical smog which is known as oxidising smog (consisting of hydrocarbons, nitrogen oxides and ozone). *London smog* (1952) is well-known for its disastrous effect. Heavy smog (SO_2) conditions prevailed in London for five days which killed about 4,000 people. The causes of death were bronchitis, pneumonia, and other respiratory troubles particularly among aged people.

Control of SO_x Pollution

SO_x (sulphur oxides) from flue gases of industrial plants can be removed by means of chemical scrubbers. The flue stack gases are led through a bed of (slurry) of limestone, $CaCO_3$ (calcium carbonate) which absorbs sulphur dioxide quite efficiently.

$$\underset{\text{(calcium carbonate)}}{2CaCO_3} + \underset{\text{(sulphur dioxide)}}{2SO_2} + \underset{\text{(oxygen)}}{O_2} \longrightarrow \underset{\text{(calcium sulphate)}}{2CaSO_4} + \underset{\text{(carbon dioxide)}}{CO_2}$$

The method is economical but the disposal of solid waste, calcium sulphate is a problem.

Alternatively, sulphur dioxide in aqueous solution is treated with citric acid salt and the resulting solution is exposed to a stream of hydrogen sulphide gas whereby sulphur is deposited. This sulphur can then be recovered and utilised.

Thermal power plants, major sources of man-made SO_x pollution, are normally constructed with tall chimneys to disperse the emissions over a wide area. This reduces the local problem but creates problems for far away areas through acid rains (*see* below).

Acid Rain

It has been described above that much of nitrogen oxides, NO_x and sulphur oxides, SO_X entering the atmosphere are transformed into nitric acid (HNO_3) and sulphuric acid (H_2SO_4) respectively. These combine with hydrogen chloride, HCl from HCl emissions (both by man-made and natural sources) and generate acidic precipitation, known as *acid rain.*

Acid rain is a major environmental issue as it badly damages the environment. It damages buildings and structural materials of marble, limestones, slate and mortar. These materials become structurally weak as calcium carbonate reacts with sulphuric acid to form soluble sulphate, which is leached out by rain water:

$$\underset{\text{(Limestone)}}{CaCO_3} + \underset{\text{(Sulphuric acid)}}{H_2SO_4} \longrightarrow \underset{\text{(Calcium sulphate)}}{CaSO_4} + CO_2 + H_2O$$

In Greece and Italy invaluable stones and statutes have been partly dissolved by acid rain. Besides these, acid rain damaged forests in Germany and lakes in Sweden and Canada. Acid rain originated from U.K. but far away in Sweden, it damaged some 8,000 lakes of which 4,000 are dead. Similarly, acid rain from USA damaged lakes and forests in Canada. In India, Taj Mahal is threatened by acid rain from Mathura refinery and other industries.

Control of Acid Rain

Acid rain can be checked if its constituents, sulphur dioxide and nitrogen oxide are controlled as discussed above.

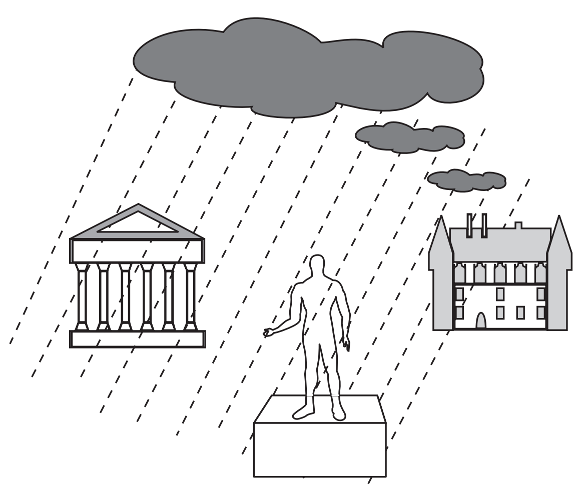


Fig. 4.2: Acid rain in Greece and Italy

4.2.5 Particulate

Small solid particles and liquid droplets are collectively termed *particulates*. They originate both from natural and man-made sources. Every year natural sources discharge 800–2,000 million tonnes and man-made sources 200–500 million tonnes of particulates. Among man-made sources, fly ash from thermal power plants deserve mention. The Table 4.4 gives a list of annual production of particulate matter from the two sources.

Table 4.4: World-wide Addition of Particulate Matter to the Atmosphere (in Million Tonnes)

	Annual Production (million tons)	
Particulate matter	***Natural source***	***Man-made sources***
Total particles	800–2000	200–450
Dust and smoke	—	10–90
Salt, forest fires	450–1100	—
Sulphate	130–200	130–200
Nitrate	30–35	140–700
Hydrocarbons	15–20	75–200

Particulates range in size from 0.0002 μ (about the size of a molecule) to 500 μ (1 μ = 10^{-6} metre). The number of particles in the atmosphere vary from several hundred per cm^3 in clean air to more than 100,000 per cm^3 in highly polluted air (urban/industrial area).

Soot

Soot particles originate from fuel combustion and consist of highly condensed product of polycyclic aromatic hydrocarbon (PAH)—roughly 100 condensed aromatic rings. The hydrogen content of soot is 1–3 per cent and oxygen content 5–10 per cent due to partial surface oxidation. Due to large surface area, soot acts as a carrier for toxic organics e.g., benzo-α-pyrene and toxic trace metals e.g., beryllium, cadmium chromium, manganese, nickel, vanadium, etc.

A soot particle has an average size 0.1–20 μ. The finer particles (< 3 μ) are the worst causes of lungs damage due to their ability to penetrate deep in our respiratory tract and thence in lungs where they remain for years and cause all sorts of diseases such as cough, bronchitis, asthma, and finally cancer. Particulates cause increased corrosion of metals which assume serious dimensions in industrial and urban areas. They are responsible for damage to buildings, sculptures, paintings, etc.

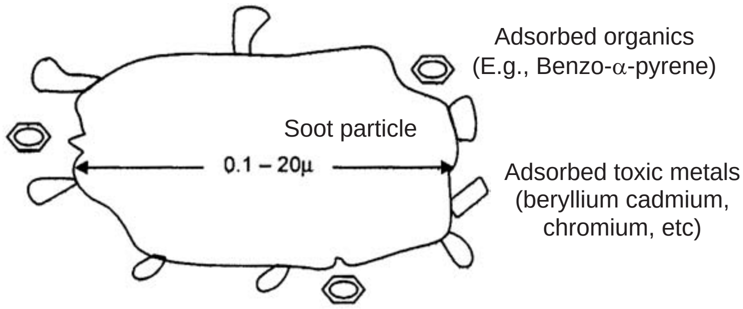


Fig. 4.3: A soot particle

Particulates play key roles in the atmosphere. They reduce visibility by scattering and absorption of solar radiation. They influence the climate through the formation of cloud, rain and snow by acting as nuclei upon which water can condense into raindrops. Atmospheric particulate levels can be correlated with the extent of precipitation over cities and suburbs.

Control of Particulate Emissions

The removal of particulate matter from gas streams is an essential step for air pollution control. There are four types of equipment used for this purpose.

(1) *Gravity settling chamber:* Effluent gases are led into a chamber which is large enough to permit gas velocities to decrease and dust or droplets to settle. The chamber is generally in the shape of a horizontal rectangular tank articles with a diameter > 50 μ are ordinarily removed in this manner. The method is, however, not suitable for fine particles which require longer setting time.

(2) *Cyclone collector:* A gas flowing in a tight circular spiral produces a centrifugal force on suspended particles, forcing them to move outward through the gas stream to a wall where they are collected. Thus, it is possible to remove 95% particles in the diameter range 5-20 μ (Fig. 4.4).

(3) *Wet scrubbers:* These utilise a liquid (usually H_2O) to help remove solid liquid or gaseous contaminants. The extent of contact and interaction are increased by the use of spray chambers or towers where· the liquid is introduced into the gas stream as fine spray.

(4) *Electrostatic precipitators:* These are based on the principle that aerosal particles acquire charges when subjected to an electrical field:

$$F = Eq$$

Where F = force in dynes, to which the particles are subjected,

E = voltage gradient (volt/cm)

q = electrostatic charge on the particles (esu).

The particles acquire a charge when a gas stream is led through a high-voltage dc-corona. The charged particles are attracted to a grounded surface from which they are removed. Ozone is a possible product of the corona discharge.

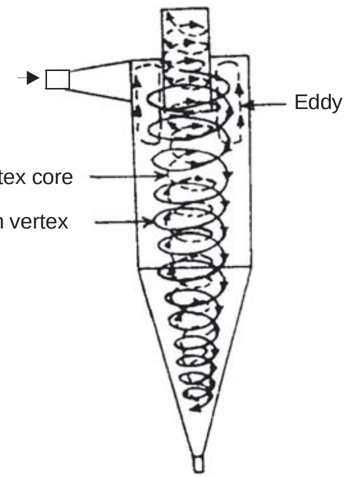


Fig. 4.4: Typical cyclone collector
[L.Byers, "Controlling Atmospheric Particulates," *Technology Tutor,* 1.46 (1971)].

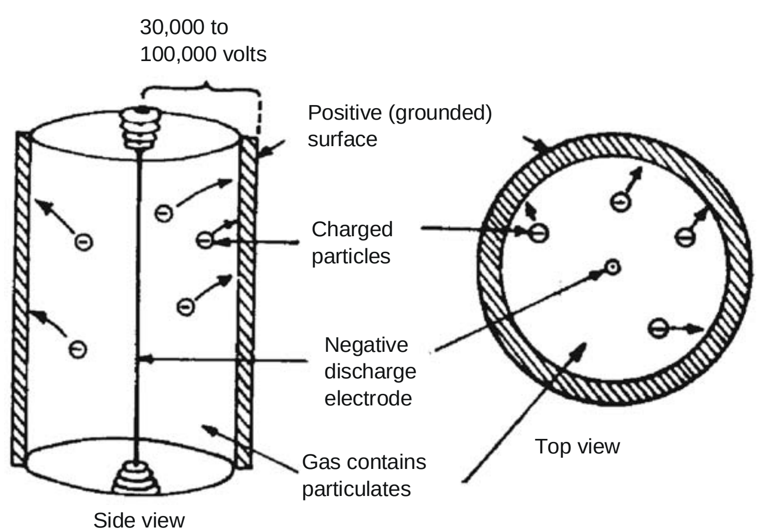


Fig. 4.5: Schematic diagram of an electrostatic precipitator
(Reprinted by permission of Brooks/Cole Publishing Company. Monetary, California 93940, USA., from *Environmental Chemistry*, 3rd edn., S.E. Manahan p. 381, 1979, Willard Grant Press, Statler Office Building, Boston, Massachusetts)

4.3 GREENHOUSE EFFECT (GLOBAL WARMING)

Carbon dioxide is a non-pollutant gas in the atmosphere and a minor constituent (356 parts per million) but it is of serious concern for the environment for its ability to change the global climate.

The earth's surface partly absorbs sun's rays while emits long-wave infra-red radiation (8000–25000 nanometres; 1 nanometre = 10^{-9} metre = 1 nm). Carbon dioxide and water vapour in the atmosphere strongly absorb infra-red radiation (14,000–25,000 nm) and effectively block a large fraction of the earth's emitted radiation. The radiation thus absorbed by carbon dioxide and water vapour is partly returned to the earth's surface. The net result is that the earth's surface gets heated and the phenomenon is known as the *Greenhouse Effect* (Fig. 4.6).

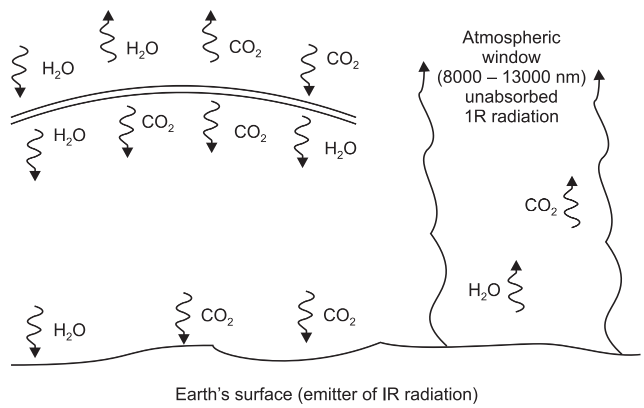


Fig. 4.6: The greenhouse effect

The carbon dioxide level in air has increased from 280 ppm (pre-Industrial revolution era 1780) to 350 ppm at present in two centuries. Fossil fuel (petrol, diesel, coal) combustion is the major source of increase of carbon dioxide level increasing at the rate of 1–2 per cent per year. At this rate of increase, the earth's surface temperature may rise as much as 2°C in the next 100 years. However, nature has its check and balance system. The rate of increase of carbon dioxide is only 50 per cent of its expected magnitude due to the sinks, viz. oceans and photosynthesis by green plants (Fig. 4.7).

It may be noted that a slight rise in temperature even by 1°C, can have adverse effect on the world food production. (1) Thus wheat producing zones in the northern latitude will be shifted from CIS (former USSR) and Canada to the north pole and in India from UP, Punjab, Haryana to the Himalayas i.e., from fertile to non-productive soil. In other words, wheat production will badly suffer. (2) The biological productivity of the ocean will fall due to warming of the surface layer. This reduces transport of nutrient from deeper layers

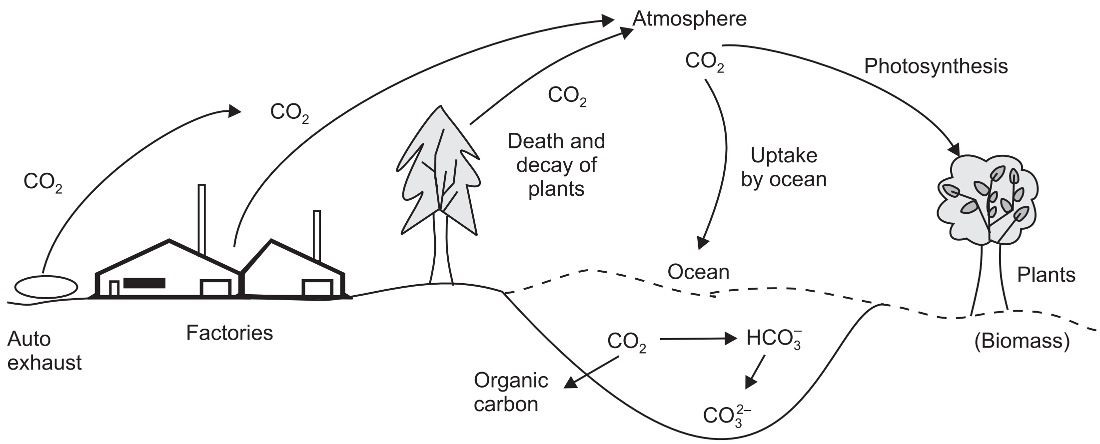


Fig. 4.7: Sources and sinks of carbon dioxide

of the ocean to the surface by vertical circulation. Moreover, there will be less photosynthesis by marine plants. In other words, the production of sea food (marine plants and fish) will decline. Sea food constitutes more than 30 per cent of our food supply. (3) Another disastrous effect is the rise in sea levels by as much as 15 cm in the next 100 years due to partial melting of polar ice caps. This sea level rise would threaten coastal cities (Kolkata, Mumbai, Chennai, etc.) and some 60-odd island nations such as Maldives, Bangladesh, etc. which will be drowned under the sea. When Himalayan snow melts and gets exhausted, the Himalayan rivers including Ganga may dry up —the Ganga valley will be hot and north India will lose its population base. At the same time India will lose its major life line, Ganga.

Other Greenhouse Gases

Carbon dioxide is not the only culprit responsible for Greenhouse Effect and global warming. Other greenhouse gases are: methane, chloroflurocarbons, nitrous oxide, ozone and water vapour. The relative contributions of these gases to greenhouse effect are:

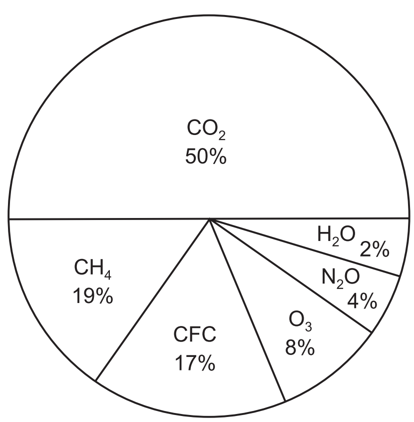


Fig. 4.8: Greenhouse gases (relative shares)

Carbon dioxide 50 per cent; Methane 19 per cent; Chloroflurocarbons 17 per cent; ozone 8 per cent; nitrous oxide 4 per cent; water vapour 2 per cent.

This shows that carbon dioxide accounts for 50 per cent of the greenhouse gases. The shares of methane (19 per cent) and chloroflurocarbons (17 per cent) (gases from refrigerators and air-conditioners) cannot be ignored.

4.4 OZONE HOLE

In the stratosphere, the second region of the atmosphere, ozone is present in small quantities but it is protective shield for the earth. Ozone strongly absorbs ultraviolet radiation from the sun (295–320 nm) which is injurious for life on earth. Thus it protects living species on earth. But recent human activities have injected some dangerous chemicals in the stratosphere which consume ozone and reduce its concentration. This is the phenomenon of *ozone hole* in the stratosphere.

Exhaust gases from jet aircrafts and artificial satellites discharge nitric oxide (NO), nitrogen dioxide (NO_2) etc., which immediately react with ozone.

$$\underset{\text{(Ozone)}}{O_3} + \underset{\text{(Nitric oxide)}}{NO} \longrightarrow \underset{\text{(Oxygen)}}{O_2} + \underset{\text{(Nitrogen dioxide)}}{NO_2}$$

$$O_3 + NO_2 \longrightarrow O_2 + \underset{\text{(Nitrogen trioxide)}}{NO_3}$$

Chloroflurocarbons (CFC) are used as coolants in refrigerators and air-conditioners. These slowly pass from troposphere and stratosphere and once there, they stay for 100 years.

In presence of ultraviolet radiation (200 nm) from the sun, CFC breaks up into chlorine-free radical (Cl) which readily consumes ozone.

$$CFCl_3 \xrightarrow[\text{Ultra-violet radiation}]{h\nu} CFCl_2 + \dot{Cl}$$

$$\dot{Cl} + O_3 \longrightarrow Cl\dot{O} + O_2$$

$$Cl\dot{O} + O \longrightarrow \dot{Cl} + O_2$$

The free radical ($\dot{Cl}$) is regenerated and continues the chain reaction. It is estimated that one molecule of CFC consumes one lakh molecules of ozone. The damage by CFC continues for 100 years. Even if CFC production is stopped now all over the world, the CFC that is already there in the stratosphere will continue to damage the ozone layer for the next 100 years.

In 1979 ozone hole was observed in the sky over Antarctica–here ozone layer thickness was reduced by 30 per cent. Later on ozone hole was discovered in the sky over the thickly populated northern hemisphere. Here in winter ozone thickness was reduced by 4 per cent and in summer by 1 per cent.

Ozone hole allows passage of ultraviolet radiation to the earth where it causes skin cancer, eyesight defect, genetic disorder, etc., in the biosphere (man, animal and plant). In Europe and USA there is an increase in the cases of skin cancer among people while some million people are suffering from eye cataract.

In Montreal Conference (Montreal Protocol, 1987) and London Conference (1992) it was decided that the developed countries would totally ban CFC production by 2000 and the developing countries by 2010 AD. But as stated above, even after the ban is enforced, the CFC and Ci shall continue their havoc for another 100 years. Researches are on for development of CFC-substitutes as coolants for refrigerators and air-conditioners.

4.5 EL NINO

Greenhouse effect, as discussed above, is an atmospheric warming phenomenon while El Nino is an ocean warming phenomenon. El Nino is a Spanish term for the Christ child as it starts in December in South American coast but it affects climate over half the globe.

Under normal conditions the water of the Eastern Pacific off Ecuador, Peru and Chile is cooler by 10°C than the waters of the Western Pacific. This promotes fisheries along the Eastern Pacific coast since cold waters, rich in nutrients, spring from the deep layers of the ocean. The trade winds blow along the equator from Southeast Pacific towards West pushing warm waters out to the ocean. But once every three to five years the trade winds reverse their direction, i.e., from west to east there- by pushing warm waters to the east. As a result, the Eastern Pacific water warms up by about 4°C (24° to 28°C) which disrupts the anchovy fishery, key to the Peruvian economy. This happens when El Nino appears. It not only kills fish but warms the air which lowers the atmospheric pressure and sparks storms and heavy rainfall along Chile coast and spreading up to Southern California (USA).

In 1982 El Nino raised sandstorms in Australia, cyclone in Tahiti, caused droughts in Africa and floods along the Californian coast in USA. Recently in 1998 El Nino activity has been felt all over the world. In the east coast of USA, winter was missing in January–February and in the west coast there was record rainfall in 100 years of US history. Research is on to understand the science of El Nino so that it can be forecast and advance warning signal sent to the regions where lives and properties can be saved in time.

4.6 AIR POLLUTION AND BIOSPHERE

Air pollutants can be transported to the earth's surface by atmospheric turbulence where they interact with the ocean surface, vegetation and upper layers of the soil and are removed by absorption or chemical reaction. Absorption at these surfaces depends on many factors about which little information is available for many pollutants.

The primary pollutants discharged into the atmosphere suffer chemical changes in presence of H_2O, O_2 and ultraviolet ray of sunlight to from secondary pollutants. Typical examples are:

$CO_2 + H_2O \longrightarrow H_2CO_3$ Carbonic acid

$SO_2 + H_2O + O_2 \longrightarrow H_2SO_4$ Sulphuric acid

$NO_2 + H_2O \longrightarrow HNO_3$ Nitric acid

$H_2S + O_2 \longrightarrow H_2SO_4$ Sulphuric acid

These pollutants have overall effects on soil, vegetation, crops, animals, man and materials.

Plants are affected by gaseous pollutants and deposition of particulates on soil. Acid rain over a period of time tends to lower soil pH and makes it acidic. Furthermore, deposition of toxic metals on soil in industrial areas render the soil unsuitable for growth of plants. Some plants are very sensitive to traces of toxic metals as the latter inhibit the action of plant enzymes. On the other hand, particulates such as dust and soot, deposited on plant leaves, block the stomata of plants. This in turn effects the plants by restricting the absorption of CO_2 and reducing the rate of photosynthesis and also the rate of transpiration. The net result is retarded growth of plants and decreased field of crops. In Leeds (U.K.) there was drastic reduction in growth of lettuce and raddish in heavily polluted (SO_2) areas compared to the less polluted area of the city.

O_3(Ozone) and PAN (Peroxyacyl nitrate) attack plants by oxidizing their-SH groups of proteins into disulphides. This oxidation results in inhibition of individual enzyme activity.

Cattle are also affected by air pollution. In 1957 Smithfield cattle show (U.K.) was held under heavy smog conditions. After the show was over, Cattle developed breathing troubles and many died while sheep and pigs were not so affected.

Corrosion of metals-SO_2-polluted air accelerates corrosion of metals. Iron and its alloys and Zn, Cu, Al used in outdoor structures as well as marble sculptures are vulnerable to corrosion. Salt spray in seaside air also corrodes iron structures in buildings in the coastal areas.

Meteorology and Air Pollution

Air pollution, one of the man-made activities, has some impact on meteorology i.e., the science of atmospheric phenomenon. Meteorology is based on the physical parameters such as temperature, wind, moisture, and movement of air masses in the atmosphere. It is also affected by the chemical properties of the atmosphere and the chemical reactions going on in the atmosphere.

The air pollutants get dispersed in the atmosphere depending on the patterns of air circulation. In this context *temperature inversion* plays an important role. It occurs when a warm air mass moves above a cold air mass resulting in air stagnation of the latter (cold air) in which air pollutants get trapped. The air above the ground becomes polluted. This happens when warm air blows over a mountain range and over cool air on the other side of the range. Such a phenomenon is observed in Denver, USA on the east of the Rocky mountains.

Human activities are partly responsible for changing the meteorology of the earth. These activities are:

1. Deforestation and loss of forest cover;
2. Shifting of surface water and ground water in large amounts;
3. Release of heat from power plants;
4. Emission of particles and trace gases into the atmosphere;
5. Release of carbon dioxide into the atmosphere by combustion of fossil fuels;
6. Emission from transport system into the lower and upper atmosphere.

The loading of particulate matter into the atmosphere influences the climate. It has been shown in Table 4.2 that each year natural sources are injecting about 800–2,000 million tonnes while man-made sources about 200–400 million tonnes of particles in the atmosphere. As already discussed, particles induce cloud formation and rainfall. It has been calculated as an approximation that if the particle loading increases by 50 per cent, the average temperature of the earth will decrease by about 0.5°C to 1°C due to particle-induced cloud formation. This partly counterbalances the temperature rise due to Greenhouse Effect.

4.7 AIR QUALITY STANDARDS

Each pollutant, present in air, has a *threshold limit value* (TLV) which, if exceeded, causes public health hazards. Table 4.5 gives a list of typical pollutants with their threshold limits (TLV). For factory workers TLV sets the limit of exposure for 40-hour week (8 hours a day) without adverse effects. These TLV values are determined mainly by experiments on animals.

Table 4.5: Threshold Limit Values (TLV) for Some Common Pollutants (Gases and Vapours)

Pollutant	***Threshold Limit ppm***	***Values mg/m³***
Acetone	750	1780
Ammonia	25	18
Arsenic	0.2–0.5	—
Benzene	10	20
Cadmium	—	0.05
Carbon dioxide	5000	9000
Carbon monoxide	50	50
Carbon tetrachloride	5	30
Chlorine	10	30
Chloroform	10	50
Hydrogen chloride	5	7
Hydrogen sulphide	10	14

Contd....

Lead	—	0.2
Nitric oxide	25	30
Ozone	0.1	0.2
Sulphur dioxide	2.0	5.0
Vinyl chloride	5	10

4.8 MONITORING METHODS FOR AIR POLLUTANTS

The monitoring methods for some principal primary pollutants will be described.

Analysis of Sulphur Dioxide

The modified *West-Gaeke spectrophotometric method* remains the standard method for monitoring of 0.0005-5 ppm SO_2 in ambient air. The method was developed by West and Gaeke and later optimised. Figure 4.9 illustrates the sampling train employed to draw samples from air. The various components involved in such sampling are shown.

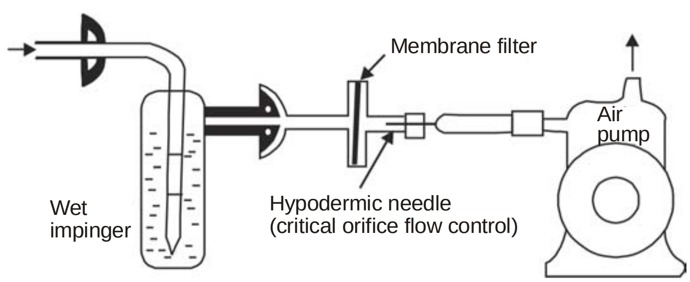
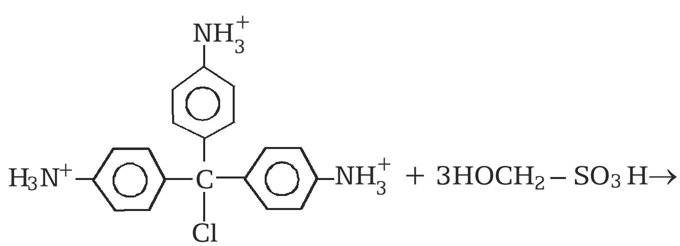


Fig. 4.9: Sampling train for the collection of sulphur dioxide from the atmosphere

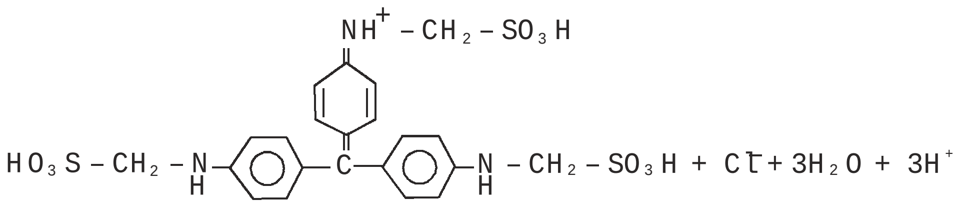
SO_2 is collected in a scrubbing solution containing $HgCl_4^{2-}(HgCl_2 + KCl)$, the collection efficiency being around 95%. The solution is allowed to react with HCHO and then with para-rosaniline hydrochloride:

$$HgCl_4^{2-} + SO_2 + H_2O \rightarrow HgCl_2SO_3^{2-} + 2H^+ 2Cl^-$$

$$SO_2 + H_2O + HCHO \rightarrow HOCH_2 — SO_2H$$



Colourless
(in acidic medium)



red voilet dye

The absorbance of the product red-violet dye is measured at 548 nm. A block diagram of a continuous SO_2 monitor, based upon the West-Gaeke method* and developed by Technicon in the form of the Technicom Air Monitor IV instrument, is shown in Fig. 4.10.

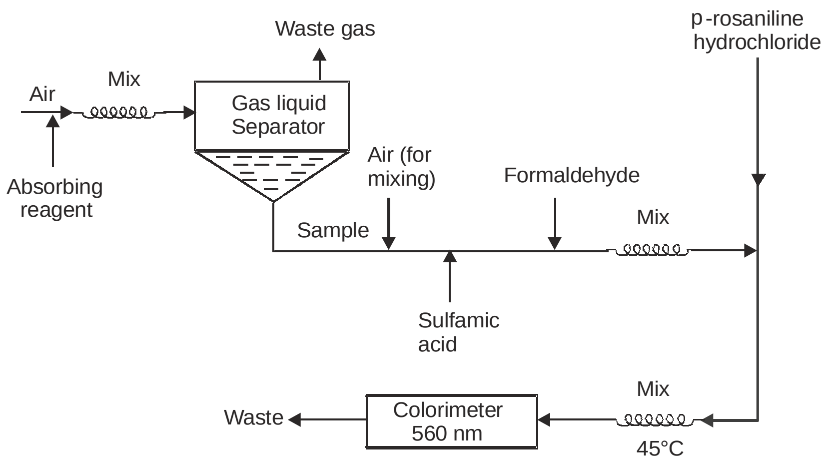


Fig. 4.10: Sulphur dioxide monitor using a modified West-Gaeke method

The major interference from NO_2 (> 2 ppm), when present, is eliminated by the addition of sulphamic acid, H_2NSO_3H. This reagent acts as a reducing agent, converting NO_2 to N_2.

Conductimetry is one of the common methods for automatic monitoring of SO_2 in industries. The sampled air contassing SO_2 is passed through a dilute solution of H_2O_2 in dil. H_2SO_4

$$SO_2 + H_2O_2 \rightarrow H_2SO_4$$

The increase in conductivity is proportional to the concentration of SO_2 in the sample. With this technique as low as 0.01 ppm of SO_2 can be detected. However, the method is subject to interference from acidic gases such as hydrogen, chloride (+ve error) and ammonia (–ve error).

Coulometry is an excellent method for automatic monitoring of SO_2. In the bromocoulometric analyzer air containing SO_2 is drawn continuously through an electrolytic cell which contains acidified bromine solutions and two sets of electrodes as shown in fig.

Philip W.West and G.C. Gaeke, Analytical Chemistry, 28, 1816-1819 *(1956).* "Reference Method for the determination of SO_2 in the Atmosphere (Pararosaniline Method)", Federal Register, 36, 8168 (1971).

* H.G.C. King and G. Pruden - Analyst, 28, 1816 (1956).

The indicator-reference set of electrodes is used to detect the Br_2 concentration while the other set comprising the generator electrode and auxiliary electrode is used to generate any Br_2 required to maintain the proper balance. SO_2 in the air sample is oxidized by Br_2 causing a reduction in Br_2 concentration;

$$2H_2O + SO_2 + Br_2 \rightarrow \overset{2-}{SO_4} + 4\overset{+}{H} + 2\overset{-}{Br}$$

This changes the oxidation-reduction potential of the reagent whereby a voltage is developed between the indicator and reference electrode. This voltage is compared to a reference voltage-the difference between the two voltages is sensed by the other electrode system causing an electric current to flow and generating sufficient Br_2 to maintain the original concentration.

$$2Br \rightarrow Br_2 + \bar{e}$$

The current flow is a measure of SO_2 concentration in the air stream. This method can measure 0.1-10 ppm SO_2 in air sample.

*Procedure** Pump 30-60 L of air through 10 ml of the scrubbing solution (13.6 g $HgCl_2$ and 7.5 g KCI in 1 litre water) in a small impinger, at 1-2 L min^{-1}. Then add 1 mL dilute pararosaniline regent solution (4 mL of 1% aqueous solution acidic with 6 ml of conc. HCL and diluted to 100 mL with water) and 1 ml of 0.2% HCHO solution (5 ml of commercial 40% solution diluted to 1 litre with water). After 20–30 min., measure the absorbance at 560 nm. Use a dilute", solution of Na_2SO_3, checked iodometrically as the standard.

*Method of Dasgupta et al.***— The only drawback by *the* above West-Gaeke method is the handling of relatively *high* concentrations of toxic and costly $HgCl_2$. Dasgupta *et al.* developed a method based on absorption of SO_2 into HCHO buffered at pH_4. Sulphite liberated from the compound by base is added to acidic p-rosaniline and the absorbance measured at 580 nm. This method is comparable to the West-Gaeke method in absorption and recovery efficiency, sensitivity and precision. No interferences are observed due to O_2, NO_2, and transition metal ions, except Mn (II).

Buffered HCHO absorber is prepared by diluting HCHO solution (37%, 530/μL) and potassium hydrogen phthalate (204 mg) to 1L. This buffer shows a pH of 4.2 at 25°C.

Midget bubblers, filled with 15 ml of the buffered HCHO absorber, are used for sampling. The usual sampling rate is 250 mL/min. The contents of the fritted tube and side arm are washed into the bubbler with 2 mL water. Then NaOH (1 mL, 4.5 M) is added from a pipette and the bubbler stoppered with a ground glass stopper and inverted once. The contents of the bubbler are then transferred into paraosaniline reagent (5 mL of 0.03% in 1.2 M HCL) kept in a 25 mL culture tube. The contents of the tube are then made up to the

* H.G.C. King and G. Pruden - Analyst, 28,1816 (1956).

** P.K. Dasgupta, K. Decesare and J.C. Ullrey-Anal. Chem. 52, 1912-22 (1980).

mark (25 mL) with water and the tube capped and inverted thrice. The absorbance of the resulting colour is measured at 580 nm after a period of 15 min.

Nitrogen Oxides

Colorimetric method- This is an excellent method-known as Griess-Saltzmann method-for measurement of nitrogen oxides. It is based on reduction of NO_2 with snlphanilic acid to form diazonium salt. The latter is coupled with N-(1-naphthyl) ethylene diamine dihydrochloride to get a pink-coloured dye complex. Colour development is complete within 15 mins, at room temperature and measured at 550 nm.

Analysis of NO can be carried out by first oxidising it to NO_2 by passing the air sample through potassium permanganate ($KMNO_4$) solution.

Chemiluminescence Method

Chemiluminescene is the standard method of monitoring of NO_2. The phenomenon results from the emission of light from electronically excited species arising out of a chemical reaction. NO reacts with O_3 to produce electronically excited NO_2 molecule, which in the next step loses energy and returns to the ground state through emission of light (600–3000 nm). The latter is measured by a photomultiplier, the intensity being proportional to the concentration of NO_2 (Fig. 4.11):

$$NO + O_3 \rightarrow NO_2^* + O_2$$

$$NO_2^* \rightarrow NO_2 + h\nu$$

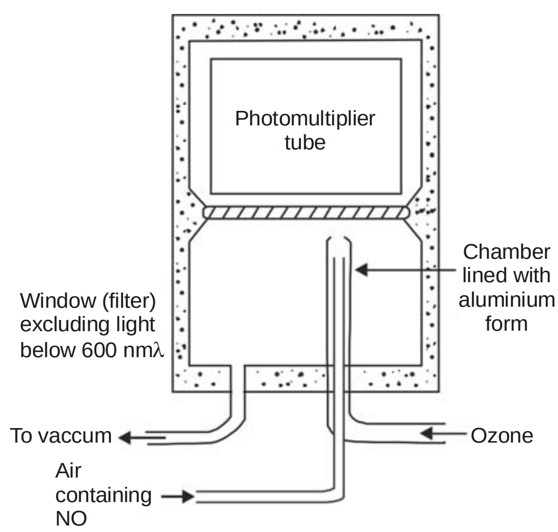


Fig. 4.11: Chemiluminescence detector for NO

NO_2 is invariably associated with NO in air sample. It is, therefore, necessary to convert NO_2 to NO before analysis. This can be effected by passing the air sample over a thermal converter which brings about the required chemical reaction. Analysis of another sample which is not led through thermal converter gives NO. The NO_2 concentration can be calculated from the difference between these two data.

Other nitrogen compounds, besides NO and NO_2, interfere if present in large excess. Particulates also interfere–however, their interference can be eliminated by using a membrane filter at the air inlet.

The method is also applicable to analysis of O_3 by interaction with NO.

Carbon Monoxide

Non-dispersive infra-red spectrometry has been introduced for the analysis of CO. When IR radiation is led through a long cell (100 cm) containing CO, part of the energy of the radiation is absorbed by CO, which can be correlated with the concentration of CO.

In the non-dispersive IR spectrometer the IR radiation from the source is not dispersed according to wavelength by a prism or grating as in a standard IR spectrometer. It is made very specific for a given compound or type of compound by using the material under investigation as part of the detector. Radiation from an IR source is 'chopped' by a rotating device so that it alternately passes through a sample cell and a reference cell (Fig. 4.12) Both beams of light are incident on a detector which is filled with CO gas and divided into two compartments by a flexible diaphragm. The relative amounts of IR radiation absorbed by CO in the two sections of the detector are determined by the CO level in the sample. The difference in the amount of IR radiation absorbed in the two compartments give rise to temperature differences so that the diaphragm, balges slightly to one side and this can be measured with a relative accuracy of 5% in the optimum concentration range.

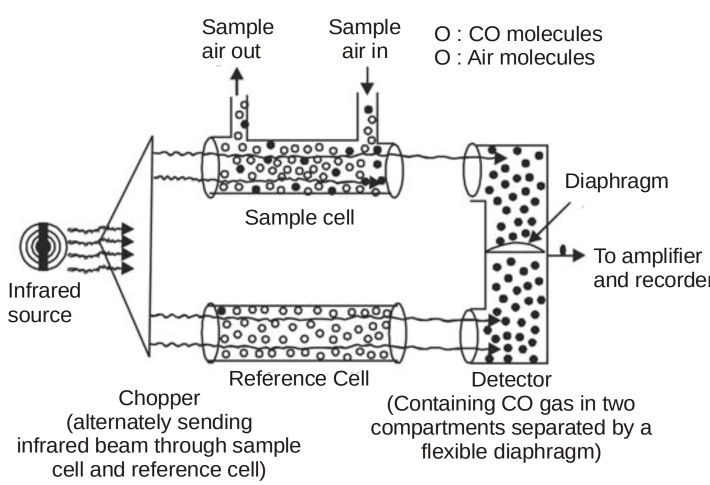


Fig. 4.12: Non-dispersive infrared analyzer for monitoring carbon monoxide

Hydrocarbons

Gas chromatography - Hydrocarbon pollutants are conveniently estimated in a gas chromatograph (GC) using flame ionization detector. As little as 0.1 μg of hydrocarbon/m^3 of air can be estimated by this technique.

Gas chromatography is based on the principle that when a mixture of volatile materials, transported by a carrier gas, is led through a column containing an absorbent solid phase or, more commonly, an absorbing liquid phase coated on a solid material, each volatile component will be partitioned between the carrier gas and the solid or liquid. Depending on the retention times in the column, the volatile component will emerge for the column at different times and finally be detected by a suitable detector. This permits both qualitative and quantitative analyses.

The block diagram of a gas chromatography is shown in Fig. 4.13 and that of a typical gas chromatography in Fig. 4.14.

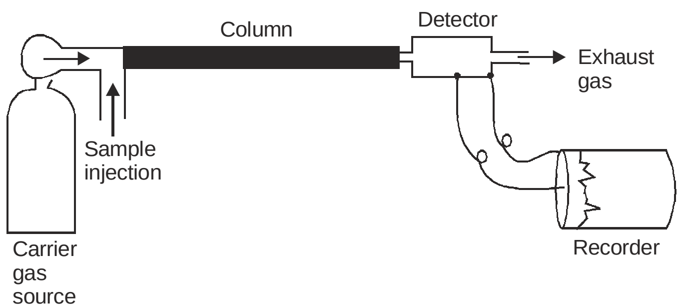


Fig. 4.13: Schematic diagram of gas chromatography

The carrier gas is Ar, He, N_2 or H_2; H_2 is not preferred because of its fire and explosion hazards and its reactive towards reducible or unsaturated sample components. The flow rate (60–80 mL/min) of the carrier gas must be controlled. The sample is injected as a single compact plug into the carrier gas stream. In case of liquid samples, the injection chamber must be heated to vaporise the liquid rapidly and avoid 'tailing' or spreading of the peaks.

In gas-solid chromatography (GSC), the fixed phase consists of a solid material such as granular SiO_2, Al_2O_3 or C. The more common type is gas-liquid chromatography (GLC) in which the fixed phase is a non-volatile liquid (silicon oil, polyethylene glycol, etc.) held as a thin layer on a solid support (diatomaceous earths or crushed firebrick, 60-80 mesh or 100–200 mesh or size). The packed column is usually 4 mm (i.d.) tubing of stainless steel or glass either bent in a V-shape or coiled. Lengths of such tubes are from 120 cm to 150 m. (Fig. 4.14).

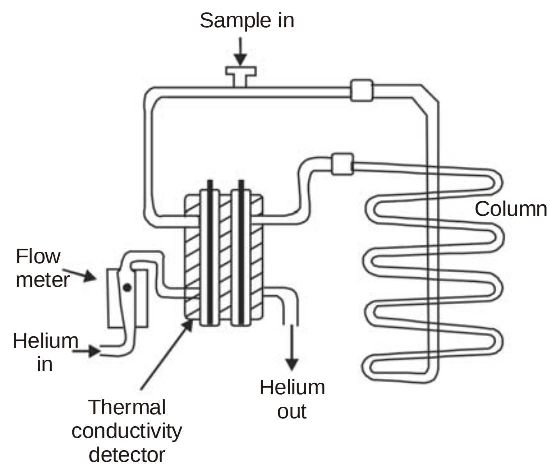


Fig. 4.14: A gas chromatograph (Both column and detector are enclosed in a thermostat chamber).

It has been the recent trend to use capillary gas chromatography where capillary columns (0.25 mm inside diameter and 50 meters long) can resolve up to several hundred components from a single sample. The capillary column may be of metal, glass or organic polymer, in which the walls act as support for the stationary liquid phase. They are superior to packed columns in terms of separations and efficiency.

For GC, the sample must show at least a few mm of vapour pressure at the highest temperature at which it is stable. In several cases, where organic compounds cannot be chromatographed directly, they may be converted to derivatives (e.g., esters) which are amenable to GC. Aqueous solution cannot be used for GC-the components must be brought into organic solvent such as benzene, chloroform, dichloromethene and hexane by solvent extraction.

The selectivity as well as sensitivity of GC are determined by the detector. The temperature of the thermostatic jacket surrounding the column and detector may be maintained between 50° and 300°C or varied for temperature programming, depending on requirement. The most common detector is the thermal conductivity cell which responds to changes in the thermal conductivity of gases passing over it. Another detector is the electron capture detector which operates through the capture of electrons emitted by a source (e.g. ^{9O}Sr). This is especially useful for halogenated hydrocarbons and phosphorus compounds (pesticides).

The *flame ionization detectors* (FID) is extremely sensitive for the detection of organic compounds. In a flame, organic compounds form highly conducting fragments, such as C^+. On applying a potential gradient across the flame, a small current is generated which is readily measured. The response of a flame ionization detector is roughly proportional to the number of carbon atoms in the compound. Halogens, nitrogen or oxygen, if present in the organic compounds, decrease the sensitivity of the detector. The FID has wide range of linear response and is sensitive to very low levels of hydrocarbons, ranging down to 10^{-3} μg.

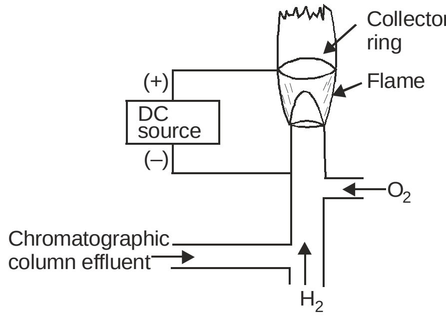


Fig. 4.15: Flame-ionization detector for the analysis of hydrocarbons.

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Questions

1. What are the major regions of the atmosphere? State their respective altitudes and temperature ranges. Name the important chemical species in these regions. Give your answer with a table and figure only.
2. Name the major, minor and trace constituents of the atmosphere. Give their percentage composition by volume.
3. "Carbon dioxide is a non-pollutant but it is of much environmental concern." Explain with reference to the Greenhouse Effect.
4. What is Greenhouse Effect? Describe its impact on global climate, food production and world geography.
5. What are the Greenhouse gases? What are their relative contribution to Greenhouse Effect?
6. What are the primary air pollutants? Describe their sources, and state their annual production figures (in million tonnes).
7. How would you control carbon monoxide and nitrogen oxides in automobile exhaust emissions?
8. How will you control sulphur dioxide and particulate emissions from thermal power plants?
9. Write explanatory notes on:
   (a) Ozone hole
   (b) El Nino
   (c) Acid rain
   (d) Photochemical smog
   (e) Effect of air pollution on public health
   (f) Effect of air pollution on Meteorology
   (g) Air Quality Standards.

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5 Water Pollution

The normal uses of water for public supply are–recreation (swimming, boating, etc.), fish, other aquatic life and wild life, agriculture (irrigation), industry, navigation, etc. Any change in the dynamic equilibrium in aquatic ecosystem (water body/biosphere/atmosphere) disturbs the normal function and properties of pure water and gives rise to the phenomenon of water pollution. The symptoms of water pollution of any water body/ground water are:

- Bad taste of drinking water,
- Offensive smells from lakes, rivers and ocean beaches,
- Unchecked growth of aquatic weeds in water bodies (eutrophication),
- Dead fish floating on water surface in river, lake, etc.
- Oil and grease floating on water surface.

The quality of water is of vital concern for mankind since it is directly linked with human welfare. It is a historical fact that faecal (human excreta or stool) pollution of drinking water caused water-borne diseases which wiped out entire populations of cities. In the developing countries like India, every day some 25,000 people die of water-borne diseases e.g., jaundice, hepatitis, cholera, dysentery, etc. In India about 2 lakhs out of 6 lakh villages have no access to safe drinking water—women have to walk 1-14 km daily for collecting water for drinking and cooking. In urban areas 40 per cent people are without access to safe water. The major sources of water pollution are domestic sewage from urban and rural areas, agricultural run-off (wash water) and industrial waste which are directly or indirectly discharged into water bodies.

5.1. WATER RESOURCES AND WATER USES

Man is using petroleum for more than a century extensively and coal for several centuries. Human civilisation spent 99.9 per cent of time without these fuels. The world's petroleum stock is likely to be exhausted in another hundred years and coal in a few centuries. This will pose a crisis before mankind. But when we realise that our usable water resources is also limited and will be out of stock in near future, then we indeed have cause for panic.

Water has no alternative–it is known as "life". It is essential for the sustenance of all living organisms including plants, animals and man. All plants, insects, animals and men have 60-95 per cent water in their bodies. This water is partly released in the form of sweat, excreta, urine and vapour. So all these species require lot of water daily. Besides much water is also needed for body growth, nutrition, etc. So it is absurd to think of life without water. But our usable water resources like any other natural resource is finite and is likely to be exhausted within a century. Moreover, it is getting polluted by man-made activities and unfit for use sooner than expected. Water crisis is more serious than food or population crisis since food production or population problems are irrelevant without water supply. Use of polluted water itself takes toll of 25,000 people all over the world every day. In India out of 6 lakh villages, one third or about 2 lakh villages are without access to water. In these villages women have to walk daily about 1-14 km. to collect water for cooking and drinking. The United Nations Food and Agriculture department estimate that if the present day practices of wasting and polluting water are not stopped, then within less than a century the world's biosphere including man will disappear.

The world's total quantum of water is 1.4 billion cubic kilometre. If all the sea beds could be filled up and brought at the level of the earth's surface, then the entire water in the seas would cover the earth's surface and make it 2.5 km-deep water mass. About 97 per cent of earth's water supply is in the ocean which is unfit for human consumption and other uses due to high salt content. Of the remaining 3 per cent, 2.3 per cent is locked in the polar ice caps and hence out of bounds. The balance 0.7 per cent is available as fresh water but the bulk of it, 0.66 percent, is ground water and the rest 0.03 per cent is available to us as fresh water in rivers, lakes and streams. The break-up of this 0.03 per cent fresh water is-lakes and ponds 0.01 per cent, water vapour 0.001 per cent, rivers 0.0003 per cent and water confined in plants, animals and chemicals 0.0187 per cent.

[United Nation's Water Conference Report, Argentina (1977)]

Thus we see that we have a very limited stock of usable water, 0.03 per cent surface water (rivers, streams and ponds) and 0.66 per cent ground water. The quantity of water vapour arising from evaporation of sea water and river water returns by the same volume to the earth's surface by rainfall and back to the water sources. The hydrological cycle in nature is more or less balanced in terms of charge (cloud formation) and discharge (rainfall). But we are drawing large quantities of ground water for agriculture and industries while the waste water from these is much polluted and on mixing with rivers is polluting the rivers also.

The mass balance of annual rainfall shows that about 70 per cent is lost by evaporation and transpiration by plants, while the remaining 30 per cent goes into the stream flow. The approximate break-up of this stream flow, as consumed by man is – 8 per cent for irrigation, 2 per cent for domestic use, 4 per cent for industries and 12 per cent for electrical utilities. Irrigation for agriculture and electric power plants are the major consumers of water.

Chemical Characteristics of Water

Sea water is unfit for our consumption due to high mineral salt content. Chemically speaking, sea water is a solution of 0.05 molar NaCI (Sodium chloride), 0.05 molar $MgSO_4$ (Magnesium sulphate) containing traces of all conceivable matter in the universe. The oceans are the final sink for many substances involved in numerous geochemical processes as well as the waste dumped as a result of human activities. They receive the run-off of the continents and materials washed from the atmosphere. They are also the important habitat of the bulk of the earth's biosphere (sea plants, sea fish, etc.). The chemical composition of sea water, river and lake water is shown:

Sea water: Sodium, chloride, magnesium 90 per cent, potassium, calcium, sulphate 3 per cent, others 7 per cent.

River and Lake water: Carbonate 35 per cent, sulphate 12 per cent, chloride 5.7 per cent, silica 11. 7 per cent, nitrate 0.9 per cent; Calcium 20 per cent, sodium 5.8 per cent, magnesium 3 per cent, potassium 2 per cent, iron, aluminium oxide 3 per cent.

Ground water (wells, tube wells) contains more mineral salts, nitrate and bicarbonate than surface water (river, lake. water, etc.)

5.2 WATER POLLUTANTS

The large number of water pollutants are broadly classified under the categories:

1. Organic pollutants,
2. Inorganic pollutants,
3. Sediments,
4. Radioactive materials and
5. Thermal pollutants.

Organic Pollutants

These include domestic sewage, pesticides, synthetic organic compounds, plant nutrients (from agricultural run-off), oil, wastes from food processing plants, paper mills and tanneries, etc. These reduce dissolved oxygen (D.O.) in water. Dissolved oxygen (D.O.) is essential for aquatic life, the optimum level being 4–6 ppm (parts per million). Decrease in D.O. value is an indicator of water pollution. The organic pollutants consume D.O. through the action of bacteria present in water.

Sewage and agricultural run-off provide plant nutrients in water giving rise to the biological process known as *eutrophication.* Large input of fertiliser and nutrients from these sources leads to enormous growth of aquatic weeds which gradually cover the entire waterbody (*algal bloom*). This disturbs the normal uses of water as the water body loses its D.O. and ends up, in a deep pool of water where fish cannot survive.

The production of synthetic organic chemicals (more than 60 million tonnes each year since 1980) multiplied more than 10 times since 1950. These include fuels, plastic fibres, solvents, detergents, paints, food additive, pharmaceuticals, etc. Their presence in water gives objectionable and offensive tastes, odour and colours to fish and aquatic plants.

Oil pollution of the seas has increased over the years, due to increased traffic of oil tankers in the seas causing oil spill and also due to oil losses during off-shore drilling. Oil pollution reduces light transmission through surface water and hence reduces photosynthesis by marine plants, decreases D.O. in water causing damage to marine life (plants, fish, etc.) and also contaminates sea food which enters the human food chain.

Pesticides have been largely used for killing pests and insects harmful for crops and thereby boosting the crop production. At present there are more than 10,000 different pesticides in use. They include insecticides (for killing insects) e.g., DDT (dichloro diphenyl trichloroethane), herbicides (for killing weeds and undesirable vegetation) and fungicides (for killing fungi and checking plant disease).

It has been found that pesticide residues contaminate crops and then enter the food chain of birds, mammals and human beings. The persistent pesticide, viz, DDT (which is not degraded in the environment) accumulates in food chain, getting magnified in each step from sea weed to fish and then to man by about ten thousand times (10^4). Thus the average level of DDT in human tissues is found to be 5–10 ppm, maximum being among Indians (25 ppm) compared to Americans (8 ppm).

Inorganic Pollutants

This group consists of inorganic salts, mineral acids, metals, trace elements, detergents, etc.

Acid mine drainage: Coal mines, particularly those which have been abandoned, discharge acid (sulphuric acid) and also ferric hydroxide into local streams through seepage. The acid on entering the waterbody destroys its aquatic life (plants, fish, etc.).

Sediments

Soil erosion, as a matter of natural process, generates sediments in water. Solid loadings in natural water are about 700 times as large as the solid loading from sewage discharge. Soil erosion is enhanced 5–10 times due to agricultural and 100 times due to construction activities. Bottom sediments in aquatic bodies (streams, lakes, estuaries, oceans) are important reservoirs of inorganic and organic matter, particularly trace metals e.g., chromium, copper, nickel, manganese and molybdenum.

Radioactive Materials

Radioactive pollution is caused by mining and processing of radioactive ores to produce radioactive substances, use of radioactive materials in nuclear power plants, use of radioactive isotopes in medical, industrial and research institutes and nuclear tests. The discharge of radioactive wastes into water and sewer systems is likely to create problems in future.

Thermal Pollutants

Coal-fired or nuclear fuel-fired thermal power plants are sources of *thermal pollution.* The hot water from these plants is dumped as waste into nearby lake or river where its temperature rises by about 10°C. This has harmful effect on aquatic life in the water body whose D.O. is reduced and as a result, fish kill is quite common.

5.3 GROUND WATER POLLUTION/ARSENIC CONTAMINATION

Ground water is relatively free from surface contamination as it is located more than about 50 ft. below the land surface and the surface water gets filtered or screened by the underlying layers of soil, sand and stone pieces. But even then it gets contaminated due to leaching of minerals below the earth's surface.

An important case is that of *Arsenic (As)-contamination of ground water.* This arises from excessive pumping of ground water by shallow tube wells for irrigation in some West Bengal districts along the Hooghly river course and also in Bangladesh along the Padma river course. In this process air (oxygen) is injected into ground water bed which leaches the overlying mineral, iron pyrites (iron, arsenic, sulphide), oxidises it and releases arsenic into ground water.

More than one million people in six districts of West Bengal drink arsenic-contaminated ground water from tube wells in the region. Among them 20 lakh people suffer from various diseases related to arsenic poisoning like loss of hair, brittle nails, bronchitis, gangrene, etc. Several hundred deaths have also been reported. Similar calamity has threatened the lives of Bangladesh in the districts along the Padma river course.

5.4 CASE STUDY OF GANGA POLLUTION

The most typical example of river pollution is the *Ganga Pollution.*

The Ganga originates from the Himalayan glacier and flows along a stretch of some 2525 km before joining the Bay of Bengal. The Ganga basin is fertile and home of about 40 per cent of population (400 million people) of the country. The river has been hailed as the "Holy Ganga" and regarded as the lifeline of the country. But in recent years it is ranked as the most polluted river of India and a killer in the highly polluted areas.

The Ganga basin carries wash water from 25 per cent of land. It is responsible for agricultural prosperity of U.P., M.P., Haryana, Rajasthan, Himachal Pradesh, Bihar and West Bengal. Ganga is the source of drinking water in the region and irrigation water for agriculture—she also supplies fish to the local markets and water to industries on both sides of the river. The Ganga basin provides maximum population density—many class I (population 100,000 and above), class II (pop. between 50,000 and less than 100,000) and class III (pop. 20,000 to less than 50,000) cities have grown in this region. Both domestic and industrial sewage join the Ganga river without any treatment and thus cause terrible pollution.

Hooghly river (in West Bengal) near Kolkata presents the worst polluted zone. There are more than 150 industries on both sides of the 125 km. stretch river belt—there are about 270 outlets of untreated sewage to the river Hooghly. The entire 140 sq. km. metropolitan area covering both banks of the Hooghly river is exposed to ecological disaster. Besides huge quantities of soil from soil erosion due to extensive deforestation are washed by rain water into the river causing siltation. This reduces the flow of water in the Ganga-Hooghly river with the result that ultimately the river will be choked and dead. In 1919 the flow of water in the Ganga was 1,10,000 cusecs (1 cusec = 1 cubic foot of water flowing per second) whereas in 1971 it was 40,000 cusecs only which during summer drops to 20,000 cusecs. This should be enough to sound the alarm bell to the Government–Calcutta and Haldia ports can survive only on 40,000 cusecs of water.

5.5 WASTE WATER TREATMENT

Water pollution is caused by domestic sewage (84 per cent) and industrial sewage (16 per cent). Though the latter has less load on water body, it contains toxic matter (inorganic and organic) which are more hazardous.

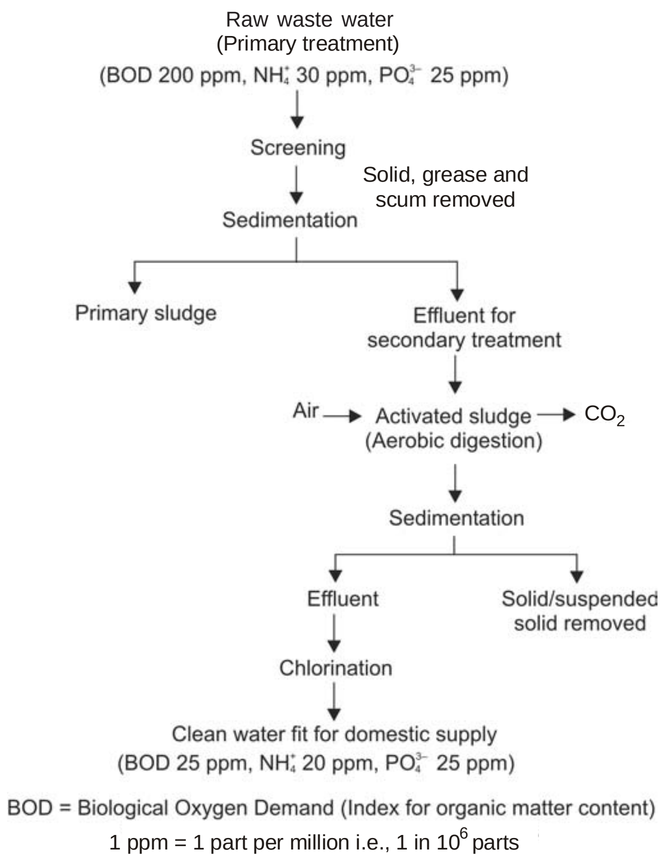


Fig. 5.1: Municipal waste water treatment (Primary and Secondary)

5.6 DOMESTIC WASTE WATER TREATMENT

Sewage treatment plants, in general, depend on biological decomposition of non-toxic organic wastes using bacteria. Such biological decomposition is carried out under aerobic conditions i.e., in presence of plenty of oxygen.

$$\begin{array}{llll} \text{Organic wastes} & + \quad O_2 & \xrightarrow{\text{bacteria}} & CO_2 \text{ (Carbon dioxide)} \\ \text{(Carbon, Oxygen,} & \quad \text{(oxygen)} & & + \; H_2O \text{ (Water)} \\ \text{Hydrogen, Sulphur,} & & & + \; NO_3^- \text{ (Nitrate)} \\ \text{Fluorine)} & & & + \; NH_4^+ \text{ (Ammonium ion)} \end{array}$$

The process, commonly used for municipal waste water, is shown in Fig. 5.1. In the first stage, solid wastes are removed from water by screening–any scum (suspended matter) is removed and the sludge (muddy solid or sediment) allowed to settle at the bottom. The residual liquid is exposed to biological oxidation of soluble organic materials through a bed of microbes in activated sludge. Then the solids are removed after sedimentation. Finally the liquid effluent is subjected to chlorination for destroying pathogenic micro-organisms. Now this effluent is fairly clean and suitable for domestic use.

5.7 DRINKING WATER SUPPLY

Treatment of drinking water supply is a matter of public health concern. The water treatment plants, in general, are simpler than sewage treatment plants. They operate in three steps—(i) aeration to settle suspended matter; (ii) coagulation of small particles and suspended matter by lime and ferric chloride; (iii) disinfection by chlorination to kill viruses, bacteria, etc. The purified water is then supplied by municipalities through pipes for domestic uses.

5.8 INDUSTRIAL WASTE WATER TREATMENT

Industrial wastes contain toxic chemicals which can damage environment (water, soil, air) much more than domestic sewage. These waste liquids (effluents) can be purified by filtration using activated charcoal or ion exchange resins. Activated charcoal has large surface area and is an effective filter medium for adsorption of organic molcules. Synthetic organic ion exchange resins are very useful for removal of industrial waste metals (cations) and non-metals (anions).

5.9 WATER QUALITY STANDARDS

The analyses required of water samples depend on the intended use of the water. For example, if its intended use is drinking, water should meet certain quality criteria with respect to the appearance, (turbidity, colour), potability (taste, odour), health (bacteria, nitrates, chlorides, etc.) and toxicity (metals, organics). These and similar criteria are established by health or other regulating agencies to ensure that the water quality in a resource is suitable for the proposed use.

Based on the criteria, quality standards are set, which reflect the current state of knowledge of various water constituents. These standards are continuously revised as more and more is learnt about the effects of water constituents on proposed uses. Hence, these standards should not be used as absolute limits, but only as guidelines that can be used for preliminary judgements. Table 5.1 summarizes several quality criteria and their standards for drinking water as suggested by the following agencies:

(1) Indian Council of Medical Research (ICMR)
(2) World Health Organization (WHO)
(3) United States Public Health Service (USPHS)

Standards have been prepared for raw waters to be used as a source for various industrial applications. The specific purpose for which the water is used usually controls the requisite water quality. Water used in food and beverage industries will need to meet standards similar to those for drinking water, while water for cooling purposes can contain much higher concentrations of impurities. Table 5.2 illustrates the water quality characteristics of raw surface waters that have been used as source for various industrial operations. The values listed are the maximum concentrations of different constituents in the raw surface waters used in the. specified industry, and not the maximum concentrations that could be tolerated.

Table 5.1: Standards for Drinking Water

A – Recommended maximum concentration[a] (mg/L except where shown otherwise)
B – Maximum permissible concentration[b] (mg/L except where shown otherwise)

	ICMR		WHO		USPHS	
	A	B	A	B	A	B
Physical:						
Turbidity (unit)	5	25	5	25	5	—
Colour (unit)	5	25	5	50	15	—
Odour	Nothing disagreeable		Unobjectionable		TO = 3	—
Chemical:						
pH, units	7-8.5	(6.5 or 9.2)	7–8.5	(6.5 or 9.2)	—	—
Total solids	—	—	500	1500	500	—
Calcium	75	200	75	200	—	
Magnesium	50	150	50	150	—	—
Iron	0.3	1.0	0.3	1.0	0.3	—
Manganese	0.1	0.5	0.1	0.5	0.05	—
Copper	1.0	3.0	1.0	1.5	1.0	—
Sulphate	200	400	200	400	250	—
Phenols	0.001	0.002	0.001	0.002	0.001	—
Fluorides	1.0	2.0	0.5	1.0–1.5	0.6–1.7	—
Nitrates	20	50	—	50-100	45	—
Toxic:						
Arsenic	—	0.2	—	0.2	0.01	0.05
Barium	—	—	—	—	—	1.0
Cadmium	—	—	—	—	—	0.01
Chromium	—	0.05	—	0.05	—	0.05
Cyanide	—	0.01	—	0.01	0.01	0.2
Lead	—	0.1	—	0.1	—	0.05
Selenium	—	0.05	—	0.05	—	0.01
Silver	—	—	—	—	—	0.05
Bacteriological:	—	1 coliform per 100 ml	—	1 coliform per 100 ml		1 coliform per 100 ml

[a.] Constituents should not be present in excess of listed concentrations where other more suitable supplies are or can be made available.

[b.] Constituents in excess of the concentrations listed shall constitute grounds for rejection of the supply.

Table 5.2: Maximum Concentrations of Constituents in Raw Water Supplies for Various Industries, mg/l

Constituent	*Boiler water (0-1500) psig*	*Cooling water (once through)*	*Textile industry*	*Pulp and paper*	*Chemical industry*	*Petroleum industry*
Silica (SiO_2)	150	50	—	50	—	85
Aluminium	3	3	—	—	—	—
Iron	80	14	0.3	2.6	5	15
Manganese	10	2.5	1.0	—	2	—
Calcium	—	500	—	—	25	220
Magnesium	—	—	—	—	100	85
Ammonia	—	—	—	—	—	40
Bicarbonate (HCO_3)	600	600	—	—	600	480
Sulphate	1400	680	—	—	850	900
Chloride	19000	600	—	200	500	1600
Nitrate	—	30	—	—	—	8
Phosphate	—	4	—	—	—	—
Dissolved solids	35000	1000	15	1080	2500	3500
Suspended solids	15000	1500	1000	—	10000	5000
Hardness	5000	850	120	475	1000	900
Alkalinity	500	500	—	—	500	500
pH (units)	—	5.0–8.9	6.0–8.0	4.6–9.4	5.5–8.0	6.0–9.0
Colour (units)	1200	—	—	360	500	25
COD	100	—	—	—	—	—
Temperature (°F)	120	100	—	95	—	—

5.10 SAMPLING

The significance of a chemical analysis depends to a large extent on the sampling programme. An ideal sample should be one which is both valid and representative. These conditions are met by collection of samples through a process of random selection. This ensures that the composition of the sample is identical to that of the water body from which it is collected and the sample shares the same physico-chemical characteristic with the sampled water at the time and site of sampling.

Table 5.3: Typical Analysis of Some Surface and Ground Waters

Constituent, ppm	***A***	***B***	***C***
Silica	9.5	1.2	10
Iron (III)	0.07	0.02	0.09
Calcium	4.0	36	92
Magnesium	1.1	8.1	34
Total hardness (as $CaCO_3$)	14.6	123	169
Sodium	2.6	6.5	8.2
Potassium	0.6	1.2	1.4
Bicarbonate	18.3	119	339
Sulphate	1.6	22	84
Chloride	2.0	13	9.6
Nitrate	0.41	0.1	13
Total dissolved solid	34	165	434

[V.L. Snoeyink and D. Jenkins, *Water Chemistry,* John Wiley & Sons, New York, 6 (1980)]

A. Pardee Reservoir, Oakland, California, USA, 1976 (Water Supply Source for East Bay area of San Francisco region).

B. Niagara river, Niagara falls, New York, USA (Water supply source for Niagar Falls City).

C. Well water, Dayton, Ohio, USA (20-meters deep well used for public water supply of Dayton, Ohio, USA).

The relevant factors for any sampling program are (a) frequency of sample collection, (b) total number of samples, (c) size of each sample, (d) sites of sample collection, (e) method of sample collection, (f) data to be collected with each sample, and (g) transportation and care of samples prior to analysis.

For analysis of natural and waste water, two principal types of sampling procedures are employed:

1. *Spot or grab samples* are discrete portions of water samples taken at a given time. A series of grab samples, collected from different depths at a given site, reflect variations in constituents over a period of time. The total number of grab samples should satisfy the requirements of the sampling programme.
2. *Composite samples* are essentially weighted series of grab samples, the volume of each being proportional to the rate of flow of the water stream at the time and site of sample collection. Samples may be composited over any time period, such as 4,8 or 24 hours, depending on the purpose of analysis. Such composite samples are useful for determining the average condition which, when correlated with flow, can be used for computing the material balance of a stream of water body over a period of time.

It may be stated, in general, that it is more meaningful to analyze a large number of separate samples taken at different times and different locations than to compile and analyse a single representative sample.

Separate samples must be collected for chemical and biological analysis since the sampling and preservation techniques are quite different For accurate analysis, it is desirable to allow a short time interval between sampling and analysis, it is desirable to allow a short time interval between sampling and analysis. As a matter of fact, temperature, pH and dissolved gases (D.O.) must be determined in the field and as quickly as possible after sampling.

Redox reactions are likely to cause large errors in analysis. Thus, soluble iron (II) and manganese (II) are oxidized to insoluble iron (III) and manganese (IV) compounds as an anaerobic water sample absorbs O_2 from the atmosphere. Microbial activity reduces phenol or COD values, changes the $NO_3^- - NO_2^- - NH_3$ balances, or alters the relative proportions of SO_4^{2-} while S^{2-}, I^- and CN^- are liable to oxidation Cr(VI) may be reduced to Cr(III), which precipitates readily. Na, SiO_2 and B are leached from glass container walls. Colour, odour and turbidity change with aging of sample. These are some of the problems which can only be solved through careful preservation techniques, described in the following section.

Collection of truly representative sample is as important as sample preservation. A representative single sample is taken from a number of different locations over a long period of time. In general, it is more significant to analyse a large number of separate samples taken at different times and different locations than it is to compile and analyze a single representative sample. It is essential to keep accurate records of the location, time and conditions of sample collection.

Preconcentration techniques—As many of the water pollutants are largely diluted, the material to analyzed (analyse) requires preconcentation before analysis.

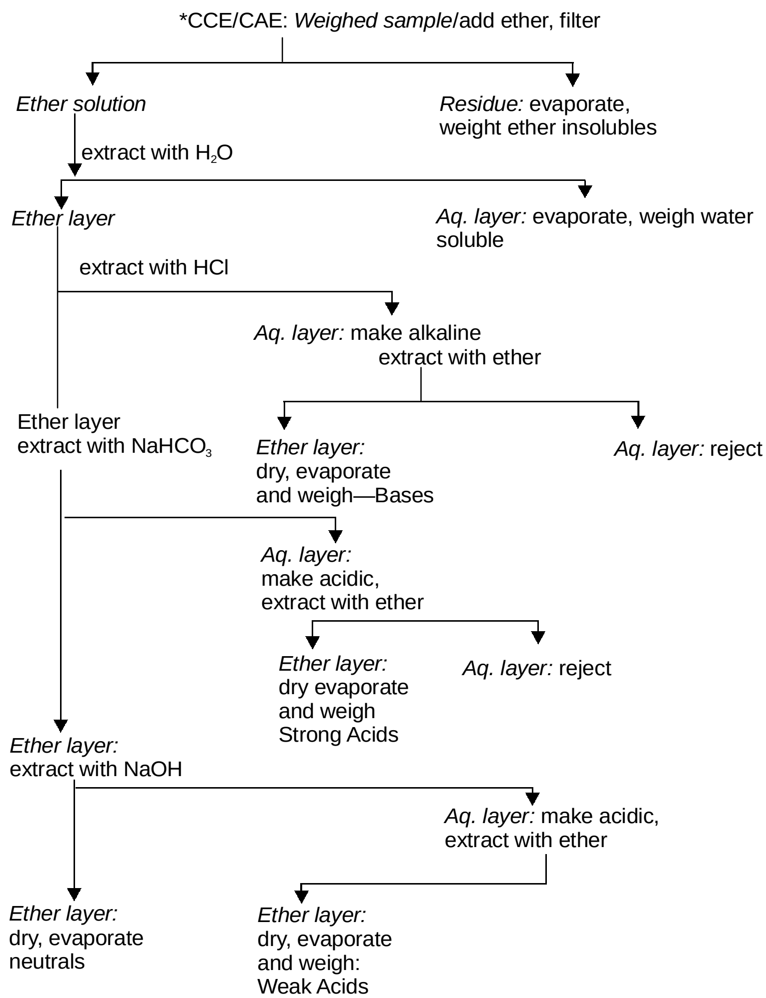
Carbon absorption method—A common concentration technique is absorption on activated carbon. A large volume of water,say 1000 gallons, may be passed over activated carbon. The organic material is extracted from the dried carbon with $CHCl_3$ followed by alcohol. The solvents are evaporated and the weights of the extracts are expressed as µg/L of carbon-chloroform extract (CCE) and carbon-alcohol extract (CAE). The chloroform extract contains organic pollutants such as phenols and oils which impart taste and odour to water. Further characterization of organic extract can be done using a member of separation procedure. Thus carboxylic acids, phenols, sulphonic acids, fulvic acids, pesticides and polycyclic aromatic hydrocarbons, can identified. A typical scheme of fractionation of CCE/CAE is shown in the following Table 5.4.

The drawbacks of the carbon absorption method may be noted: some chemical reactions may occur on the carbon surface; some organics are evaporated during the drying process while others are not completely extracted. However, the method enjoys wide popularity because of its simplicity, speed and efficiency.

Freeze concentration—The water sample, on freezing produces very pure crystals of ice leaving water soluble impurities in a liquid phase of much reduced volume. The low temperature required for freezing minimises loss of volatile constituents.

Solvent extraction—This is a very useful method for separation of organic soluble materials from water using a water-immiscible organic solvent. Where an organic material is more soluble in an organic solvent than in water, it may be concentrated in a small volume of the organic solvents by the process of solvent extraction. An important application is the isolation of chlorinated pesticides parts per billion (μg/L) quantities of Co(II), Fe(III), Pb(II), Ni(II) and Zn(II) in saline water can be determined by extraction of these metal complexes with ammonium pyrrolidine ditho-carbamate into methyl isobutyl ketone and feeding the organic extract directly into atomic absorption spectrophotometer.

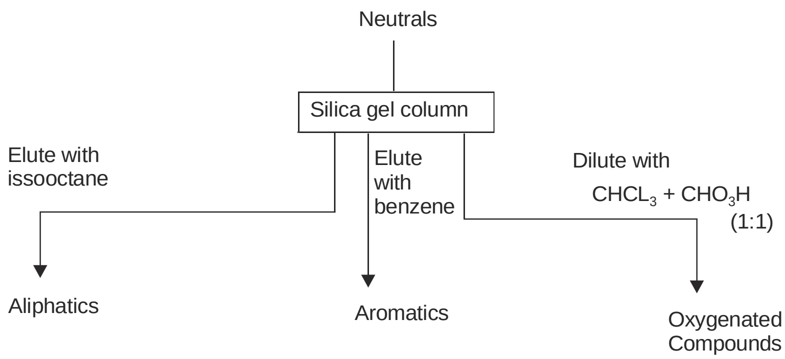
Table 5.4: Separation Scheme for Organic Compounds in Water



*CCE = Carbon Chloroform Extract
CAE = Carbon Alcohol Extract

Contd....

Table 5.4: Contd....



Ion exchange—This technique is used extensively for concentration and separation of metal ions from large volumes of natural and waste waters. The total free metal ion content of a water sample is determined by passing the sample through H^+ -cation exchanges and titrating the acid liberated with a standard alkali solution. Another aliquot may be titrated with EDTA to estimate the total hardness of water.

Ion exchange chromatography provides an excellent method for concentration and separation of ions from waste water. The ions are first concentrated on a suitable ion exchange column and then selectively eluted to be measured polarographically, spectrophotometrically, radiometrically etc. Ion exchange membranes are also useful for separation and concentration of metal ions prior to analysis.

Some general comments: The different stages of metal in water may be defined from sample treatment following collection. A sample to be analyzed for dissolved metals is filtered through a 0.45 µm membrane filter as soon as possible after collection. The first lot of the filtrate is used to rinse the container and sufficient amount is then collected for analysis. The solution collected for analysis is acidified to pH 2 or 3 to ensure storage for some time before analysis. The addition of acid prevents hydrolysis and precipitation.

For analysis of suspended solid for metals, the solid is collected from 100 mL of well-mixed sample on a 0.45 µm membrane filter. After filtration, the membrane filter is transferred to a beaker and digested in hot conc. HNO_3. The sample is diluted to a fixed volume and then subsequently analysed by AAS.

The treatment of extractable metal is done as folows. At the time of collection, the water sample is acidified with conc. HNO_3 (5mL/L).

Before analysis the sample is well mixed and 100 mL aliquot is taken in a beaker or flask. 5mL of redistilled HCL is added. The sample is heated to near boiling for 15 mins. and then filtered. The volume of the filtrate is made up to 100 mL with distilled water and subsequently analysed by ASS.

5.11 PRESERVATION

It is essential to protect samples from changes in composition and deterioration with aging due to various interactions. The optimum sample-holding times range from zero for parameters such as pH, temperature and D.O., to one week for metals. The preservation techniques for various parameters are summarized in Table 5.5. As mentioned above, these

Table 5.5: Water Sample Preservation

Parameter	***Minimum Sample size, mL***	***Container***	***Preservation***
1	**2**	**3**	**4**
pH	100	Polythene	Measure within 0–4 hrs.
DO	100	Polythene	
COD	500	Polythene	Add H_2SO_4 to pH 2; refrigerate
Nitrogen			
Ammonia	500	Polythene	Analyze as soon as possible; add 0.8 mL conc. H_2SO_4/L
Nitrate + nitrite	500	Polythene	Add 40 mg $HgCl_2$/L and refrigerator
Cyanide	500	Polythene	Add NaOH to pH 12 and 25 mL of 2% ascorbic acid and refrigerate
Sulphide	500	Polythene	Add 1 mL of 2N $Zn(CH_3COO)_2$ and 2 mL of 1M NaOH; stir and refrigerate.
Phosphate	500	Polythene/glass	Add 40 mg $HgCl_2$/L and refrigerate.
Phenol	500	Polythene/glass	Acidify with H_3PO_4 to pH 4.0 and add 1g $CuSO_4$ $5H_2O$ per L to inhibit biodegradation.
Tannin and lignin	500	Polythene/glass	Analyze as soon as possible
Chromium, arsenic, lead, zinc, mercury	500	Glass/Polythene	Add 5 mL conc. HNO_3/L and refrigerate.
E. Coli/total bacteria/ actenomycetis	100	Glass bottle	Sterilize the bottles in autoclave at 121°C at 15 lb/inch^2 pressure for 15 minutes. Collect the sample in sterilized bottle and refrigerate immediately.
Microplankton/algae and other biological organisms	500	Glass bottle	Add 5 mL formalin per 100 mL sample and refrigerate immediately.

M.C. Rand, A.E. Greenberg and MJ. Taras, *"Standard Method for the Examination of Water and Waste Water."* American Public Health Association. Washington DC. USA. 14th edn., p. 42-43 (1976).

are essential for retarding biological action, hydrolysis of chemical compounds and complexes and reduction of volatility of constituents. It is desirable, for accurate results, that analysis must be undertaken within 4 hours for some parameters and 24 hours for others, from the time of collection, and it must be concluded within a week.

The bottles (glass/polythene) for sample collection should be thoroughly cleaned by rinsing with 8M $HN0_3$, followed by repeated washing with deionized distilled water. They should be rinsed thrice with the sample water before collection. For bacteriological examination, the bottles have to sterilised as mentioned in the Table.

5.12 MONITORING METHODS FOR WATER SAMPLES

Dissolved Oxygen (D.O.)

In natural and waste waters, D.O. levels depend on the physical, chemical and biological activities of the water body. The analysis of D.O. plays a key role in water-pollution control activites and waste-treatment-process control. Two methods are used, the Winkler or iodometric method and the electrometric method using a membrane electrode.

Winkler Method

D.O. is allowed to react with I^- to form I_2, which is then titrated with standard $Na_2S_2O_3$ solution. A fast quantitative reaction is ensured by addition of Mn(II) salts in strongly alkaline medium:

$$Mn^{2+} + \frac{1}{2}O_2 + 2OH^- \rightarrow MnO_2 \downarrow + H_2O$$

$$MnO_2 + 21^- + 4H^+ \rightarrow Mn^{2+} + I_2 + 2H_2O$$

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

$$5 \text{ mL of } 0.025 \text{ M } Na_2S_2O_3 \equiv 1 \text{ mg L}^{-1} \text{ D.O.}$$

Interferences due to oxidizing agents such as NO_2^- and SO_3^{2-}, present in waste water, may be eliminated by addition of NaN_3 to alkaline I^- solution. On acidification NO_2 is decomposed.

$$N_3H + HNO_2 \rightarrow N_2 + N_2O + H_2O$$

Procedure

1. To a 100 mL sample in a 250 mL bottle, add 2 mL of 40% KF (to mask Fe^{3+}), 2 mL of 36% $MnS0_4$ and 2 mL of alkaline iodide-azide solution (50g NaOH + 13.5 g NaI + 1.0 g NaN_3 diluted to 1 litre).

2. Shake well, allow the precipitate to settle, and then add 6 mL of 12 NH_2SO_4.
3. Shake the mixture well till the precipitate dissolves.
4. Titrate the liberated I_2 with 0.025 M $Na_2S_2O_3$ solution.

Ammonia

It is naturally present in surface water, ground water and domestic sewage. It is produced largely by the deamination of organic nitrogen-containing compounds and hydrolysis of urea. In water bodies, it is produced naturally by the reduction of nitrates under anaerobic conditions. The spectrophotometric Nessler's method is useful for ammonia nitrogen up to 5 ppm, while titration procedures are valid when the NH_3 level exceeds 5 ppm. Distillation is necessary when the sample is coloured and when the titrimetric method is followed.

Nessler's Method

The method is based on the reaction between NH_3 and HgI_4^{2-} tetraido mercury (II) anion in alkaline solution:

$$NH_3 + 2HgI_4^{2-} + 3OH^- \rightarrow \underset{\text{Orange-brown}}{NH_2Hg_2IO} + 7I^- + 2H_2O$$

The orange-brown reaction product tends to precipitate at higher concentration, while at lower concentration it is measured at 420 nm spectrophotometrically.

Procedure

I. 1. To a 100 mL sample, add a little NaOH to neutralize the acid used for storage and then add 1 mL 10% $ZnSO_4$, $7H_2O$ followed by 1 mL of 10% NaOH. Stir and filter. (Ca, Fe, Mg, S^{2-} are precipitated).

2. Collect the colourless middle fraction, add 1 drop of 50% EDTA (disodium salt), mix well and add 2 mL of Nessler's reagent (70g KI + 160 g HgI_2 + 160g NaOH (ice-cooled) diluted to 1 litre). Shake well.

3. Measure the *resulting yellow colour* at 420 nm.

II. 1. When the sample is coloured, distil a 500 mL sample with di. NaOH and collect, the distillate in an erlenmeyer flask containing 200 mL of 0.1 NH_2SO_4.

2. Make up the volume of distillate to 250 mL in a volumetric flask.

3. Take 5-10 mL aliquot, neutralize with 0.1 N NaOH 10 pH 4-5, and add 2 mL Nessler's reagent. Proceed as above for measurement.

III. Distil as above and collect only 100 mL of the distillate in an erlenmeyer flask. Titrate with 0.02 N H_2SO_4, using a mixed indicator (200 mg methyl red in 100 mL 95% ethyl or isopropyl alcohol + 100 mL methylene blue in 50 mL 95% ethyl alcohol), until the indicator turns a pale lavender. Carry a blank through all the steps.

Metals and Metalloids

The presence of metals and metalloids (As, Se) in potable waters, domestic waste and industrial effluents is a subject of serious concern due to the toxic properties of these materials. They affect public health to a large extent, waste water treatment systems and the biological systems of water bodies. The impact of heavy metals in drinking water containing traces of heavy metals is dangerous for health in the long run. The metals Pb, Cd, Hg are particularly deemed to be undesirable. Their permissible limits are 0.05, 0.01 and 0.001 mg L^{-1} (ppm), respectively. Detection and quantitation of such low levels of metals and metalloids require highly sensitive instrumental techniques. Sometimes analysis is preceded by a preconcentration step, particularly when spectrophotomety or flame photometry is used.

For sampling, the containers (glass or polythene) must be thoroughly washed and rinsed with 8N HNO_3 followed by redistilled water. Then 5 mL conc. HNO_3 per litre of sample must be added at the time of collection to minimize adsorption of metals on the container walls.

For estimation of dissolved metals, it is necessary to filter the water sample through a 0.45 μm membrane filter. The residue on the membrane filter is treated for estimation of metals in the suspended matter (particulate). The material (mass) balance of metals at particulate site may be obtained by determined metals in the sediments and adding to it the quantities of metals in water and suspended particulates at the same site.

Arsenic

Acute arsenic poisoning* can arise from the ingestion of as little as 100 mg As. Chronic effects can appear from its accumulation in the body at low intake levels for prolonged periods. The usual As level in potable waters is within 10 ppb, although up to 100 ppb. As has been reported. As occurs in water as a result of mineral dissolution, industrial discharges or the application of insecticides.

Silver Diethyldithiocarbamate Method

Inorganic As is reduced to AsH_3 by Zn in acid solution in a Gutzeit generator. AsH_3 is then led through a scrubber containing glass wool impregnated with $Pb(CH_3COO)_2$ solution and into an absorber tube containing Ag-diethyldithiocarbamate ($AgSCSN(C_2H_5)_2$) dissolved in pyridine. As reacts with this Ag-salt forming a soluble red complex which is measured at 535 nm.

* Cases of arsenic poisoning have been reported from six districts of West Bengal where people use tube well water containing as much as 1.5 ppm arsenic. Lakhs of people are suffering from various diseases in these areas where arsenic is being leached out of iron pyrite crystal lattice (School of Environmental Studies, Jadavpur, University).

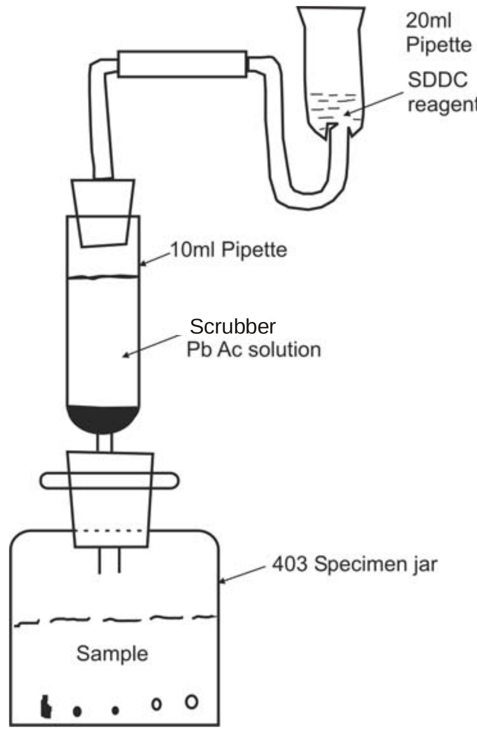


Fig. 5.2: Arsine generator and absorber assembly

Procedure

1. Take 25-35 mL sample in a clean generator bottle. (Gutzeit generator). Add successively, with thoroughly mixing after each addition, 5 mL conc. HCI, 2 mL KI (15%) solution and 0.5 mL of 40% $SnCl_2$ reagent. Allow 15 mins. for reduction of As(V) to As(III).
2. Add 3 g Zn (20-30 mesh) to the solution in the generator and connect the scrubber absorber assembly immediately.
3. Allow 30 mins. to complete the evolution of AsH_3. Warm the generator slightly to ensure that all AsH_3 is released. AsH_3 passes through scrubber containing *glass* wool impregnated with 4-5 drops of 10% $(CH_3COO)_2$ and then to the absorber containing 4 mL of 0.05% Ag-*diethyldithiocarbamate* in pyridine for 45 mins.
4. Pour the solution from the absorber directly into 1 cm-cell and measure the absorbance of the red solution at 535 nm against a reagent blank.

   The method is suitable for measurement of 0.002–0.1 ppm As.

Mercury

Organic compounds (alkyl) of Hg have attained notoriety for their toxic effect. Their presence in water bodies requires constant monitoring. The permissible limit of Hg in drinking water is 2 ppb.

The best and most convenient method is the Flameless Atomic Absorption Method, while the dithizone method may also be used as it is fairly selective for Hg.

Dithizone Method

2-10 µg Hg can be estimated by this spectrophotometric method. Hg^{2+} reacts with dithizone in 1 N H_2S0_4 medium to produce an orange chelate which is extracted into CCl_4 and measured at 490 nm.

1. Take a 100 mL sample in a 500 mL distillation flask. Add 5-10 mL 5% $KMnO_4$ and mix thoroughly.
2. Reflux for 4 hrs with ice-cold water circulation in the condenser.
3. Cool, add a few ml of 30% H_2O_2 to remove $KMnO_4$ and boil to remove excess H_2O_2.
4. Cool and adjust the solution to 1 NH_2SO_4.
5. Extract twice with 10 mL dithizone solution (20 mg dithizone in 100 mL Cl_4). Combine the extracts, make up to 25 mL in a volumetric flask. Measure at 490 nm against reagent blank.

Flameless Atomic Absorption Method (Mercury Analyser)

This specific technique for Hg is based on room temperature reduction of Hg to Hg^o (elemental) by $SnCl_2$ in solution, followed by sweeping Hg^o by air into an absorption cell. Nanogram (10^{-9} g) quantities of Hg can be estimated by measuring absorbance at 253.7 nm.

1. Take a 100 mL sample in a 500 ml distillation flask. Follow steps (1) to (3) above.
2. Make up the volume of the solution 250 mL.
3. Add 2 mL of 20% $SnCI_2$ in 10 mL conc. HCI and 8 mL of 10% HNO_3, to the reaction vessel(R_2). Mix vigorously for 5 mins. with a magnetic stirrer. Pump the resulting Hg vapour, remaining in the reagents as impurity, through 3 mL of 22% NaOH and 3 mL of 50% H_2SO_4.
4. Introduce 1-2 mL of digested sample into the reaction vessel (R_2) containing 2 mL of Hg-free $SnCl_2$ and 8 mL of 10% HNO_3.
5. Try the mixture vigorously for five mins.
6. Pump the resulting Hg vapour through 22% NaOH (R_2), 50% H_2SO_4. (R_4) and then to the absorption cell.
7. Measure the absorbance at 253.7 nm using mercury hollow cathode lamp as the light source.
8. At the end of the measurement absorb Hg vapour in 1% $KMnO_4$.-10% H_2SO_4 in the outlet.

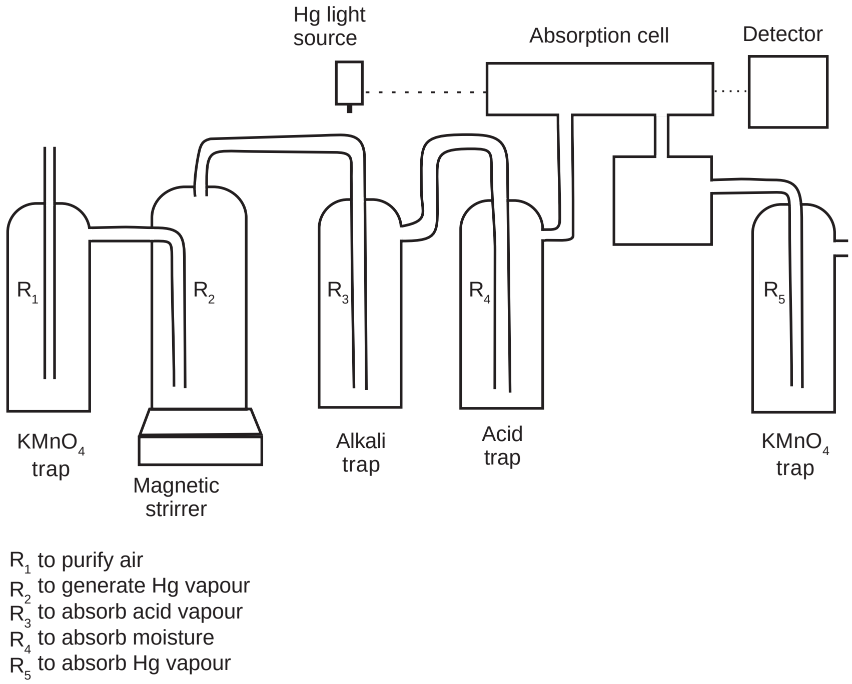


Fig. 5.3: Vapour generator system of mercury analyser

Chemical Oxygen Demand (COD)

This is a satisfactory method for determining the organic load of a water body, which is preferable to the biochemical oxygen demand (BOD) mentioned below. It is a rapidly measurable parameter for stream, and industrial waste studies and control of water treatment plants. The method is based on the chemical oxidation of material in the presence of a catalyst by $Cr_2O_7^{2-}$ in 50% H_2SO_4:

$$3\{CH_2O\} + 16H^+ + Cr_2O_7^{2-} \rightarrow 4Cr^{3+} + 3CO_2 + 11H_2O$$

The amount of unreacted $Cr_2O_7^{2-}$ is then determined by titration with a standard Mohr's Salt solution.

Ag_2SO_4catalyses the oxidation of straight chain aliphatic compounds, aromatic hydrocarbons and pyridine. $HgSO_4$ ties up Cl^- as soluble complex and prevents its interference.

Procedure

1. Take 5-50 mL sample in a conical flask (250 mL) with a ground glass joint. Add 10-20 mL 0.25 N $K_2Cr_2O_7$ in 18 N H_2SO_4, 1g Ag_2SO_4 and 1g $HgSO_4$.

2. Reflux for 6 hrs.
3. Cool and titrate excess $K_2Cr_2O_7$ with 0.1 N Mohr salt solution in 8 N H_2SO_4 using 8-10 drops of ferroin (1.485 g O-phenanthroline + 0.695 g. $FeSO_4$ g. $7H_2O$ dissolved in 100 ml water) as indicator.

Biochemical Oxygen Demand (BOD)

This is an empirical, semi-quantitative method, based on oxidation of organic matter by suitable microorganisms during a 5-day period. There is nothing sacrosanct about 5 days but the test originated in England where the maximum stream flow is 5 days.

The degree of microbially mediated O_2 consumption in water is known as the *Biochemical Oxygen Demand.* This parameter is commonly measured by the quantity of O_2 utilized by suitable aquatic microorganisms during 5-day period.

$$\{CH_2O\} + O_2 \xrightarrow{\text{microorganisms}} CO_2 + H_2O$$

The selection of microorganisms (seed) is crucial and the results are obviously not reproducible.

The purpose of seeding is to introduce into the sample a biological population capable of oxidizing the organic matter in the waste water. Where such microorganisms are already present, i.e. in domestic waste water or surface waters, seedling is unnecessary. But when the sample is deficient in microorganisms, the dilution water needs seedling. The standard seed material is settled domestic waste water which has been stored for 24 to 36 hrs. at 20°C.

Procedure

(a) *Preparation of dilution water*—Take desired volume of distilled water in a suitable bottle and add 1 mL of phosphate buffer (pH 7.2), 1 mL of $MgSO_4$ (22.5 g/L), 1 mL of Cl_2 (27.5 g/L) and 1 mL of $FeCl_3$ (0.25 g/l).

(b) *Dilution technique*—The dilution depends on the nature of the sample: 0.1-1% for industrial wastes: 1-5% for raw and settled sewage; 25-100% for polluted river water and 5-25% for oxidized effluents.

(c) *Procedure*—Aerate the water sample thoroughly by bubbing air through a diffusion tube into the sample for 5 min. or until the DO is 7 ppm. Make a measured dilution with dilution water if BOD is greater than DO level. Seed with a little diluted domestic waste water (1.2 mL/l). Measure DO on a suitable aliquot (D_1).

Fill a screw-topped incubation bottle (250-300 mL) to the brim with the remaining diluted sample. Seal the bottle and incubate in the dark for 5 days at 20°C. Measure DO on an aliquot of the sample (D_2).

$$\text{mg / L BOD} = \frac{(D_1 - D_2) - (B_1 - B_2)f}{P}$$

where D_1 = DO of diluted sample; D_2 = DO of diluted sample after incubation; B_1, B_2 are DO of dilution water containing seed before and after incubation; f = ratio of seed in sample to seed in control and p = decimal fraction of sample used.

BOD of 80 mg/L means that biodegradation of organic matter in a litre of sample consumes 80 mg. of O_2.

Total Organic Carbon (TOC)

This is the best method for the measurement of total organic matter in water samples. As it is an instrumental method, it is superior to the COD method and is quite popular. The oxidizing agent is $K_2S_2O_8$ and the oxidation is promoted by the free radical $HO^\bullet$ generated from ultraviolet light.

$$\text{Organics} + HO^\bullet \xrightarrow{K_2S_2O_8} CO_2\uparrow + H_2O$$

A sketch diagram of a TOC analyzer employing UV irradiation is shown in Fig. 5.4. To the sample $K_2S_2O_8$ and H_3PO_4 are added. H_3PO_4 is sparged with air or N_2 to expel CO_2 formed from HCO_3 and CO_3^{2-} in solution. After sparging, the sample is pumped to a chamber containing a UV lamp emitting radiation at 184.9 nm. The $HO^\bullet$ formed by UV irradiation is the active species which brings about the rapid oxidiation of dissolved organic compounds. At the end of oxidation, CO_2 is sparged from the system and measured with a gas chromatographic detector or by absorption in ultrapure water followed by conductivity measurement.

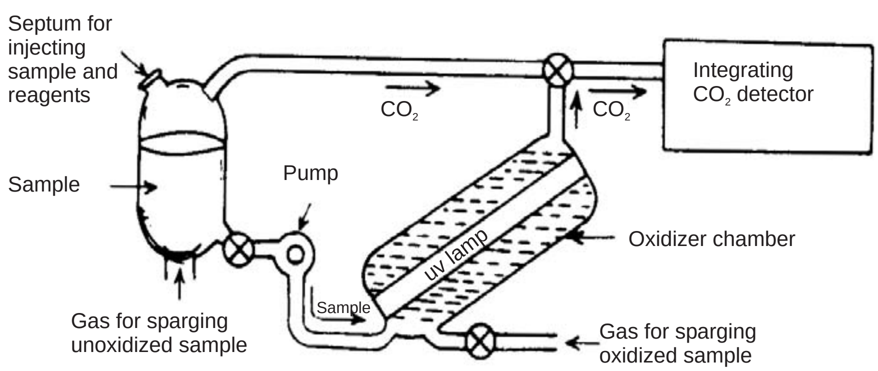


Fig. 5.4. TOC analyzer employing UV-promoted sample oxidation

5.13 WATER POLLUTION CONTROL AND WATER MANAGEMENT—WATER RECYCLING

Clean water is essential for healthy environment to support life systems on this planet. The task of delicately balancing the ratio of available and exploitable water resources and sustaining their quality is most important for India as rainfall distribution is confined to 3–4 months in a year. Moreover, man-made global and local climatic distortions due to global warming (*see* Chapter 4), deforestation, loss of top soil, etc., have adverse effect on the monsoon pattern in India.

India is blessed with good rainfall (average 200 cm in a year) but 70 per cent of it is wasted. The country faces recurring problems of floods, and droughts and highly polluted water resources. It is necessary to do rain harvesting, i.e., build large tanks and reservoirs all over the country to store rain water, flood water and excess water from the Ganga, Brahmaputra and other rivers. The rivers, the lifelines of our culture and economy, are dying because of severe pollution. This water pollution abatement and resource management should be at the top of our national agenda.

The river water pollution has three dimensions—agricultural run-off, industrial effluents and domestic sewage. A typical example is that of the Ganga pollution. The total quantity of fresh water used in the Ganga basin is 150 billion cubic meters out of which 26 per cent is discharged as waste water. Agricultural run-off is 27 billion cubic metre compared to 1530 million cubic metre from industrial and domestic sewage.

Ganga Action Plan

This best illustrates the strategy of water pollution control and management. In order to rejuvenate (i.e., bring back to life) Ganga, the first step is to stop dumping of all sorts of garbage to the river and at the same time to promote public awareness on this issue. The sources of such garbage are domestic sewage, industrial sewage and agricultural run-off. Every day about 1200 million litres of waste water (mainly from West Bengal) enter the Ganga.

Industrial sewage has to be treated at the plant site through treatment plants and then the treated effluent discharged into the river or recycled for reuse. Domestic sewage in rural and urban areas should be diverted into separate diversion canals and collected in lagoons, subjected to treatment plants and the resulting clean water used for irrigation in agricultural fields. The biogas (methane, CH_4) emitted from the treatment plants can be used for domestic fuel in industrial areas.

With this objective, the Government of India launched Ganga Action Plan in 1986 and entrusted the job to the State Governments concerned (UP, Bihar and West Bengal) for implementation. The Action Plan has the following agenda:

(i) To divert sewage from the small and large towns on both embankments of the Ganga into separate diversion canal, accumulate it in big lagoons, subject it to sewage treatment plant and use the clean sewage water for agriculture. The emitted biogas (methane CH_4) from the plant is utilised as domestic fuel through piped gas supply in adjoining towns.

(ii) To construct low cost sanitary latrines (about 30,000) so that people don't commit nuisance on the river embankments.

(iii) To construct the Ganga embankment ghats and construct electric furnaces at selected sites for funeral rites so that the Ganga is saved from dead bodies.

(iv) To make it mandatory for all industries to install treatment plants in their premises for treatment of their solid and liquid effluent as well as gaseous emission.

For the success of the Ganga Actions Plan, it is essential that the public must be involved—at least they must be made aware of the critical condition of Ganga and need for recovery. For this purpose public awareness campaign deserves top priority. It must be noted that Ganga has three major problems—pollution, erosion and siltation. 70 per cent of pollution is generated from towns (class I 27, class II 23 and class II 48) on both sides of the river, 20 per cent from factories and 10 per cent from agricultural lands. The Ganga Action Plan, however, could not be properly implemented. It required active government-people interaction and participation and furthermore, continuous monitoring of the Projects by experts on a long-term basis. The Ganga Action Plan should be executed as a matter of 20 year plan instead of one or two 5 year plans only.

Desalinisation

Only 0.69 per cent of total water resource is available as fresh water for our consumption. But this resource is shrinking due to reckless water pollution so that in future we may lose it. In that case we have to turn to the vast resource, i.e., sea water (97 per cent), which, at present, is unfit for our consumption due to high salt content. It is possible to utilise sea water with appropriate technology after removal of salts and thus solve water crisis. The technology of removing salts from sea water is known as *desalinisation.* Israel and Arab countries have started applying this technology for solving their chronic problem of water scarcity.

There are several methods for desalinisation of sea water. The most economical method is to use solar energy for evaporation of sea water and separation of salts. For this purpose metal tanks with low height are used for collecting water. The tanks are painted black on the outside walls so that they become hot in the sun while the tanks are covered on the top with transparent plastic sheets. The water vapour from evaporation of sea water by the sun collects on the inside wall of the plastic sheet—on condensation, this water vapour gives pure water. At the end of the operation, salts are recovered from the tanks. Recently Israel is getting each year 30 million cubic metres of salt-free sea water.

Electrodyalysis and Membrane Technology are being used in Japan to obtain salt-free sea water and salts separately. Though these techniques are costly, at present, but with enhanced technology, it may be possible in future to run these on commercial basis.

Questions

1. What are the various uses of land?
2. Give an account of land use planning.
3. What is meant by “Water Shed”? Explain with reason the importance of water shed management in our national policy.
4. What are the sources of fresh water? Give their quantities in terms of total percentages of water resources.
5. List the uses of water by man giving their relative percentages.
6. Compare the chemical composition of sea water with that of lake and river water.
7. What are the organic water pollutants? How do they cause water pollution?
8. Write notes on—(a) Eutrophication, and (b) Pesticide with reference to their ability to damage aquatic ecosystem.
9. Write an account of domestic waste water treatment.
10. Give a flowsheet diagram of municipal waste water treatment (primary and secondary).
11. List water quality parameters for drinking water (USPH standard) and give their permissible limits.
12. Describe briefly the Ganga pollution mentioning the pollution sites with their relative order of pollution.
13. Illustrate water pollution control and management with the example of Ganga Action Plan.
14. Write a note on desalinisation of sea water.

6 Soil Pollution

6.1 SOIL POLLUTION

Lithosphere with humus cover is known as soil. It is a limited natural resource but most important resource which supports life and contributes to the development of the country. Indeed the soil quality of a nation is its most precious material heritage.

The top soil provides water and all the nutrients required by plants for their growth. The survival of man depends upon agricultural crops, grassland and trees which grow on soil and supply food, fibre, timber, fuel and other products. But it faces threat of erosion from man-made activities. It takes 500–1000 years to build up one inch of top soil while loss of soil takes only a few years. Deforestation alone accounts for loss of 6000 tons of top soil each year.

The soil pollution sources are:

(i) indiscriminate solid waste disposal on land;

(ii) random discharge of industrial waste effluents on land and water courses;

(iii) excessive use of pesticides, herbicides and chemical fertilisers, in agriculture;

(iv) excessive irrigation;

(v) open defecation on land by animals and man particularly in rural areas and city slums;

(vi) radioactive materials from radioactive fall-out arising nuclear explosion tests,reactor accidents etc.

Dumping of solid wastes on land is quite harmful since heavy metals and toxic elements present in the wastes contaminate the soil and ultimately seep into underground water after rainfall. It is estimated that about 15 million tons of solid wastes are generated every year by more than 110 million urban citizens in India.

In general, in rural areas poor illiterate people have the nasty practice of open defecation in absence of sanitary toilets. Both human and animal excreta contain many pollutants which degrade not only soil but also nearby ponds and canals where they mix after being washed by rain water.

Many industries generate huge volume of liquid effluents and solid wastes, which are mostly thrown on land and in water courses (streams and rivers). These effluents and wastes contain phosphorus, chromium, lead, zinc, nickel, cyanides etc., which affect the quality of soil and render it injurious for plants and animals and ultimately man.

Agriculture run-off (wash water from agricultural fields) contains lot of pesticides, fertilizers, herbicides which find their way into water courses causing water pollution in addition to soil pollution. Excessive irrigation increases the salt content of soil and makes it saline, thereby decreasing soil fertility.

Each nuclear test is accompanied by radioactive fall-out which spreads radioactive contaminants in nearby areas over land and water bodies. Moreover, radioactive wastes from atomic power plants pose long-term health hazards after they contaminate land and water bodies.

6.2 CONTROL OF SOIL POLLUTION

Solid waste disposal methods are actually the methods for control of soil pollution. Non-hazardous wastes are managed by two techniques (i) Landfil and (ii) Incineration. Miscellaneous waste materials—food wastes, vegetable and animal wastes, paper, wood, rubber, leather, plastics, tin cans, crockery, glass etc., are desposited in a regulated manner in general pit in backyards of houses and municipal areas. These are then covered with 15 cm. thick soil. The wastes may be burnt from time to time. Another option for municipal wastes is to use biological process: organic wastes are allowed to be decomposed into humus-like substances after removal of iron and metallic particles. In presence of stream of air, aerobic micro-organisms ensure rapid decomposition of the wastes. Such compost plans are in operation in several parts of the country e.g., Ahmedabad, Mumbai, Chennai, Delhi, Pune, Hyderabad and Kolkata.

The second method viz. Incineration is the preferred technique for waste management particularly in developed countries. It reduces the bulk of waste by 90 per cent at 900–1000°. This is an environment-friendly technique.

6.3 WASTE TREATMENT

Waste water treatment has already been discussed in Chapter 5. Primary and secondary treatment of domestic waste water (municipal waste water) has been discussed. Industrial waste water treatment has also been dealt with.

Disposal of gaseous wastes and their control has been illustrated in Chapter 4. In this chapter only solid waste disposal will be discussed.

6.3.1 Waste Classification and Disposal

Wastes can be broadly classified as domestic, trade and industrial. Domestic waste includes garbage from houses and other residential premises. Industrial waste originates from all mineral, manufacturing and processing establishments.

The break-up of annual solid waste production is given below:

Domestic and trade	8.5 %
Other industries	15.2 %
Thermal power stations	7.3 %
Construction	2 %
Mining and quarrying	67 %

Some typical toxic wastes (liquid/solid) are listed below:

Tarry liquids;
Solid tarry matter;
Sludge from tar distillation;
Acid tars;
Waste oil;
Lubricants;
Water-kerosene mixtures;
Waste paint;
Lacquers;
Pesticide residues;
Mercaptans;
Photographic wastes;
Plating sludges;
Leaded petrol sludges;
Sludges containing copper, zinc, cadmium;
nickel, arsenic, etc.
Cyanide wastes;
Sulphides, fluorides;
Alkaloid wastes;
Aromatic hydrocarbons;
Chlorophenols;
β-naphthylamine;
Noxious organic solvents

6.3.2 Solid Waste Disposal

The methods of waste disposal depend on the nature of waste. Most solid wastes are dumped on land as soil heaps or as landfill to quarries or mine shafts or as dumps consisting or a wide range of materials. Besides these some wastes are dumped into the seas. The various modes of waste disposal are illustrated in Fig. 6.1.

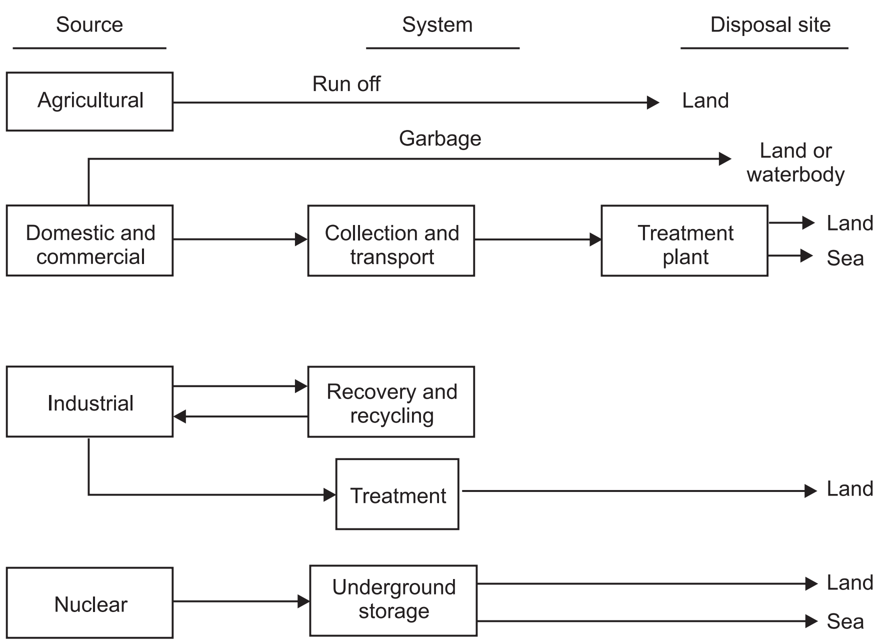


Fig. 6.1: Modes of waste disposal

6.3.3 Detoxification of Toxic Wastes

The toxic wastes are converted into less hazardous products by treatment with acids; cyanide containing wastes are decomposed by interaction with oxygen to form carbon dioxide and nitrogen. The decomposition can also be carried out biologically by means of suitable micro-organisms (bacteria). Sludge from petroleum refineries may be spread on the soil and left to decay into harmless products.

Incineration of toxic wastes is another method for their disposal. However, incinerators need pollution control devices and careful monitoring to make sure that they do not release toxic by-products into the environment.

6.3.4 Land and Ocean Disposal

Radioactive wastes from nuclear power stations are generally fused in glass containers and lowered to the ocean floor. In USA such wastes are sealed in metal drums and buried underground at great depths. But they may leak or be damaged by earthquake and release the wastes into ground water.

Hazardous wastes dumped into soil/ditch have chances of leaking to the ground. A typical case history is that of the ***Love Canal*** in Niagara Falls, New York, USA. In 1930–53 the canal ditch was the dumpsite for hazardous chemical wastes and municipal wastes. In 1953 the ditch was filled up; it was covered with clay and sold to the city Board of Education which built an elementary school. Some houses were also built. Soon the residents of these houses (300 families) and the school authorities complained of foul odour and illnesses. In 1978 it was found that some 25 toxic organic compounds known as carcinogens, leaked into the basements in the area and dispersed into air. As a result of these findings, the State of New York declared emergency in the area and transferred all the families and the school from the site (Fig. 6.2).

6.3.5 Non-Hazardous Waste Management

Two techniques are available—(i) Landfill and (ii) Incineration.

Sanitary Landfill

Miscellaneous refuse materials are those from household, hotels, stores, markets, restaurants, etc., (e.g., food wastes, vegetable and animals, wastes, paper, cardboard, wood, boxes, rubber, leather, plastics, tin cans, crockery glass, metals etc.), ashes (from fires used for cooking, heating buildings, etc.) dead animals, industries and agricultural fields, etc. In the developed countries, e.g., USA it is a common practice for each household to burn the bulk of waste in a backyard incinerator. Mainly food scraps, bottles and combustible articles are contained in packets for collection by municipality. The percentage of paper, rubber, leather, plastics, metals and glass increases considerably with increasing industrialisation in developed countries compared to developing countries because of wide application of these materials in their daily lives.

Most of the solid waste is dumped on land in heaps in uncontrolled manner in developing countries. Some waste is used for landfilling in abandoned quarries or mines. The developed countries prefer the second method, viz. incineration (*see* next section). Industrial wastes are treated in treatment plants and valuable materials recycled. In other cases, the volume of the waste is reduced by pulverisation (33 per cent) or by incineration.

For sanitary landfill, the following principles should be followed:

(i) solid wastes should be deposited in a regulated manner, preferably in gravel pit;
(ii) solid wastes should be spread in thin layers with ground cover of at least 15 cm;
(iii) all factors likely to contribute to water pollution should be eliminated;
(iv) the wastes should not be burnt openly.

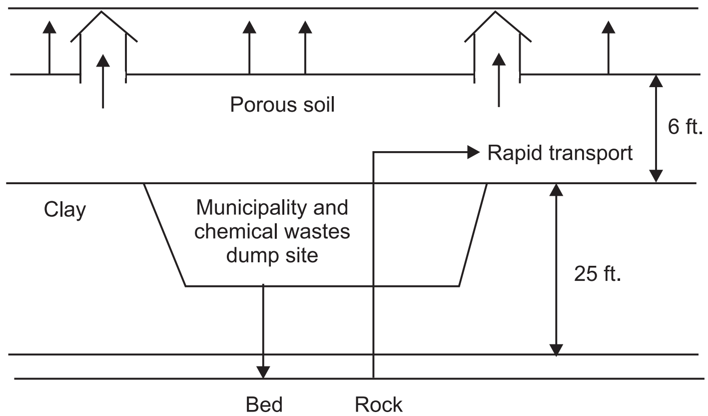


Fig. 6.2: Transport of toxic organic chemicals from love canal dumpsite into adjoining areas

In the man-made gravel pit fine grained soil is useful in containing undesirable gas and water movements outside the landfill area. With increase in urbanisation and expansion of cities beyond the periphery, land suitable for landfill becomes more and more scarce. In such cases planned sanitary landfill, backed by modern solid waste management can provide the community with better environmental management.

Composting and Municipal Waste Composting Projects

This is biological process where fresh organic wastes are allowed to be decomposed into humus-like substances. The process is conducted by a complete automatic system which consists of several steps: (1) The crude refuse is dumped into container or to a belt conveyor. (2) Iron or metallic particles are removed by a magnetic separator. (3) The material is then transferred in a wet condition to a rotatory cylinder, analogous to a rotatory drier. The cylinder rotates slowly on large tyres and the wastes move from one end to the other. They are thoroughly mixed and pulverised by abrasion. Air is introduced at low pressure throughout the length of the cylinder. Here aerobic micro-organisms ensure rapid decomposition of the wastes under aerobic conditions.

In several parts of India compost plants are in operations, e.g., in Ahmedabad, Kolkata, Mumbai, Chennai, Delhi, Pune and Hyderabad. The minimum plan capacity is 100 tons per day. The Government encourages feeding of compost plant by municipal wastes as raw materials. Compost has been used by Indian Agricultural Research Institute (IARI), New Delhi to develop strains of blue-green algae for application to rice fields with a view to nitrogen fixation. An appropriate technology is being developed by IARI to produce blue-green algae-coated granulated compost.

Incineration

This is the preferred technique for waste management, particularly in the developed countries. It reduces the waste volume by 90 per cent at 900–1000°C. Incineration offers environment-friendly technique—free from corrosion, emission of offensive odours and also free from bacteria and wet organic matter which gives off foul odours and gases. The waste heat from incineration can be utilised for supplementing electricity generation for domestic heating, etc. The only drawback is that the technique is costly at present requiring expensive equipment.

Two types of incinerators are used for unsorted wastes. The batch type plant is manually stoked and has a relatively small rated capacity. The operation is intermittent and lacks uniform burning temperature. This leads to incomplete combustion and yields an unstable residue. These units are not suitable for large cities. The continuous feed plant has larger storage bins, automatic feed hoppers and variety of moving gates and ash removal systems. The unit maintains a uniform combustion range, can be fitted with pollution control devices and yields stable residue.

Japan since 1970 and Germany since 1990 developed recycling technology of plastic wastes. The latter was subjected to incineration and gasification—the gaseous products were converted to chemical raw materials (water gas, i.e., carbon monoxide and hydrogen mixture which can be utilised for production of methanol) and the heat generated used for electrical generation units or for domestic heating. The waste volume shrinks to 20 per cent and carbon dioxide released to the atmosphere is minimum so that the technique offers good recycling.

6.4 OCEAN DUMPING

In the developed countries such as USA about 50–75 million tons of waste are dumped every year within 200–300 km of ocean shore. In earlier years waste dumped into the ocean 100 km from the shore did little damage. But over the years industrial wastes and domestic wastes have become more toxic.

Industrial wastes contain numerous toxins and sewage sludge also contains lot of toxic metals. Disease-causing organisms and heavy metals have destroyed many coastal fisheries. Anti-dumping Act (1972) has been violated and many metropolitan cities—New York, Tokyo, etc.—continue to dump sewage into the ocean. It has been the practice in all countries including India to throw radioactive wastes into the oceans and high seas.

6.5 SOLID WASTE MANAGEMENT BY BIOTECHNOLOGY

According to biologists, bacteria and fungi are capable of decomposing organic waste and it may be possible to recover resources by this process. Natural micro-organisms can do this job—it is also possible to produce such micro-organisms by genetic engineering. The promising development is the isolation of bacteria which can break down polychlorinated biphenyls (PCBs).

New biodegradable plastics are important step towards solving our solid waste problems in respect of plastic wastes. On exposure to micro-organisms which metabolise glucose, biodegradable polymers break down into short carbon chains that decomposers can metabolise. Photodegradable plastics have been developed, which break down on exposure to sunlight.

Questions

1. How would you classify wastes? Give a list of typical toxic wastes.
2. Give an outline of the modes of solid waste disposal.
3. What are hazardous wastes? How can you provide for their detoxification?
4. Comment on land and ocean disposal of hazardous wastes.
5. Give an account of the Love Canal Dumpsite incident.
6. Classify the main categories of the solid wastes and characterise the contents and sources.
7. How do you propose solid waste management? Discuss the merits and demerits of each method proposed by you.
8. Write short notes on:
   (a) Sanitary landfill method for waste disposal,
   (b) Incineration method for waste disposal,
   (c) Municipal waste composting in India,
   (d) Biotechnological approach to solid waste disposal.

7 Radioactive Pollution

7.1 RADIOACTIVITY

The process by which certain elements undergo spontaneous disintegration, accompanied by emission of radiations, is known as **radioactivity.** The elements are called radioactive elements. Examples are: uranium, thorium, radium etc.

7.2 RADIATIONS—NATURE AND TYPES

The radioactive substances generally give rise to three types of radiations—alpha (α), beta (β) and gamma (γ).

Alpha particles (α): These are positively charged particles carrying a charge of $+2$ units and mass 4 units so that they are identical with helium nuclei $\left({}^{4}_{2}\text{He}\right)$. This has been confirmed by the fact that a strong alpha source, e.g., radium, sealed in a glass capsule, ultimately produces helium gas which can be detected by its spectrum. Alpha particles have ionizing power i.e., they produce ion pairs their course in air.

Beta particles (β): These are identical with electrons. They are more penetrating than α-rays i.e., they travel a little further than the latter in air but are absorbed by a thin layer of metal e.g., aluminium foil. The ionizing power of the β-particles is less than that of α-rays.

Gamma rays (γ): These consist of short-wave electromagnetic radiation or photons emitted by a nucleus in an excited state. Gamma rays, being electromagnetic in nature, have no mass and so cannot be thought of as particles. Their penetrating power is greater than those of α- and β-particles. Thus while α-particles are stopped in air (3–9 cm) or thin Al-foil (5 mm thick), γ rays can pass through 25cm of iron and 8 cm of lead.

Radioactive Decay: Radioactive elements undergo spontaneous transformation of one atom to another and radiations are emitted in the process.

Thus radium ($^{226}_{88}Ra$ mass 226 and charge 88 units) emits α-particles and thereby loses mass by 4 units and charges by 2 units and is transformed into radon (mass 222 and charge 86):

$$^{226}_{88}Ra \xrightarrow{\alpha} {}^{222}_{86}Rn$$

By β ray emission, the product element retains its mass but increases charge by 1 unit and its position is shifted to the next higher group in the periodic table:

$$\underset{\text{Lead}}{^{210}_{82}Pb} \xrightarrow{\beta} \underset{\text{Bismuth}}{^{210}_{83}Bi}$$

In case of radium, the position in the periodic table is shifted two places to the left.

7.3 NATURALLY OCCURRING RADIOACTIVE SUBSTANCES

All elements found in natural sources with atomic number greater than 83 are radioactive. Three well-known families are the series 4*n* (thorium), 4*n*+2 (uranium) and 4*n*+3 (actinium). Each of these series is characterised by a single long-lived parent, a single gaseous isotope and a common end product i.e., lead, isotope which is stable.

Series	***Parent***	***Half-life, T½ Years***	***End Product***
4*n* (Thorium)	^{232}Th (At. wt. 232)	1.39×10^{10}	^{206}Pb (Atomic weight 206)
4*n* + 2 (Uranium)	^{238}U	4.5×10^{9}	^{206}Pb
4*n* + 3 (Actinium)	^{235}U	7.07×10^{8}	^{208}Pb

T½ = Half life + period within which the radioactivity decays by 50%
e.g., ^{238}U activity decays by half or 50% in 4.5×10^9 years.

^{238}U undergoes 14 transformations –8 by α-particle emission and 6 by β-particle emission to end up as the stable ^{206}Pb or Ra–G.

7.4 BACKGROUND RADIATION

Cosmic rays from upper atmosphere and also radionuclides in earth's crust (uranium–238, uranium–235, thorium–232, potassium–40 and carbon–14) are sources of background radiation reaching the biosphere. Though usually the background radiation is below tolerable level, the level may be exceeded and it may become critical on exposure to man-made radiation (due to mining and refining of radioactive minerals, leakage and waste from nuclear power plants and reactors, nuclear test explosions etc.).

7.5 INTERACTION OF RADIATION WITH MATTER

Radioactive particles lose energy on passing through matter by interaction with atoms and molecules. Such interaction may lead to ionization of atoms and molecules or their dissociation.

α-particles travel only short distances in matter and produce ion pairs by interaction with electrons (in atom and molecules). Then they lose energy and are stopped. The interactions of β-particles with matter is similar to that of α-particles i.e., they lose energy by ion-pair production. γ-rays have less ionizing power and travel greater distances than the latter i.e., they have greater penetrating power.

Radiation Chemistry

The study of the chemical and biological effects caused by radiations (α-, β- and γ-) in their passage through matter forms the discipline of radiation chemistry. The processes for inorganic compounds include ionization, formation of excited electronic states, molecular excitation, dissociation of excited vibrational states etc. The reactions involve unstable intermediates (excited molecules, free radicals and ions.). The radiation decomposition of H_2O (water) into H_2 (hydrogen), O_2 (oxygen) and H_2O_2 (hydrogen peroxide) involves H and OH (hydroxyl) radicals as intermediates.

Biologically Permissible Doses

The biological effects of radiation are brought about through chemical changes in the cells caused by ionization, excitation, dissociation and atom displacements. Radiation effects on living organisms depend on nature and extent of exposure to radiation. The unit of radiation dosage that is used in measuring biological effect is **rem** (i.e., **roentgen equivalent man**). Another parameter is the **relative biological effectiveness (RBE)** which reflects the effects of different quanta of ionization along the path of the radiation. Thus RBE for α-particles is 10, β-rays 1.0, γ-rays and x-rays, 1.0. For whole body exposure the maximum permissible dose has been set at 3rem—applicable to persons having occupational exposure to radiation during working hours. Excessive radiation leads to cancer and death and causes genetic damage among survivors for generations. Examples: Atom bomb explosions at Hiroshima and Nagasaki (1945).

7.6 RADIATION POLLUTION EFFECTS

Radiation pollution is more fatal than any other type of pollution. Man-made radiation has increased in quantity since the invention of atom bomb and use of nuclear energy for reactors and power plants. Radiation damages living cells by ionization leading to skin burn, cancer and anemia which are beyond medical treatment. It may be noted that the discoverer of radiation were themselves victims of radiation—W.H. Roentgen who discovered x-rays died of bone cancer in 1923 while Madam Curie, the discoverer of radium, died of anemia and cancer. They were not aware of the precautions against radiation.

The horrors of **Hiroshima and Nagasaki** (August 6, 1945) in Japan are tragedy in human history. The two atom bombs instantly killed about 6 lakh people, destroyed the two cities and unleashed radiation which has caused generations to suffer from various diseases including genetic disorder. Radiation still continues to damage plants, soil and biosphere in the region even after 60 years.

The worst nuclear accident occurred at **Chernobyl**, USSR (now CIS) on 28th April, 1986. The reactor exploded as a result of runaway nuclear reaction—radioactive fuel and debris shot up in the air like volcanic explosion and spread far out in the surrounding areas. The accident killed about 2000 people and damaged soils, water and vegetation in an area of 60 sq. km. around Chernobyl. Several generations in the region will suffer from genetic damage.

Control of Radiation Pollution

It is necessary to take utmost precautions regarding safety devices for reactors, strictly ban and enforce the ban on nuclear test explosions. Leakage from reactors, careless handling and use of radioactive fuels, fission products and radioisotopes must be stopped. The practice of dumping radioactive wastes into seas and oceans should also stop. These wastes should be buried underground for a long period to ensure that the radioisotopes lose their activity.

Questions

1. What is radioactivity?
2. Discuss the characteristics of alpha- and beta-particles and gamma rays. Compare their ionizing and penetration powers.
3. Explain with examples how radioactive decay shifts the position of an element in the Periodic Table.
4. List the three well-known radioactive series with their respective parent, half life and end product.
5. Explain the interactions of α- and β-particles with matter.
6. Write notes on:
   (a) Radiation Chemistry
   (b) Radiation Pollution

8 Noise Pollution and Health

Noise is part of our environment. With progress in industrialization, the noise level has been rising continuously. In the 19th century the development of the steam engines, petrol engine and machines in factories resulted in increasingly noisy environment. In the 20th century this was further accelerated by introduction of diesel engine, jet engines, turboprop, high tech machineries, construction site machineries and automobile traffic. Noise has been recognized as one of the dimensions of pollution which brings about degradation of the environment and creates health and communication hazards.

8.1 SOUND AND HUMAN ACOUSTICS

Sound consists of wave motion in an elastic medium such as air, water or solids (e.g., metals, plastics, wood, bricks, etc.). Sound waves travel through the medium from the source to the recipient or listener. The rate of the oscillation of the medium is known as the *frequency* of the sound, the unit being *Hertz* (*Hz*) or *cycles per second*. The frequency is a measure of the pitch of the sound received by the listener. High frequencies mean high pitched sounds which are more irritating to the individual than low frequencies. The second parameter of sound is *sound pressure* which is measure in Newtons per sq. meter (N/m^2). The third parameter on sound is its *intensity,* expressed in watts per sq. metre i.e., the quantum of sound energy that flows through unit area of the medium in unit time.

The human ear receives sound waves which set tip oscillations in the ear drum (tympanic membrane). These oscillations cause movement of three small bones in the middle ear behind the ear drum. These then pass through the fluid in the inner ear to the auditory nerve and finally transmitted to the brain. The oscillations or sound are identified and interpreted in the brain, which can select sounds into different categories—speech, music, noises, etc.

The sensitivity of the ear varies from person to person. With ageing, people lose hearing power gradually. A young person, 18 year old, with normal hearing, has audio range between 20 Hz and 20,000 Hz. The audio sense is sharpest in the frequency range 2000–8500 Hz.

8.2 NOISE MEASUREMENT UNITS

As mentioned before, sound pressure and sound intensity are two important parameters of noise. The common scientific acoustic unit is the **Decibel (dB).** It is not an absolute physical unit like volt, metre, etc. but is a ratio, expressed in logarithmic scale relative to a reference sound pressure level.

$$1 \textbf{ decibel } (\text{dB}) = 10 \log_{10} \frac{\text{intensity measured}}{\text{reference intensity}}$$

The reference intensity used is the threshold of hearing which means sound which can be first heard at a sound pressure of 2×10^{-5} Newtons per sq. metre or sound intensity of 10^{-12} watts per sq. metre.

Noise meters have been designed for noise measurement from low to high frequencies, characteristic of human ear capacity. These meters record the dB scale for routine measurement of general noise levels. Refined noise meters have been developed to take care of peak noise levels, duration of noise exposure and quality of noise which are aspects of specified noise situation.

Table 8.1: Sound Measurement (Intensities, Pressures and Decibels) in Air at Room Temperature and Sea Level Pressure

Intensity (WM^{2-})	*Pressure (Nm^{2-})*	*dB*	*Sound Source*
100	2,00,000	200	Saturn rocket take off
1.0	20	120	Boiler shop
10^{-2}	2.0	100	Siren at 5 metres
10^{-4}	0.2	80	Heavy machinery
10^{-6}	0.02	60	Normal conversation at 1 metre
10^{-8}	0.002	40	Public library
10^{-12}	2×10^{-5}	0	Threshold of hearing

L_{10} (18 Hour) Index

This is used for road traffic measurement, adopted in UK for noise legislation. The index is expressed in dB–it is arithmetic average hourly values of the noise level exceeded for 10 per cent of the time over 18 hours between 06:00 and 24:00 hours on any normal week day.

It includes peak noise values and fluctuation of noise depending in the type of vehicle and traffic density.

Effective Perceived Noise Level (L epn)

This is recommended for aircraft by the International Civil Aviation Organisation (ICAO) as the standard for use in noise evaluation. The index is based on the scale equivalent to the dB scale + 13 and takes care of the peak frequency of jet aircraft noise as well as duration of aircraft flyover.

8.3 NOISE CLASSIFICATION

There are broadly three categories of noise:

(i) Transport noise,

(ii) Occupational noise, and

(iii) Neighbourhood noise.

Transport Noise

Transport noise can be further sub-divided into (i) Road traffic noise, (ii) Aircraft and (iii) Rail traffic noise.

Road Traffic Noise

Traffic noise is increasing over the years with increase in the number of road vehicles. Traffic speed is the major cause of noise. The noise volume is enhanced with increase in traffic speed. Modern highways and traffic system encourage higher speeds.

In general, on urban roads there are distinct traffic peaks in the morning and evening (10 A.M. and 6 P.M.) as people travel to and fro workplaces. Heavy diesel-engined trucks are the noisiest vehicles on roads at present. The permissible noise levels for cities are prescribed by the Central Pollution Control Board, India:

Areas	*Day*	*Night*
Industrial	75 dB	65 dB
Commercial	65 dB	55 dB
Residential	50 dB	45 dB
Sensitive areas up to 100 m around hospitals, schools	50 dB	40 dB

These limits are, however, violated in all big cities in India, Kolkata being the worst case. The average noise levels in busy streets in Kolkata during rush hours (between 10:30–12:00 hrs. and 18:00–19:30 hrs.) are 90 dB. People live in an environment of noise generated by blasting horns, rumbling tyres and screeching brakes. Awful road accidents contribute to the misery.

Aircraft Noise

The noise levels have peak values when aircrafts fly low and overhead or take off and land at airports. The noise limits prescribed by UK airports for take-offs are 110 PNdB (1 PNdB = dB scale + 13) during day and 102 PNdB during night. These may be compared with the values in USA: 112 PNdB during day at New York.

Rail Traffic

It is less of a nuisance as compared to the previous types of traffic noise.

Occupational Noise

Industrial workers are exposed to noisy working environment for 48 hours a week (8 hrs. a day for 6 days a week). Some typical occupational noise levels are given below:

Table 8.2: Occupational Noise Level

Industrial Source	*Noise Level (dB)*
Steel plate riveting	130
Oxygen torch	126
Boilers' shop	120
Textile loom	112
Circular saw	110
Farm tractor	103
Newspaper press	101
Bench lathe	95
High speed drill	85
Supermarket	60

Millions of workers suffer from progressive hearing damage and become prone to accidents under their working conditions. Their working efficiency is also affected.

Neighbourhood Noise

Loud TV and radio sets, loud cassettes, loudspeakers in public functions, disco music, etc., are sources of neighbourhood noise which disturb and irritate the general public and also harm the patients.

8.4 NOISE POLLUTION HAZARDS

The human ear drum is struck by noise in the form of airborne mechanical energy. While the tolerable conversation level is 65 dB at a distance of 1 metre, 125 dB gives the sensation of pain in the ear and 150 dB might be a killer.

High intensity noise for continuous periods is the major cause for ear damage. If a noise level exceeding 90 dB in the mid-frequency range reaches the ear for more than a few minutes, then the sensitivity of the ear is reduced.

Noise pollution can cause pathological or psychological disorders. High frequencies or ultrasonic sound above the audible range can affect the semi-circular canals of the inner ear and make one suffer from nausea and dizziness. Mid-audible frequencies can lead to resonance in the skull and thereby affect the brain and nervous system. Moderate vibration can also cause pain, numbness and cyanosis (blue colouration) of fingers while severe vibration results damage to bones and joints in the bands with swelling and stiffness.

In industrial and other establishments the general impact of noise pollution is lower efficiency, reduced work rate and higher potential for accidents and injuries.

In residential areas even low frequency noise of 50–60 dB at night disturbs sleep, particularly among the aged people, causing adverse effect on health.

Children, exposed to excessive noise, show signs of behavioural disorder which in later age develop into destructive nature and neurotic disorders in the adult.

Excessive noise is one of the major factors for chronic exhaustion and tension in our daily lives. This may explain why more and more people tend to become addicted to alcohol, tobacco and drugs.

Noise pollution has also impact on travel of migratory birds from winter to tropical climate. Thus the increase of noise pollution in Kolkata and construction of high-rise buildings near Alipur Zoological garden have led to decline in the number migratory birds from CIS (former USSR) from 15,000 in 1980 to 2000 in 1990.

8.5 PERMISSIBLE NOISE LEVELS

In this age many people work and live in environment where the noise level is not hazardous. But over the years they suffer from progressive hearing loss and psychological hazards. The maximum permissible noise levels are summarised as follows:

Table 8.3: Maximum Permissible Noise Levels

Situation	*Permissible noise, dB*
Road traffic near residential areas	70
Ear protection required	85
Factory work (48 hr. week)	105
Prolonged noise causing permanent damage	100
Threshold of pain (30 secs duration)	120
Maximum for sonic boom	150
Ear drum rupture	180

Questions

1. Define: Hertz, Decibel. What are the different categories of noise? State their permissible levels in cities during day and night.
2. Give permissible noise levels in some typical industries/shops: (a) steel plate (b) boilers' shop (c) newspaper press and (d) supermarket
3. Explain how noise pollution can cause physiological/psychological disorders in humans and affect movement of migratory birds.
4. What are the maximum permissible noise levels for

(i) road traffic in residential areas

(ii) factory (48-hr week)

(iii) jet aircrafts

(iv) ear drum?

9 Environment and Public Health

9.1 POLLUTION AND PUBLIC HEALTH ISSUES

Very few people have paid any attention to the dark side of industrialisation, particularly to the growing dangers it poses to the health of people. Hardly a day passes when hundreds do not succumb to the accidents or diseases caused by growing pollution of the environment in general and the increasing occupational hazards or die in major industrial disaster as in Bhopal.

Industrialisation is creating a high-risk environment for all. But it is the poor labourers/ workers who suffer the most. They get the dirtiest and most hazardous job and are compelled to live in the dirtiest environment in close proximity to the industries. The society benefits from the industries but at the cost of the poor workers who are most neglected.

Hazardous Products

During the last 50 years about 6 million chemicals have been synthesised at the rate of 10,000 new ones every month. Some 60,000–70,000 chemicals are used extensively in millions of different commercial products. The world produces chemicals—faster than it can manage.

These chemicals include extremely toxic substances which can cause allergies, damage vital organs of the human body like the eye, brain, liver, kidney and reproductive organs, produces deformities in babies during pregnancies of mothers and promote cancer. In case of accidental release into the environment in large quantities, as in case of Bhopal, they can lead to mass murder. What is amazing is that we know nothing about the toxic effect of 80 per cent of the chemicals used.

Industries which produce potentially toxic and hazardous wastes are pesticides, dyes and pigments, organic chemicals, fertilizers, non-ferrous metals, steel and chlor-alkali manufacturing plants.

The major locations of such industries are Delhi, Udaipur, Kanpur, Chandipur, Bokaro, Jamshedpur, Rourkela, Kolkata, Raipur, Ahmedabad, Baroda, Mumbai, Hyderabad, Visakhapatnam, Bangalore, Chennai and Cochin. Bhopal is not included in the list, which shows that unlisted factories can cause major disasters.

Phosphatic fertiliser factories and thermal power plants generate large quantities of conventional solid wastes which are stored near the sites. Some 5 million tons of by product phosphogypsum are generated at 12 major phosphatic fertiliser plants. 20 per cent of this waste is used to produce ammonium sulphate, while the rest containing thousands of tons of heavy metals and toxic metals such as chromium, copper, lead, manganese and fluorides are dumped into low lands for land filling or into lagoons in the form of slurry.

Table 9.1: List of Toxic Chemicals used in Industries

Name	***Uses***	***Hazards***
Arsenic	Pesticides/Unani medicines/glass	Toxic/dermatitis/muscular paralysis/ Damage to liver and kidney/Loss of hair/gangrene/cancer
Asbestos	Roofing/insulation/Air-conditioning roofs/plastics/fibre/paper	Carcinogenic to workers and family members
Benzene	Gasoline additive/Manufacture of many chemicals	Leukemia/chromosome damage
Beryllium	Aerospace industry/Ceramic parts/ House-hold appliances	Fatal lung disease/heart and lung toxicity
Cadmium	Electroplating/Plastics/Pigments/ Superphosphate fertilisers	Kidney damage/carcinogenic
Chlorinated Organics (DDT, BHC, etc.)	Pesticides/Fungicides	Nervous depression/carcinogenic
Chromates	Tanning/Paints/Pigments/Corrosion inhibitors/Fungicides	Skin ulcers/kidney inflammation/ carcinogenic
Lead	Pipes/Storage batteries/Paints/ Printing/Plastics/Gasoline additive	Neurotoxin/blood system and brain damage
Manganese	Mining/welding/dry cell battery/ Ferromanganese material (alloy)	Nerve damage/damage to reproductive system
Mercury	Chloralkai cells/Fungicides/ Pharmaceuticals	Nerve damage/kidney damage/fatal effect of alkyl mercury
Polychlorobiphenyls (PCB)	Transformers/insulation of electricity	Carcinogenic/nerve, skin and liver damage
Sulphur dioxide	Sugar industry	Irritation to eyes and respiratory system/damage to plants/damage to marble structures, monuments, etc.
Urea	Fertiliser	Bronchial problems/kidney damage
Vinyl chloride	Plastics/organic synthesis	Toxic/carcinogenic

Thermal power plants, which produce more than 50 per cent of electricity generated in India, are other major source: of solid wastes. Fly ash, the solid waste, accumulates in mountainous heaps near the power stations or carried as slurry into ponds and rivers where it creates serious water pollution problems. Fly ash itself contains toxic metals such as beryllium cadmium, zinc, arsenic, manganese, etc.

From pesticide industries some 15 tons of DDT and 25 ton of BHC (hexachlorobenzene) are carried as wastes every year which ultimately travel in the environment, enter our food chain and finally enter our body tissues where they are retained. Indians have shown maximum DDT content (25 ppm) in body tissues in the world. For the last 40 years DDT has been banned in the western countries but it is still being used as before in India.

Occupational Hazards

Workers in mines, factories, commercial firms, forestry an agriculture are exposed to risks, high to low, which are called the *occupational hazards.* According to the United Nations, some 2 lakh workers die each year throughout the world due to accidents and occupational diseases. Another 10 millions suffer from non-fatal injuries.

Deadly Dust

The worst occupational diseases are caused by dust. These are broadly termed lung diseases (pneumoconiosis) and their effect depends on the nature of dust, its fineness, concentration, period of exposure and the victim's health.

Silicosis

It originates from dust containing free silica or silicon dioxide. It was first reported in 1947 in India in the Kolar gold mines and then found to occur in various other mines and industries—coal, mica, silver, lead, zinc and manganese mines and pottery and ceramics, sand blasting, metal grinding, building construction, rock mining, iron and steel industry and others.

In Jharkhand's mica mines 33 per cent workers suffer from silicosis. The slate pencil factories in MP villages employ the entire village population where people do not survive beyond 40 years. Children have to work to support their mothers and often succumb early to the diseases. According to an NGO report, the workers 'sign their own death warrants for economic reasons'.

Asbestosis

Asbestos is the Greek expression for 'unquenchable'. Because of its versatility—it resists heat and moisture—it is largely used in home construction, insulation of buildings and ships and also in car brake linings. Besides it finds some 3,000 different industrial applications where it has to be processed into proper size. The finest fibres, invisible to the naked eye, are the most dangerous as they find ready access to our respiratory tract, line the air tubes and accumulate in the lungs.

The silica dust (from asbestos fibres), deposited in the lungs, causes pulmonary fibrosis leading to respiratory problems and death—in severe cases, it causes cancer of the air tubes and gastrointestinal tract. In UK people living within 1 km of an asbestors factory were reported to be suffering from cancer. What is really alarming is that cancer may strike 5–10 years after exposure.

Byssinosis

Some 2 million textile and cotton mill workers are victims of byssinosis. Cotton emits lot of dust in various stages of its processing. The disease strikes 10 years after exposure. It progresses step by step, starting from temporary sickness of wheezing and coughing to permanent breathlessness which shortens life span. Incidence to byssinosis from 6 to 20 per cent has been reported in cotton textile mills in Ahmedabad, Mumbai, Delhi, Kanpur, Chennai, Madurai and Nagpur.

Pneumoconiosis

It is commonly associated with mines and known as the source of 'black lungs'. Coal mine workers who are long exposed to coal dust lose their capacity to work hard and succumb to the disease which leads to tuberculosis and death.

Child Labourers

India has a bad image abroad for employing the largest number of child labourers (16–18 million/age group 8–14). The International Labour Organisation (ILO) reports that the child labourers are underpaid (Rs.2.00–6.00 per day) for 12–16 working hours and they have to toil under inhuman conditions. The brass industries of UP, carpet industries of Kashmir and match factories of Chennai employ most of the child labourers. The 'Sibkasi' match factories (in Chennai) employ some 50,000 children (8–12 years old), 80 per cent being girls, who work for 14 hours a day under inhuman conditions. Most of them are vulnerable to accidents and do not live beyond 40 years.

9.2 EPIDEMIOLOGY

Hippocrates' suggestion over 2000 years ago that environmental factors can influence the occurrence of disease is believed to be the origin of epidemiology. However, it was not until the middle of the 19th century that the distribution of disease in specific human population groups was measured to any great extent. The first epidemiological study was made by Snow in 1854. He identified that the risk of cholera in London was related, among other things, to the drinking water supply by a particular company in London. On the basis of epidemiological studies Snow suggested that cholera was spread by contaminated water.

Following Snow's work, public health measures, such as improving water supply and sanitation, have made notable contributions to the health of populations. Since 1854, epidemiological studies have provided the information required to identify the measures to be taken.

Epidemiology may be defined as the *study of the distribution and determinants of health-related states of events in specified populations and the application of this study to the control of health problems.*

Hygiene

Hygiene is closely related to epidemiology. It is defined as the science of health that includes all factors which contribute to healthy living. The purpose of hygiene is to allow man to live in healthy relationship with his environment.

Personal hygiene includes all those factors which influence the health and well-being of an individual. It comprises day-to-day activities for rigorously observing the elementary rules of hygiene for keeping ourselves physically fit and mentally alert through neat and clean habits as our way of life. Our daily routine should involve maintaining regular habits, e.g., taking meals at regular hours, body care (bath, wash, care of teeth, nails and hair, exercise, etc.), use of neat and clean dresses, work and sleep at fixed hours, etc. In other words, we should enforce strict discipline and hygiene in our daily lives. Any disruption of such activities will affect our health. For example, improper care or negligence of teeth leads to pyorrhoea and dental carries (cavities); dirty skin gives scabies, eczema, dermatitis and fungal infection; lack of sleep causes loss of concentration, mental depression and inability to work with vigour; dirty nails are home for ova of intestinal parasites, etc. The habit of washing hands with soap and water before eating will reduce the risks of diseases such as diarrhoea, dysentery, etc.

Health and Disease

According to the World Health Organisation (WHO), health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

Diseases are due to disturbances in the delicate balance between man and his environment. Three ecological factors are responsible for a disease—Agent, Host and Environment. The disease agent is identified in a laboratory. For example, hepatitis can be identified by the presence of anti-bodies in blood in a laboratory. The host (patient) is available for clinical examination. But the environment from which the patient comes is mostly unknown. The prevention and control of a disease depends on the knowledge of environment. Without the knowledge of environment, it is difficult to cure the disease.

Depending on the sources, diseases can be classified under the categories—(i) Water-borne disease, (ii) Air-borne disease, (iii) Food-borne disease and (iv) Vector-borne disease, which have water, air and food respectively as the sources for (i) and (iii). In vector-borne disease (iv), it is transmitted by various vectors such as mosquitoes, flies or animals. Various agency like viruses, bacteria, parasites are responsible for the diseases. Some common diseases are tabulated in Table 9.2.

Table 9.2: Some Common Diseases

Type	*Disease*
Water-borne disease	Cholera, Bacillary dysentery, Amoebiosis, Diarrhoea, Viral hepatitis, Poliomyletis, Typhoid, etc.
Air-borne disease	Influenza, Measles, Chicken Pox, Asthma, Bronchitis, Pheumonia, Tuberculosis etc.
Food-borne disease	Cholera, Dysentery, etc.
Vector-borne disease	Malaria, Filaria, Encephalitis, Dengue, Kalazar, etc.

9.3 VECTOR-BORNE DISEASES AND THEIR CONTROL

Malaria

Malaria (meaning bad air) was so named because of association of the disease with odour'ous air of swamps, particularly at night. Malaria results from dirty environment and it has been eradicated in most of the developed countries. However, it still exists in the developing countries, e.g. Africa, Brazil, Colombia, Afghanistan, India and Sri Lanka. Every year malaria affects 300–500 million people of the world and kills at least 2 million. In recent outbreaks in India it killed 2000 persons in Rajasthan (1994) and 1000 persons in Assam, Tripura and Bangladesh (1995).

Malaria is characterised by periodic paroxysms of fever, associated with shivering and terminating with sweating. It is caused by various species of parasites. *Plasmodium* and transmitted by the vector, *Anopheles* mosquitoes (female). The fever is usually intermittent with tertian (every third day) or quartan (every fourth day) periodicity, The fever may be occasionally remittent and rarely the disease may be steady throughout its course. There is anaemia and spleen enlargement among the sufferers. The characteristic symptoms appear when the parasites have reached a concentration of about 200 per mm^3 of blood or about 1 billion in the whole body. The fever attacks most commonly between midnight and noon, instead of in the evening. This helps in distinguishing malaria from other intermittent fevers.

The parasites which are responsible for malaria in man are four species of *PlasmodiumL* They are *P.vivax, P.falciparum, P.malariae and P.ovale. P.vivax* is the commonest and the most widely distributed species, prevalent in both tropical and temperate zones. It is the cause of "tertian" or "vivax" malaria. It has a 48 hour cycle of development in man and is particularly likely to cause relapses. *P.falciparum* is very prevalent in the tropics but does not thrive as far north *vivax* does. It has a 40-48 hour cycle of development and is the cause of "malignant tertian" or "falciparum" malaria. *P.malariae* is also widely distributed in both tropical and temperate climate but it is less common than *vivax* or *falciparum.* It is the cause of "quartan malaria". It has a 72 hour cycle. The fourth species, *"P.ovale"* is very rare.

Prevention of Malaria

The prevention of malaria requires community effort rather than individual effort. The discovery of DDT in 1939 by Paul Muller opened a new chapter in malaria control Malaria was identified in 1951 by WHO as a grave threat to public health and several malaria control projects were undertaken. By 1955 the number of cases all over the world dropped by about 33 per cent. Paul Muller was awarded the Nobel Prize for his contribution to eradication of Malaria.

In India, the National Malaria Control Programme was started in 1953. At that time the annual incidence of malaria cases was 75 million with about 1 million deaths-in 1976 there were 6.4 million cases with about 60 deaths. The Malaria Eradication Programme, launched in 1958 for eradication of malaria within ten years, was not successful. In 1977 the Modified Control Plan was initiated to prevent deaths due to malaria. Spray operations in infected area were done with DDT, malathion. As a result of spraying, mosquitoes die before transmitting the disease. Some mosquitoes live outdoors but they enter houses, bite the people and then run away. In such cases, the breeding grounds of mosquitoes (stagnant water, stored water outside houses) must be sprayed to kill the jarvae. Inside houses water must not be kept stored in open pots or containers where the mosquitoes can breed. Storage water tanks should be cleaned at regular intervals.

Treatment of Malaria

Quinine, an alkaloid, has been used as an effective drug for malaria for the last 300 years. Other anti-malalial drugs are-chloroquinine, camoquinine, primaquinine, etc. A synthetic vaccine against malaria was invented by a Colombian scientist, M.E. Patarroyo and was on trial in South America. Africa and South-East Asia.

Vector Control

The vector control measures are described under the respective diseases in this book (pp.117-118). Here the general outlines will be summarised. Three control methods are generally used–(i) destruction of adults, (ii) destruction of larvae and (iii) elimination of breeding places.

(i) *Destruction of adults: In* houses, schools, restaurants, etc. mosquitoes, flies and insects can be destroyed by means of 'aerosol bombs' from which DDT and oil dissolved in freon under pressure are released. The freon immediately, evaporates liberating the pesticides in minute particles (2-10µ). For continued protection residual sprays with DDT or other pesticides in suspensions or emulsions at the rate of 200 mg per sq. ft. are required.

(ii) *Destruction of larvae:* This can be achieved by the application of pesticides as sprays, dusts, granules of pellets for open water pots, cans, jars, etc. and by clearing of shrubs, floating vegetation in water bodies (ponds, etc.) so as to allow fish to eat the larvae. Lowering of water levels in reservoirs prevents breeding on water surfaces. When the water level is lowered, most of the larvae get stranded and die. Chlorinated insecticides (DDT, BHC, etc.) are used as larvicides.

Some fish can play important role in the control of mosquito larvae in natural water or pondss by eating the larvae. Where algae, weeds and debris are removed from water surface, fish can move freely and eat the larvae—in such cases spraying is unnecessary.

(iii) *Elimination of breeding places:* This is the permanent solution to mosquito control. Small pools of stagnant water must be eliminated and proper drainage system maintained so as to make it unsuitable for breeding. The Vector Control Research Centre at Pondichery undertook cleaning operation of water and sewer systems of Pondichery city in 1982–85. Sea water was used to flush 50 km. of previously clogged drains—mosquito eggs were killed stagnant water pools were filled in, fish were allowed to feed on insects; the single breeding ground was reclaimed and transformed into a public park. This operation killed 99 per cent of the mosquitoes and reduced significantly, the risk of transmission of diseases by the vector. The cost of the operation was not high. The Project shows that environmental control measures are very effective vector in control in India.

9.4 WATER-BORNE DISEASES

The names of common water-borne diseases are given in Table 9.2. The causative agents for water-borne diseases may be virus, bacteria, protozoa or helminths. The diseases like viral hepatitis (hepatitis A, hepatitis B), poliomyletis and diarrhoea are caused by virus. The diseases like cholera, bacillary dysentery, typhoid and paratyphoid are caused by bacteria and the diseases like amoebiosis, giardiasis are caused by protozoa. Some common water-borne diseases are discussed in detail in the following section.

Cholera

This is a highly contagious disease (water-borne and food-borne), caused by the bacteria; *Vibrio Cholerae.* Typical symptoms are diarrhoea with rice water stool, vomitting, rapid dehydration, muscular cramps and anuria. In severe case, acute renal failure is possible. Epidemics of cholera occurred in the past in India during Kumbha mela or Ardha Kumbha Melas. Outbreaks of cholera were also reported in the past from Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka, Bihar, Orissa and West Bengal.

The bacteriology of cholera is complicated. *Vibrio Eltor* replaced the classical *V.Cholrae* by the end of 1965. Most of the *Eltor Vibrios* isolated were found to belong to the serotype Ogawa. *V.Cholerae* is a gram-negative, coma-shaped actively motile organism. The *Eltor Vibrioes* resemble the true cholera vibrioes morphologically, serologically and also biochemically.

Factors for Spread of Cholera

Environmental Factors

Among environmental factors, water, food, and flies play important role in spreading cholera in the community. Cholera vibrioes do not multiply in water but they may survive up to two depending on temperature, pH, salt content, organic matter, sunlight and other factors. In our country there are a large number of uncontrolled water suppplies (e.g., polluted river, ponds, canals, etc.) which are major sources of cholera infection. Cholera vibrioes can multiply readily in certain foods and drinks like milk, milk products and some varieties of boiled rice. Fruits and vegetables get contaminated when washed or sprinkled with water from infected areas.

Social Factors

Big fairs like Kumbha Mela or Ardha Kumbha Mela where lakhs of people assemble at the river ghats in UP are the most important factor for the spread of cholera. The crowd bathe and drink the same river water (Ganga) and rapidly spread the disease. Cholera is a disease of the poor people who come from low income groups, live in slums under unhygienic and inhuman conditions. They participate in these melas and contaminate the river water.

Control of Cholera

The control of cholera can be achieved by early detection of the disease, isolation of the patients and their prompt treatment, improvement of sanitary facilities along with adequate supply of safe drinking water *to* the community. Active immunisation and health awareness are also important measures for cholera control.

For early detection, bacteriological examination of stools is required for confirmation of the disease. The disease should at once be notified to the local authority who will send the information to the State Health Authority and finally to the Central Health Authority.

The treatment of cholera consists of rehydration and antibiotics. Rehydration saves life. In case of kidney failure dialysis is required. The rehydration should be accomplished either by injecting intravenous solutions of saline (consisting of sodium chloride: sodium bicarbonate: potassium chloride = 5:4:1) or by giving oral fluid containing a mixture of sodium chloride, sodium bicarbonate, potassium chloride and glucose in the ratios of 3.5:2.5::1.5:20 gm. dissolved in 1 litre water. Tetracycline and co-trimoxozole should be administered as antibiotic.

Improvement of sanitation for the entire community and their residential area is the most effective approach for the prevention and control of cholera. Provision for sanitary latrine for every household is essential for checking the incidence of cholera. Water to be used for domestic purposes, viz. drinking, washing, cooking, cleaning utensils, etc., from sources such as rivers, ponds, lakes, canals, etc. should be boiled. The provision of safe drinking water for all is the permanent solution as it will minimise the incidence of cholera. It is also necessary to observe the rules of hygiene rigorously-household pests-flies, cockroaches, etc. should be eliminated; cut fruits and vegetables which are exposed to dust and flies in open markets should be avoided.

Amoebiasis

This is a water-borne disease, defined by WHO as the condition of harbouring *Entamoeba histolytica* with or without clinical manifestations. It has world-wide distribution. The disease is characterised by liquid stools with mucous and blood.

E.histolytica are found as cysts or motile trophozoites. They can live outside the human body as cysts. Trophozoites cause ulcer in the large intestine. Some amoebas reach liver through portal vein any may cause hepatitis or abscess. Intestinal and hepatic amoebiasis are the main manifestations of the disease.

The cysts can live for several weeks outside the human body, if kept moist and cool In a refrigerator they can live in water for 6-7 weeks. They do not survive at moderate temperature, e.g., 50° C.

Man gets the infection through food chain (cut fruits, salads, vegetables, contaminated drinking water, cold drink, etc.). Uncooked food and vegetable can be disinfected by washing with iodine solution (200 ppm) or acetic acid (5–10 per cent) or vinegar. From water cysts can be removed by filtration and boiling. The cysts can be killed in milk by pasteurisation. The diagnosis is usually based on the detection of *Entamoeba histolytica* in the stools.

The antibody of the parasite can be easily detected by Immuno-fluoresecence method.

Prevention of Amoebiasis

The disease can be prevented by (i) sanitary disposal of human excreta; (ii) provision of safe drinking water to all (water should be boiled and filtered before drinking); (iii) hygienic kitchen practice (uncooked fruits and vegetables must be thoroughly washed or disinfected as described before, (iv) protection of foods against flies.

Treatment

The drugs usually prescribed by physicians are:

1. Metronidazole (400-800 mg) (Flagyl) to be taken one tablet thrice a day for 5-7 days.
2. Entrozyme (250 mg)—one tablet thrice a day for 7 days.
3. Trinidazole(1-2 gm)—one tablet for 3 days.
4. Furamide (500 mg)—one tablet thrice a day for 10 days.

9.5 PEST CONTROL AND MANAGEMENT (IPM) IN AGRICULTURE

In an agricultural field crops are susceptible to attack by insects, nematodes, pathogens, mites, birds and mammals which together form a complicated interacting *pest complex.* The control of a pest complex requires careful assessment of the pests and integration of several methods for control/management (Integrated Pest Management, IPM).

9.5.1 Pesticides

In the early period of human civilisation it was realised that pests harm crops and transmit diseases to both animals and men. The first use of chemicals to kill pests was in 70 AD when arsenic was recommended to kill insects. In the 16th century, the Chinese used arsenic sulphide as an insecticide. During the 20th century lead arsenate was used as insecticide. Paris green (copper acetoarsenite) was used extensively in pools in the tropics for controlling malaria transmitting mosquitoes. However, it is known that arsenical pesticides can persist in the soil for years and damage crops.

Pesticide is the general term for insecticides, rodenticides, molluscides, herbicides, fungicides, etc. The era of synthetic organic pesticides started around 1940. At present there are more than 10,000 different pesticides. They are classified as:

Insecticides	Organophosphorus group (e.g., malathion); Organochlorine group (e.g., DDT); Carbamate group (e.g., Carbaryl)
Herbicides (designed to kill weeds or undesirable vegetation)	Chlorophenoxy acid group
Fungicides (designed to kill fungi and disease)	Dithiocarbamate group; Organometallic group (e.g., phenyl mercury acetate)

The uses of pesticides helped in the eradication of diseases such as malaria (by DDT) and typhus and also in boosting crop production. About 0.1 per cent of the total insects (500) out.

Questions

1. List some public health/issues arising from environmental pollution.
2. Give an account of hazardous products from
   (i) fertilizer factories
   (ii) thermal power plants and
   (iii) pesticide factories

3. What is meant by ‘Occupational Hazards’? Give examples.
4. Write notes on:
   (a) Asbestosis
   (b) Silicosis
   (c) Byssinosis and
   (d) Pneumoconiosis
5. What is ‘Epidemiology’? How is it related to hygiene? Illustrate with examples.
6. Name some water-borne and air-borne diseases.

10 Environment Conservation and Management

10.1 RESOURCES—CLASSIFICATION

Resource is defined as *a form of matter and energy which is essential for the functioning of organisms*, *populations and ecosystems*. Man depends on the resources for his day-to-day living. These resources are air, water, soil, forests, vegetables, milk, fish, animals, energy (fossil fuels, solar power etc.) etc.

Man himself constitutes an important resource viz., human resource. Human resource development through education, skill and knowledge has now been given top priority in national policy since it is an index of the development status of a country. This has been exphasized by the United Nations Development Programme (UNDP).

Classification

The resources are classified as Renewable and Non-renewable or Conventional and Non-conventional.

Renewable Resources

These are exhausted within a limited period but can be regenerated and used again i.e., recycled. Examples are: forests, plants, water, solar energy etc. Forests are renewable resources since after felling of trees for wood, fuel etc., they can be recovered by fresh plantation (afforestation).

Non-renewable Resources

These cannot be renewed after being exhausted. Examples are: fossil fuel (coal, petroleum), natural gas and mineral. All these took thousands of years for their formation under the earth's surface. For example 100-million year old coal deposits can be burnt to carbon dioxide in a matter of a few seconds by power plants. But by no means coal can be restored or renewed. Non-renewable resources get exhausted due to over-exploitation by man and then they can neither be regenerated or renewed.

10.2 NATURAL RESOURCES—USES AND ABUSES

10.2.1 Mineral Resources

Mining and processing of minerals involve environmental problems such as disturbance of land, air pollution from dust and smelter emission as well as water pollution from disrupted aquifiers.

The rate of depletion of mineral resources is measured by two parameters—per capita mining and per capita consumption.

Per capita mining is calculated by dividing the amount of resource mined by the population. *Per capita consumption* is obtained by dividing the resource amount by the population.

It is known from the world per capita mining figures that five minerals are mined to the maximum extent—coal, petroleum, iron ore, aluminium and phosphate rock. The demand on natural resources varies from Asian to American continent. USA imports substantial quantities of mineral resources so that its per capita consumption exceeds its per capita mining figure.

The major non-metal resources include asbestos, carbonates, chlorine, granite, oxygen, phosphate, sand etc. Asbestos, sand, gravel and calcium carbonate together with granite constitute the common and most widely used building materials. Chlorine, magnesium, sodium chloride are the major representatives of the group of resources with a vast reserve viz., the oceans.

10.2.2 Land Resources

Land is used for many purposes—construction of houses and buildings, roads, railway lines, airports, agriculture, grazing of cattle, setting up of industries etc.

In India the total available land is about 300 million hectares. It is, however, a fixed asset. As a result of our population explosion, we possess the lowest man: land ratio, barely 0.50 hectare per capita due to use and abuse over the centuries.

The percentage break-up of land use pattern in our country is:

(i) Waste land 24%

(ii) Pasture land 4%

(iii) Forest land 21% and

(iv) Agricultural land 51%

Considering the size of India, available pasture land is insignificant while forest land has been reduced due to conversion of forests into agricultural land and also for housing, roads, industries etc.

10.2.3 Soil Resources

We depend on soil for our daily food and also for meeting our needs for fibre, timber, firewood etc. Hence, soil is indeed an important resource. But this is getting depleted mostly due to erosion and degradation. Large scale deforestation and intensive grazing of grassland have exposed the soil to the weathering forces—water and wind. Apart from these, the prevailing practice of jhum cultivation in the N.E. region, canal irrigation, road construction and surface mining also favour soil erosion. Top soil (most fertile zone) is lost as a result of soil erosion leading to loss of soil productivity. It is estimated that every year 25 billion tons of top soil are lost from farm land by erosion. In India about 80 million hectares of cultivated land is subjected to severe erosion and about 30 per cent of the total eroded soil is permanently lost to the sea. This is critical issue as it affects our survival in terms of supply of food, fodder, fuel and daily necessities.

10.2.4 Wildlife Resources

The bounties of Nature include wonderful variety of flora and fauna with their habitats in different types of forests but deforestation has destroyed their habitats in the past whereby many plants and animals are on the way to extinction.

Wildlife population has been considerably depleted because of reckless hunting of animals and birds for food, furs, feathers, skin, tusks etc., since the 1950s. Thus out of 65,000 species of animals, almost 600 have been identified as endangered species. We also have lost many species of colourful birds out of a total number of 1200. This wave of man-made extinction has already upset the ecological balance in the environment and badly damaged India’s economy.

10.2.5 Fish Resources

Fresh and marine waters provide fish, an important renewable resource. It is a well-known food item with rich protein content. Fish oil is a useful tonic and fish residues are used as fertilizers. People in developing countries cannot afford meat for their diet and so they depend on fishes the only source of animal protein in their diet. In the earlier days fish was used on a small scale but now with population explosion, it has been transformed into a large scale industry. There are abundant fish resource in the country with about 30,000 species of fish.

But in recent years fish resources, as a whole, have been hit by increasing water pollution. This has caused fish scarcity in general.

Over-consumption and over-fishing have turned fish like halibut and salmon into endangered species. World-wise annual catch of fish is about 8.5 crore metric tons. The major fishing grounds are the North Coast of USA (the Grand Banks) and North Sea (Dogger Banks)—these centers conduct major trade in fish products. Japan and Norway are the principal fishing nations in the world. Japan is in the forefront accounting for 26.5 per cent of the total global catch. In India fishing is done in inland water—rivers, lakes, ponds etc., to satisfy the requirements for local consumption. Marine fishing is practised in coastal areas but is handicapped due to shortage of modern equipments like trawlers and large ships and also lack of training and facilities.

Recently the government is paying attention to the development of pisciculture or fish culture by setting up fisheries in lakes, ponds and rivers. It is necessary to control over-fishing and water pollution.

10.2.6 Agricultural Resources

From ancient times India has been predominantly an agricultural country. Hence agriculture is the pillar of Indian economy. Agricultural resources are man-made using land, soil and water as the basic resources. Production of a variety of crops provide us with our staple food and fruits. Food crops are wheat, paddy, maize and barley. Fruit trees yield mango, banana, coconut, orange, apple, grape etc. In addition to these there are plantation crops such as tea, coffee and rubber; fibre crops such as cotton, jute and commercial crops such as tobacco, sugarcane, sugar, beet etc. Each crop needs specific type of soil, climate and environment for its cultivation.

At present agriculture in India involves about 70 per cent of people and 47 per cent of land area of the country (c.f. USA twice the size of India and less than half the population engages 2.4 per cent of people and 20 per cent cropland). Our production of food grain has gone up from 50 metric tones (Mt) (1950–51) to 155 Mt in 1984–85 and 250 Mt in 2000 A.D. The production is about three times the soil capacity (75 Mt). This has been possible with the application of advance technology of high input-high output i.e., use of high-yield variety of seed, increased amounts of fertilizers and pesticides and extensive irrigation resulting in **Green Revolution**. Punjab and Haryana are the leading beneficiaries of Green Revolution with record production of wheat.

However, this western model of high-input high-output agriculture, inspite of paying rich dividends in terms of production and making the country self-sufficient in food production, has brought in its trail a downward trend since the last decade. The latter is due to loss of fertility of soil, loss of top soil, soil degradation, depleting groundwater reserve as a result of heavy withdrawal for irrigation, increased surface water pollution etc.

The present crisis facing the agriculture front can be overcome with the help of advanced techniques e.g., organic farming, biotechnology, less use of chemical fertilizers and pesticides etc. As a matter of policy, deforestation should be minimized, afforestation should be enhanced, population time bomb should be diffused while over-consumption of food and agricultural crops should be kept under control. This will help in bridging the gap between agricultural yield and its potential yield and demand for food by increasing population.

10.2.7 Animal Resources

Domesticated animals providing us with meat and milk products (animal protein) are known as animal resources. They supplement our food from agriculture. They also supply us with out requirements for wool, hides and skin.

In India animal breeding and rearing have not received much attention and have not been commercially developed. Animals are used to supplement human labour for agriculture. For example, cattle and buffaloes are used for ploughing, drawing water from wells and pulling carts. This is an unfortunate abuse of animal resource. India happens to have the largest cattle population in the world but due to negligence and misuse, milk yield is poor on an average and is not available to the poor sections of the population. The net result is that poor children are denied milk supply and suffer from mal-nutrition.

However, in urban centers dairy units have been set up to supply dairy milk, butter, cheese and milk powder to the urban population from their commercial centers in Gujarat and Maharashtra. Networks of Mother Dairy and Metro Dairy products have dominated the market (urban).

10.2.8 Water Resources

"*One can live several weeks without food, several days without water but only a few minutes without air*."

Like air, water is an essential constituent of the life-support system. India is blessed with good rainfall, about 200 cm. per year. The quantum of water is about 6 trillion m^3 which is among the largest in the world for a country of comparable size. But due to wastage and inefficient water management along with unequal distribution of rainfall, a large part of the country suffers from water scarcity while during the dry months even place like Cherrapunji in Meghalaya with heaviest rainfall in the world (1200 cm) experiences water shortage. Again during rainy season surface water from rivers runs off rapidly causing floods in Assam, W. Bengal and Bihar.

Among the major consumers of water, is the agricultural sector. Table 10.1 shows that irrigation (inclusive of livestock) and power use 79.6 per cent and 13.7 per cent water respectively, followed by domestic (3.6 per cent) and industrial (3.2 per cent) consumption.

With increasing population, the demands of water from each sector will also increase further (at least by 25 per cent by 2025 A.D.). Moreover, surface water pollution is likely to increase within the same period. These will put severe constraint on water resource in near future. At present 480 million of India's 1 billion people do not get safe drinking water. Only a sound water Resource Management Policy can save India in the foreseeable future.

Table 10.1: Water Consumption in India (2000 A.D.)
(Available water is 1900 million m^3 per year)

Uses	*Input*	*Consumed (in 100 million m^3/year)*	*Unutilised*
Irrigation and Livestock	869	783	86
Power	150	5	145
Industry	35	10	25
Domestic	38	8	30
Total	1092	806	286

10.2.9 Forest Resources

Forests are valuable renewable resource for a country. They are closely related to vegetation, grassland and wild life resources. They have contributed substantially to the economic development of the country by providing goods and services to the people and industries. Furthermore, they play a very major role in enhancing the quality of environment by influencing the life support system. Forests are also linked with our culture. As a matter of fact, Indian philosophy and religion grew up under the guidance of our *rishis* in the forests in total communion with Nature.

India has 64 million hectares of forest land out of a total geographical area of 329 million hectares. It is on record that the country had 80 per cent forest cover 5000 years ago which has now been reduced barely to 21 per cent. Per capita forest land is 0.1 hectare compared to the world average of 1 hectare. This shows the poorest record of India. We are losing 1.3 million hectares of forest cover every year and at this rate of deforestation we are likely to lose all the forest cover and face total disaster within the next 25 years.

During 1951–2000 i.e., almost 50 years after Independence, India witnessed maximum loss of forests, namely, 6.0 million hectares of forest area. This overconsumption has been due to population explosion (both human and livestock population) accompanied by rapid urbanization and industrialization as well as change of life style. There has been tremendous pressure on forest systems to meet ever-increasing demands on fuel or fire wood, timber and pulp wood for housing, furniture, agricultural implements, railway slippers, sports goods, ship and boat building, paper and pulp industries etc. Annual consumption of fire wood in the country is about 170 million tons while 10–15 hectares of forest cover is destroyed each year to meet fuel requirements. The consumption of fire wood is 80 per cent in villages and 20 per cent in urban areas. There is a shortfall of about 195 million m^3 in the demand and supply of fuel wood. Similarly, the gap for timber between demand and supply is about 15 million m^3. Because of the importance of timber, India has started importing timber from other countries.

The use of wood and its requirement are tabulated on next page:

Table 10.2: Use of Wood

Region	*Total wood consumption (billion m^3)*	*Wood use %*	
		Industrial	*Fuelwood*
World	3.2	46	54
Developing countries	1.8	18	82
Developed countries	1.4	84	16

Deforestation has not only brought about environmental disaster along with loss of economic benefits. The disaster includes increased carbon dioxide content in the atmosphere and hence increases Greenhouse Effect, soil erosion, drought and flood, loss of habitats of wild birds and animals and also loss of valuable species including medicinal plants.

Table 10.3: Requirement of Wood (in Metric Ton)

Unutilised	*Requirement (1980)*		*Requirement (2000)*		*Addl. Requirement*	
	m^3	*% of total*	*m^3*	*% of total*	*m^3*	*% of increase*
Fuel Wood	188.6	87.5	225	78	36.4	10
Timber	22.7	10.5	46.8	16	24	106
Pulb Wood	4.2	2.0	17.7	6	13.5	323

Source: FAO Year Book of Forests (1981).

As forests are renewable resources, priority should be given to afforestation i.e., plantation of new trees to make up the loss due to deforestation. The regeneration cycle of forests can vary widely in different climatic regions from 15 to 80 years. Afforestation is intended to ease the present pressure on forest resources and sustain the environment. It is also essential to control utilization and consumption of forest wealth.

10.3 ENERGY RESOURCES

10.3.1 Conventional Energy Resources

The demands on energy are increasing with progress in human civilization. The quality of life or standard of living is linked with the quantum of energy consumption. In USA per capita energy consumption is 200 million British thermal units, BTU (1 BTU = energy required to raise the temperature of 1 lb. of water by 1°F), 125 million BTU in UK, 50 million BTU in Japan and only 5 million BTU in India. But generally much of the energy (about 60 per cent) is wasted. Maximum wastage is observed in power plants and vehicles.

The conventional energy resources are fossil fuel (coal petroleum and diesel), wood, natural gas, hydroelectricity and nuclear energy. The energy, as consumed by man, is 33 per cent from petroleum and diesel, 27 per cent from coal and 5 per cent from nuclear fuels.

Coal

Coal is substantially more abundant than oil or gas, the total reservoir being 7×10^{12} metric tons which is equivalent to 5×10^{22} calories. This is 1000 times more than the total global energy consumption from all fuels. The stock of coal is likely to last several centuries.

The natural defect of coal is that it is a dirty fuel to burn. On combustion, it emits sulphur dioxide which is an offensive gas which forms sulphuric acid in air and causes acid rain in far away places. Thus, it poses environmental hazards (*see* acid rain in previous chapter). Excavation of coal from mines is followed by soil subsidence (depression) which endangers the residential areas above the coal mines. Moreover, fly ash arising from combustion of coal is a nuisance as solid waste which brings about environmental problems. Also being a solid, coal is less convenient to handle than petroleum or natural gas.

In order to overcome these problems, the developed countries use less polluting forms of coal by transforming it into gaseous, liquid or low sulphur, low ash solid fuel. In a typical case, high grade ash-free coal is produced as solvent-refined coal (SRC) by suspending pulverized coal in a solvent and treating with 2 per cent of its weight of hydrogen at a pressure of 1000 pounds per sq. inch and 450°C. The product is a semisolid, m.p. 170°C having a calorific value of 16,000 BTU per pound. This compares well with the best grade anthracite coal.

Methanol, CH_3OH

It is a convenient liquid fuel which can be produced from coal. On a commercial scale, it is produced by the reaction of carbon monoxide, CO and hydrogen, H_2 at 50 atmosphers pressure and 250°C in presence of copper-based catalyst. The reactant (CO and H_2) are obtained from coal, oxygen and steam:

$$CO + 2H_2 \longrightarrow \underset{\text{(methanol)}}{CH_3OH}$$

15 per cent methanol makes an excellent additive to gasoline which improves fuel economy and also cuts down the emission of practically all automotive pollutants.

Petroleum or Mineral Oil

The consumption of petroleum and natural gas is maximum in the developed countries and has become the status symbol of a country. USA is the largest consumer of petroleum in the world (about 80 per cent of total energy consumption in USA).

The Industrial Revolution (1780) was initially fuelled by coal but later on preference was given to oil and gas which provide cleaner fuels and easy transportation. The world reserve of petroleum is about 800 billion barrels (1 barrel = 31.5 gallons = 120 litres) which will last for less than 100 years.

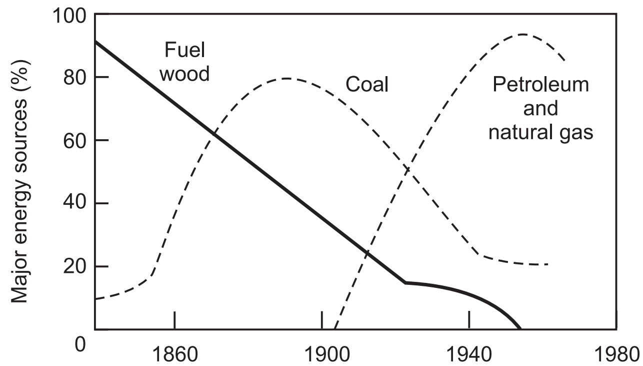


Fig. 10.1: Energy consumption patterns in USA

Hydroelectricity

The output from hydroelectricity (electricity from water) accounts for 21 per cent of total electricity generation, which is less than that from thermal power but greater than that from nuclear power. In Venezuela, South America 10,000 megawatts of hydroelectricity are produced which are equivalent to the production of electricity from 10 thermal power plants. In India, if water resources are properly utilised, it may be possible to generate more than 10,000 megawatts of electricity. But at present only 16 per cent or 6,500 megawatts of hydroelectricity are generated.

For generation of electricity from **hydel project** it is necessary to utilise energy produced from the descent of water from higher to lower level. In practice, a water reservoir is constructed by means of dam in a river for storage of water. Subsequently the stored water is released from upper level into a water-driven turbine placed at a lower level (Fig. 10.2) whereby electricity is generated. The Hydel Projects of Maithon, Panchyet and Jaldhaka are typical examples.

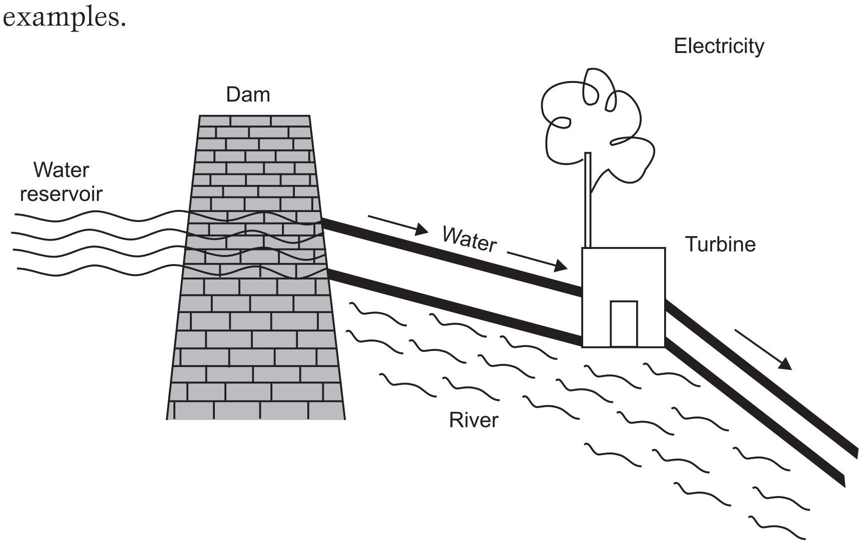


Fig. 10.2: Hydroelectricity from hydel project

The merits of hydroelectricity are: (1) clean source of energy; (2) no emission of greenhouse gases; (3) no consumption of fuel; (4) no need of high technology. But there are several environmental issues—flora and fauna in the region are disturbed due to construction of dam; local people become refugees as they are uprooted from their houses; the capacity of the reservoir gets reduced due to siltation; occurrence of floods in the area when surplus water has to be discharged in monsoon season. Hydroelectric dams are costly and take a long time for construction. In order to make Hydroelectricity generation viable, it is necessary to adopt a long-term programme of afforestation, environmental conservation, housing, public health and transport and ensure close co-ordination among these departments.

Nuclear Power

It contributes only 5 per cent of total electricity generation. Nuclear power plants do not emit polluting gases such as carbon dioxide, sulphur dioxide like thermal power plants. But they have some severe drawbacks, viz., they are costly and they release large quantities of radioactive fission products.

The radioactive wastes remain lethal (deadly) for thousands of years and for this no foolproof disposal method has been devised. That is why big nuclear power projects have not succeeded in the long run.

In India the production target was fixed at 10,000 megawatts by 2000 A.D., but the actual production is much less in the nuclear power stations at Tarapur, Rajasthan and Chennai. Nuclear power plants cannot match thermal power plants at present but in future, its unlimited resources will allow it to dominate the energy scenario when other energy resources are exhausted.

At present nuclear fission is used to produce nuclear power. Heavy large atoms like Uranium and Plutonium split up into smaller atoms when bombarded by neutrons (nuclear particles with mass 1 and zero charge). This splitting or fission liberates vast amounts of energy, which through conventional techniques is converted into electricity. Thus nuclear power is generated.

It has been calculated that 1 kg of Uranium–235 on a complete fission by slow neutrons releases energy equal to 1.7×10^{13} calories. This means energy-wise, 1 lb. of Uranium–235 $\equiv$ 5 million lbs. of coal $\equiv$ 20 million lbs. of T.N.T (highly explosive, chemical).

This is the secret of nuclear energy/power.

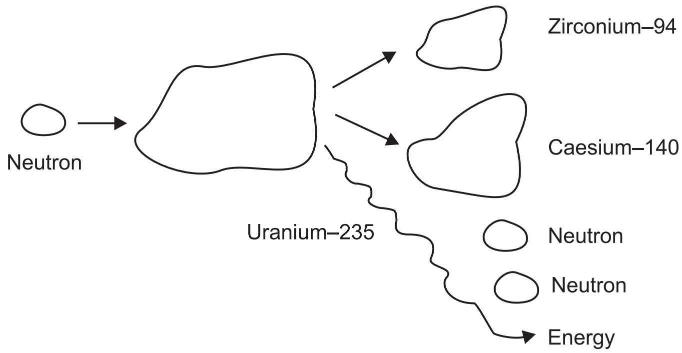


Fig. 10.3: Nuclear fission

Wood

Wood is a major renewable natural resource. The major important products are wood, paper, cellophane, rayon, plywood, plastic, particle board, turpentine, methanol, etc. In USA the production of wood and wood products is the fifth largest industry. Ideally, as in USA forests cover 38 per cent of the total land area; in India it has come down to about 15 per cent at present from 80 per cent, two thousand years ago.

It is interesting to compare between India and USA in respect of deforestation. In USA the Sunday issue of the leading newspaper, New York Times consisting of 500 pages requires 25 hectares (1 hectare = 2.5 acres = 7.5 bighas) of forest. According to an estimate, an American destroys as much forest for his needs for paper as an Indian for his domestic fuel. The value of a 50-year old tree has been estimated as about more than Rs. 20 lakhs—the various functions of a 50-year old tree are roughly evaluated as follows:

(i)	Oxygen production (for 50 years)	Rs. 2,50,000
(ii)	Transformation into protein	Rs. 20,000
(iii)	Control of soil erosion and soil fertility	Rs. 2,50,000
(iv)	Recycling of water and control of humidity and atmospheric temperature	Rs. 2,50,000
(v)	Habitat for birds and other animals and insects, etc.	Rs. 2,50,000
(vi)	Control of air and heat pollution	Rs. 5,00,000
	Total	Rs.15,20,000

This estimate excludes the value of timber/wood for furniture, fuels, medicines, etc. which will be an extra Rs. 3–4 lakhs.

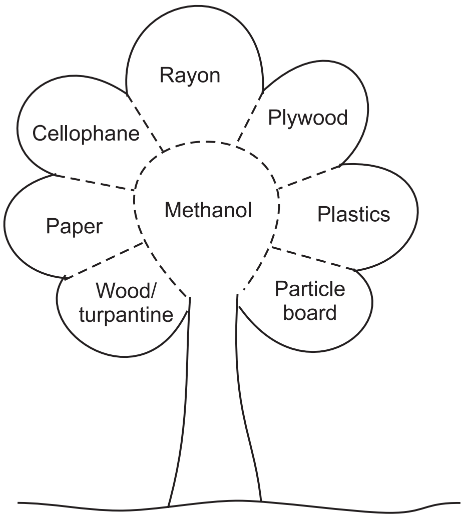


Fig. 10.4: Trees—Sources of many important products

Thus the tree, with its 50-year services as above, costs about Rs. 20 lakhs (1980 estimate) which at present market prices, will be around Rs. 40 lakhs. The public should be made aware of the value of a tree and its services to man and environment during its life time.

In India 76 per cent of population lives in villages—almost all of them use wood as fuel for cooking. This is the main reason for extensive deforestation in rural areas: each year we are losing about 1.3 million hectares forests. Deforestation helps increase in greenhouse gas, carbon dioxide concentration. Hence for the welfare of the country as a whole, it is essential to minimise deforestation by adopting alternative resources of afforestation on a large scale to meet the needs of domestic fuel.

Natural Gas

It is better fossil fuel than coal and petroleum since on burning, it produces less carbon dioxide. For production of one unit of energy, mineral oil, coal and wood, on burning, produces 35 per cent, 75 per cent and 80–90 per cent more carbon dioxide than natural gas. Hence natural gas is the obvious choice as a cleaner fuel. Its reserve, however, are limited and can continue to feed only for the next 70–80 years. At present, in India the exploitable reserve of natural gas is about 700 billion cubic metres.

10.3.2 Non-Conventional Energy Resources

Solar Energy

India, being a tropical country, is blessed with abundant sunshine, 2,000 kilowatt hour/ sq. metre (kWh/m^2) per year for about 200–300 days in a year. The daily sunshine is between

5–7 kWh/m^2. This is an enormous and model energy resource, which is clean, pollution-free and inexpensive. It requires to be converted into other forms of energy by suitable techniques—it can meet our energy demands for ever. The solar energy, incident on earth in one week, is equivalent to the energy from the entire coal reserve of the world. Again the solar energy available on earth for 45 minutes is enough to meet our energy demand for one year.

However, the major problem is that sunlight is diffuse (widespread) in nature and difficult to be stored and utilized. But with advance technology, the present high costs may be cut down so that solar energy can be utilized on a large scale in future. At present, solar energy is ten times more expensive than thermal power. But with advance technology, it will be cheaper and hold the key to meet our energy demands in future.

Sunlight may be directly converted into electricity through photovoltaic cell. The latter is a device for conversion of light energy into electrical energy. The efficiency of conversion of light into electricity is only 18 per cent and it is expensive at current prices. We can use solar energy in two ways: (1) use of solar heat and (2) use of solar electricity. Use of the former permits one to boil water or dry foodgrains. Accordingly, several gadgets have been produced such as solar cooker (for cooking), solar dryer (for drying grains), solar water heater (for heating water), solar distillation (for water purification), etc. Recently there have been extensive use of these solar equipments in rural and semi-urban areas. By using the second method, i.e., solar cell, sunrays are converted into electricity. Since these solar cells are made of silicon, these are called silicon cells.

The advantages of solar photovoltaics are that they can replace systems which use diesel and they are free from chemical and noise pollution. They could be installed in remote areas in forests and deserts where installation of electric cables are cost-prohibitive.

Solar power, with government subsidy (Department of Non-conventional Energy Source, DNES, Government of India) is being used in remote rural areas in West Bengal in the forms of solar lanterns, solar streetlight and solar pump (for irrigation). Solar powered small pumps are being used in Delhi, Haryana and Himachal Pradesh. It is desirable to use solar cookers in villages on a large scale so that extensive deforestation can be prevented. About 1 ton of wood per head per year can be saved by this process.

Figure 10.5 illustrates a detailed design for a solar heated house during winter in developed countries like USA. In these countries 20–25 per cent of fuel is consumed for providing hot water to houses and buildings. Sunlight is collected on plates in the roof and the heat transferred to a circulating water system. An average house with roof area about 1300 sq. ft. in central USA can get its energy supply for heating and hot water supply in December by this method. This may well apply to hill station houses in India in Jammu and Kashmir, Nainital, Mussorie, Darjeeling, etc., in December-January.

Figure 10.6 illustrates the function of a **solar** cell. Light is absorbed in a plate, with the generation of positive and negative charges, which are collected at the electrodes on either side. The silicon solar cell, developed for space programmes, consists of a sandwich of a *n*-type and *p*-type silicon semiconductors (e.g., silicon, germanium is a crystalline substance which is intermediate between a metallic conductor on one hand and non-conducting insulator on the other)—the charge separation is developed across the junction between them. *p*-type silicon conducts positive charge while *n*-type silicon conducts negative charge. The silicon cell produces electricity but is quite expensive since very high-grade crystalline silicon is required for the cell.

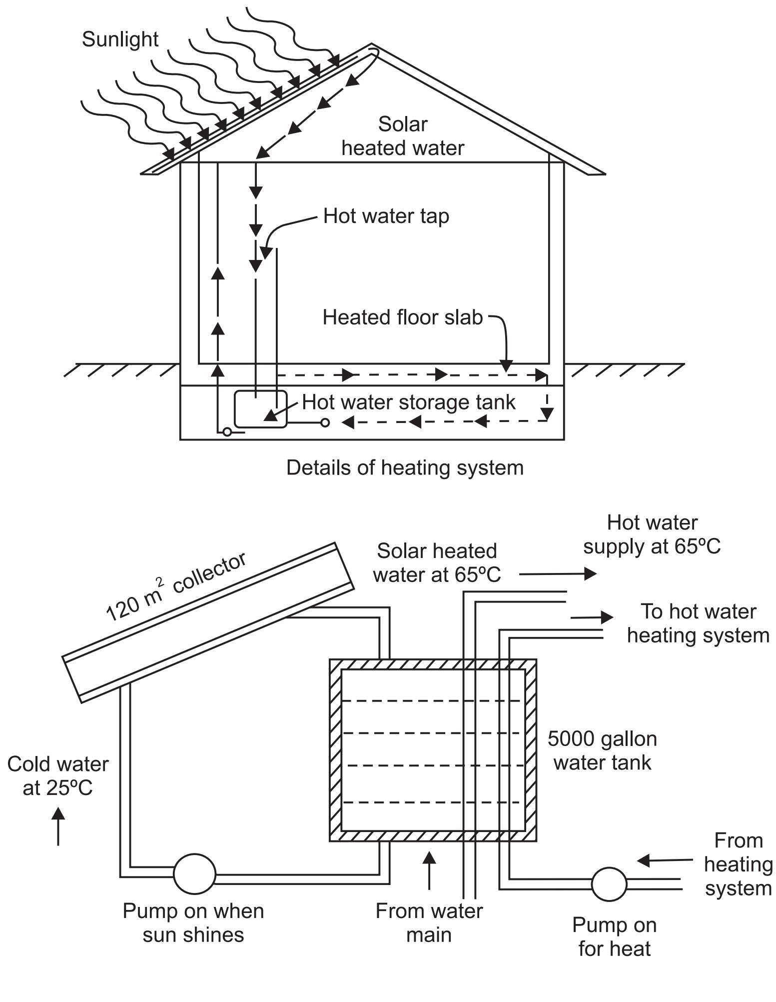


Fig. 10.5: Solar heated house

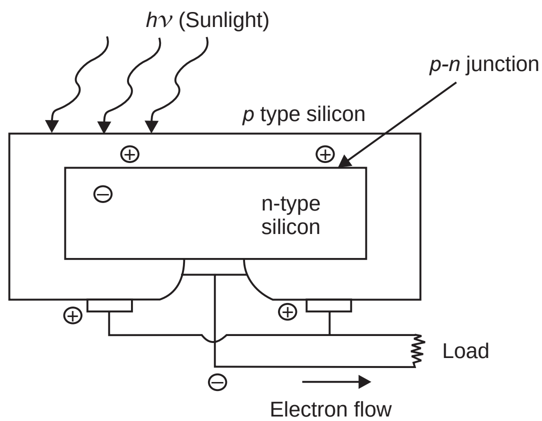


Fig. 10.6: Solar cell for electricity generation

Biogas

This offers an important solution to the present energy crisis in rural areas. Besides being an important domestic energy source, it offers an environmentally clean technology. There is a vast reserve of biogas in Indian villages. It is estimated that 1000 million tons of animal dung per year is available from 250 million cattle population. On an average 10 kg of wet dung is available per animal per day, which at 66 per cent collection efficiency, can yield 22,500 million cubic meters of biogas through biogas plants. This can replace kerosene oil whereby 14,000 million litres of kerosene per year can be saved in villages. Besides biogas slurries can produce 200 million tons of organic manure per year which can be good substitute for chemical fertilisers for agriculture.

The composition of the biogas is: methane, carbon dioxide, hydrogen and nitrogen. The proportion of methane and carbon dioxide varies considerably as does the calorific value. At 40 per cent methane content, the calorific value is 3200 kcal/cubic metre, while at 50 per cent it is 4500 kcal/cubic metre.

Wind Energy

This is a cheap and clean energy resource. India, with its climatic diversity, has areas which are quite windy. According to the Indian Meteorological Department, average annual wind velocity of 6.5 metres per second at a number of places in peninsular India as also along coastlines in Gujarat, Western Ghats and parts of Central India. Such velocities are available for 6-7 months in a year.

There are some limitations for setting up of wind power mills or wind mills. They require locations where the wind velocity is at least 6.5 metres per second. In Denmark and Holland there are rows of wind mills in extensive areas and these generate 50 megawatts of electricity. A standard wind mill produces 55 kilowatts of electricity daily. Windmills spread over extensive areas on sea shore or very high site present a beautiful scenario. Windmills prevent earthquakes where continuous wind flow causes soil erosion. In Scotland, Wales, Sweden, Germany and USA many wind mills have been constructed for cheap generation of electricity.

The technology for harnessing wind energy has become commercial in some developed countries but in India it is still in the preliminary stage. The Department of Non-conventional Energy Sources, Government of India has installed several wind pumps with pumping capacity of 20 metres. A wind mill with a capacity to pump 400 litres of water per hour at a pumping head of 19 metres has been installed. Prospective sites are in Gujarat and Orissa on the sea coast. A 100 km stretch of coast in areas having wind speed of 10 km/hour from sea would lead to an installed capacity of 5000 megawatts. Wind energy can be used advantageously in remote rural areas and would help in saving fossil fuels.

Ocean and Tidal Energy

Ocean waves splash on ocean shores at tremendous speed—the mechanical energy in this process can be harnessed and converted into electrical energy. It has been found that in the middle of North Atlantic Ocean each wave per 1 metre height can generate 90 kW electricity whereas on the oceanshore the waves can generate 25–70 kW. During storm the generation level can rise up to 5 megawatts. Lot of research is on in this area in U.K., Canada, Norway and Japan.

In a large chamber the sea water is enclosed by oscillating water column method. Ocean/sea wave enters the chamber through an inlet pipe and forces the enclosed water upward at terrific speed—it will exert hydraulic pressure on enclosed air which in turn can rotate a turbine. Such method is expensive at present but it has immense potential which can be exploited in future with advance technology.

Tidal Wave

Tidal wave can also be tapped for generating electricity. During flow tide sea water enters river—it is possible to store such sea water in a big tank and rotate turbines by the mechanical force in the process and generate electricity. It is necessary that about 3–5 meters high sea water through flow tide enters the chamber. USSR (now CIS) and China have built small tidal power plants. In India the probable sites for exploration of tidal energy are the Gulf of Kutch and Cambay and Sundarbans and also near Andaman, Nicobar and Lakshadeep islands. The sites should be within 20–30 km from the shore in order to facilitate power transmission to the islands.

Geothermal Energy

The earth's core has a vast source of thermal energy, which has been tapped in many developed countries. In France and Hungary, hot water from hot springs has been utilized for heating houses and agricultural farms. Italy is the pioneer in this field. Later on USA, Philippines, Japan and New Zealand have been working on exploration of geothermal energy as an energy resource.

During the oil crisis period in 1973, England developed the technology for harnessing geothermal energy. If in many areas wells are dug about 5 km deep, then geothermal energy may be exploited. With advanced technology, it may be possible to generate electricity from geothermal energy in India and other developed countries.

10.4 RESOURCE/ENVIRONMENT MANAGEMENT

The problem of conservation of the environment is that the human population has been going through explosion and along with it consuming the planet's resources, both renewable and non-renewable. In the relentless march towards development, industrialistion and urbanisation, the earth's natural resources have been plundered which have finally threatened human survival on earth. The problems of air, water and terrestrial pollution have assumed alarming dimensions day by day. In the not too distant future, foreign tourists may be advised not to drink local water nor breathe air while traveling abroad.

The Government of India in its Sixth Five Year Plan (1980–85) framework, laid down the following policy:

"It is imperative that we carefully utilize our renewable resources of soil, water, plant and animal life to sustain our economic development. Over-exploitation of these is reflected in soil erosion, siltation, floods and rapid destruction of our forest, floral and wild-life resources. The depletion of these resources often tends to be irreversible and since the bulk of the population depends on these natural resources to meet their basic needs, particularly of fuel, fodder and housing material, it has meant deterioration in their quality of life."

It is important to note the response of an unknown Red Indian Chief (USA) to the President of USA regarding the latter's proposal for purchase of land belonging to the Red Indians some 130 years ago. This is very much relevant even to-day.

"The Great Chief in Washington sends word that he wishes to buy our land. How can you buy or sell the sky, the warmth of the land? The idea is strange to us. If we do not own the freshness of the air or sparkle of the water, how can you buy them?…the land is sacred to us…the rivers are our brothers—they quench our thirst…**The earth does not belong to man, man belongs to the earth**…All things are connected. **Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, he does to himself**…"

10.4.1 Sustainable Development

The Policymakers of the World Conservation Strategy (1980's) introduced the term "Sustainable Development". However, it was not commonly used till the Bruntland Commission (World Commission on Environment and Development, headed by Norway Prime Minister, Gro Hartlem Bruntland) published its Report "Our Common Future" in 1987. According to this Report, *Sustainable Development is development that meets the needs of the present without compromising the ability of the future generations to meet their own* *needs.* In other words, *sustainable development means a balanced development which satisfies the current needs with limited utilisation and conservation of natural resources without sacrificing the quality of environment and future of the next generations.* Such balance between environment and development only lays the foundation of Sustainable Development.

Sustainable development should be part and parcel of our national plan. While noting the population explosion trend and shrinking resource base, we should practice recycling and reusing matrials including food and controlling pollution so that resources are not exhausted quickly and environment does not suffer. The idea of Sustainable Development was strongly supported the Earth Summit (1992) held at Rio de Janeiro, Brazil (United Nations Conference on Environment and Development i.e., CED). The Earth Summit adopted a historic Agenda 21—a comprehensive plan for leading to Sustainable Development (CED) busted with the task of monitoring progress in implementing Agenda 21.

The Commission has formulated the following guidelines for achieving sustainable development:

(i) Substantial reduction in population growth rates;
(ii) Housing, health care and education for the poor;
(iii) Education and empowerment of women, particularly in rural areas;
(iv) Afforestation (making up deforestation) in cities and rural areas;
(v) Use of non-conventional energy resources by industries and proper treatment of urban wastes and industrial effluents;
(vi) Conservation of land, soil, water, forest, wild life, fish and non-renewable resources by application of modern tools of science and technology;
(vii) Efficient use of resources avoiding wasteful and excessive utilization;
(viii) A global and national strategy to eradicate poverty and
(ix) People's participation in conservation and improvement of environmental quality.

The Rio Summit through its Agenda 21 gave priority to population control, poverty eradication and people's participation involvement in the management of natural resources.

10.5 ENVIRONMENTAL MOVEMENTS IN INDIA

In India the conservation of environment has a long history. India has a long tradition of love, respect and reverence for Nature, plants and animals. The Rigveda, Upanishads, the ancient recorded scriptures in India urge every person to conserve the five elements of the world—land, water, energy, air and space and hold respect for Mother Earth and all its living beings including plants and animals.

But we failed to learn from our history of environmental ethics as we were overwhelmed by western life style. Our concern for environment started only after more than a decade after the world took note of it and became active in handling the environmental issues. Some typical environmental movements on record are described in this section.

(a) Bishnoi Tradition: In Rajasthan desert area there is a small village, Khedaji where by the end of 15th century a Rajput saint founded the Bishnoi cult based on the conservation of environment. The tribal community living in this village are familiar with the Bishnois who believe in non-violence and respect for all forms. According to them, cutting trees or killing animals is a sin.

In 1730 the Maharaja of Jodhpur ordered his men to cut some khejri trees in Khedaji village to produce lime mortar for the palace. The Bishnois adopted a new strategy at the cost of the lives. When the king's men reached the site, about 350 villagers mostly women and children and led by a woman, hugged the trees in the forest and sacrificed their lives as they were hacked to death by king's axemen. Ultimately the king had to bow before the people's wishes. He announced prohibition of cutting trees and killing animals all over the state in the Bisnoi villages. The supreme sacrifice of the Bishnois has become a legend in the annals of forest conservation. This was the forerunner of the Chipko movement more than 300 years later. The Bishnoi tradition continues—the Bishnois have been protecting the environment of their villages all these years.

(b) Chipko Movement: This is the most famous and powerful people's movement in Garhwal region (Himalayan) of Uttarakhand. It originally started as the tribal women's protest against felling of trees by contractors but gained momentum under the leadership of Chandi Prasad Bhatt and Sunder Lal Bahuguna. It coincided with the UN Conference of Human Environment held at Stockholm (1972) which recognized the Chipko movement as a mighty Environment Protection Movement.

The term "Chipko" literally means "hugging". Dasholi Gram Swarajya Mandal (Dasholi village Self-rule Forum) spearheaded the movement in Gopeswar, Chamoli district of Uttarakhand. The DGSM under the leadership of Bhatt and Bahuguna started grassroot level movement involving hill women to protect the hill ecosystem. Reckless destruction of hill forests by timber contractors caused landslides and floods in the valley of Alaknanda and Bhagirathi and was destroying the fragile hill ecosystem. A unique feature of the movement was the active participation of hill women from villages who were the worst sufferers of deforestation as they had to walk 10–15 km everyday to collect their fuel for cooking. Whenever the contractors with their axmen came for cutting trees, the women hugged the trees and protected them from the axemen. The contractors withdrew from the spot and the forest was saved. Thus the entire Himalayan Garhwal region hill forests were protected from further destruction.

In course of time the Chipko movement spread all along the hill region saving all hill forests and greenery and then moved to the South in Karnataka in 1983 where it was named "Appico" movement. Soon it gained international recognition and crossed geographical boundaries to be observed as Chipko Day at New York, USA in April, 1983. A group of school children assembled at Union Square Park hugged a big tree, followed by some adults. Environmentalists from France, Germany, Sweden, Switzerland, etc., came to visit the Chipko camps and hailed the Chipko Movement.

(c) Silent Valley Movement: Silent Valley occupies an area of 8950 hectares at an altitude of 3000 ft. in Palaghat district, Kerala. It is surrounded by the Nilgiri forests to the north and Attap forests to the east—together they comprise 40,000 hectare pristine (i.e., primitive) forest. This tropical rain forest in Western Ghat is a precious reservoir of genetic diversity which has not been fully exploited—here plant species and other forms of life have survived for centuries in the forest. It is this resource to which man has to turn in future for new materials for agriculture..for life-saving drugs, etc.

The Kerala State Government decided to construct a dam on the Silent Valley for generation of 120 MW (Megawatts) of electricity in 1976 at an estimated cost of Rs. 25 crores (revised in 1984 to Rs. 51 crores). The proposed dam would store 270 billion cubic feet water in a reservoir spreading over 700 hectares. In order to save the Silent Valley from destruction in the processing of Government dam project, the Kerala-based NGO, Kerala S. Sahitya Parishad (KSSP) launched the Silent Valley Movement supported by students, teachers and people of Kerala.

Soon the apex policy making bodies NCEPC, DOEn and Switzerland-based IUCN (International Union for Conservation of Nature and Natural Resources) strongly supported the cause of Silent Valley. Finally the Prime Minister (Indira Gandhi) accepted the recommendation of top scientists and environmentalists and declared the Silent Valley as the Biosphere Reserve cancelling the hydel project proposal of the State Government. This is the success story of an environmental movement for protection of an important biosphere reserve.

Narmada Dam

Narmada is the largest west flowing river arising from the Kantaka plateau in Shahdol district of Madhya Pradesh and 1300 km draining 9.88 million hectares between the Vindhya and Satpura ranges. This vast basin—average annual flow of billion cubic metres—is mostly untapped because of inter-(Gujarat, MP) water disputes. The MP Government undertook gigantic plan—Narmada Basin Development Programme—which involves construction of 31 large dams for Narmada and its tributaries, 450 medium-sized projects and several thousand minor structures at a cost of about Rs. 25,000 crores. The benefits were projected—several million hectares of land irrigated; water supply to thousands of industries; several thousand magawatts of power etc.

But according to environmentalists and environment action groups massive damming of the Narmada river could be a blueprint for disaster. The basin is one of the most densely forested in India. The project would imply displacement of over 1 million people, mostly tribals, submerging of over 1000 villages and over 50,000 hectares of agricultural land and also loss of forests in the region. The damage to environment and people far outweighs the projected benefits. The environmental action groups, led by the environmentalist, Smt. Medha Patekar, organized sustained movement to stall the projects of Sardar Sarovar and Narmada Sagar dams and partly succeeded.

10.6 GREEN BENCH

The Supreme Court of India felt the need of establishing the Green Benches in different High Courts in India with the objective of dealing with the environmental issues in the States. In the Eastern Region the Supreme Court transferred the cases of tannery effluent issues and of 68 categories of industries to Calcutta High Court for passing necessary orders.

Accordingly the Green Bench was established in the Calcutta High Court and started functioning since June, 1996. The Green Bench dealt with about 900 cases up to 2000 A.D. These cases related to various kinds of environment-related issues such as:

(a) industries without pollution control system and allegedly violating norms;
(b) illegal filling of water bodies/tanks;
(c) cutting/felling of trees;
(d) auto-emission;
(e) bio-medical wastes and health hazards;
(f) dumping of garbages on streets and non-clearance;
(g) pollution generated from morgues in the state and
(h) regeneration of lakes and parks.

Questions

1. What do you mean by Resources? Give examples.
2. Distinguish between Renewable and Non-renewable Resources with examples.
3. How do you classify lands on the basis of land use?
4. Discuss the importance of top soil. Indicate the annual loss in India.
5. Discuss the role of Forest Resources in the Indian context.
6. Write a brief note on Jhum cultivation.
7. Comment on: “Wood is a major renewable energy resource; it offers multiple benefits to man. But it is a vanishing resource.”
8. What is Sustainable Development?
9. Write notes on:
   (a) Biogas
   (b) Tidal wave energy

(c) Hydroelectricity
(d) Geothermal energy
(e) Chipko Movement
(f) Silent Valley Movement
(g) Save Narmada Movement
(h) Green Bench

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11 Environmental Policies

11.1 ENVIRONMENTAL INSTRUMENTS AND INSTITUTIONS

The Central and State Governments own, control and develop almost all the country's forests, dams, major irrigation systems, power stations, railways, ports, roads, mines and many industries. The Government is not just the protector of the country's environment but it also has the role of destroyer if it neglects its responsibility. The Government has immense responsibility for sustaining environmental conscience.

India's active interest in environment was initiated in 1972 when the then Prime Minister (late Smt. Indira Gandhi) attended the United Nations Conference on Human Environment. A National Committee on Environmental Planning and Coordination (NCEPC was created to act as the apex advisory body in the Department of Science and Technology (DST). The Fourth Five Year Plan (1969-74) mentioned the need for comprehensive recognition of environmental issues in any developmental plan. The successor of NCEPC was the Department of Environment (DOEn) in 1980 within the Ministry of Science and Technology, headed by the Prime Minister. The DOEn is the nodal agency to ensure environmental protection, to conduct environmental impact studies of development projects and have the administrative responsibility for, pollution monitoring and control. In 1985, the topics of wild life and forests were added to the list and a new Ministry of Environment and Forests was created which remained under the charge of the Prime Minister.

The assignments of the Ministry of Environment and Forests are:

(i) Environmental Laws and Policies
(ii) Environmental Monitoring and Control
(iii) Survey of Conservation of Natural Resources
(iv) Management of Forests and Conservation of Wildlife
(v) Environmental Education, Awareness and Information
(vi) International Co-operation

The Ministry of Environment and Forests is the Government's main instrument for generating eco-consciousness within the Government and outside. But with passage of time, it has been found to be bogged down in bureaucracy and to fail to respond to environmental issues. The Ministry has three major units:

(a) Department of Environment, Forests and Wildlife

(b) National Wastelands Development Board (NWDB) and

(c) Ganga Project Directorate

The State Governments also set up their own Ministries of Environment. The Central Prevention and Control of Pollution Board attends to water and air pollution problems at national level while their counterpart State Boards are in charge of their respective State issues.

11.2 ENVIRONMENTAL POLICIES

The Government's environmental policy focusses on the areas:

1. Conservation of natural resources by direct action such as declaration of Reserved Forests, Biosphere; Wetlands, Mangroves and protection of endangered species;
2. Check further degradation of land and water through Wasteland Management and Restoration of river water quality programmes;
3. Monitoring development through Environmental Impact Assessment Studies of major project proposals; and
4. Penal measures for industries which violate Pollution Control Act.

Forests

The policy for conservation of natural resources mainly focusses on the policy for conservation of forests. The latter has undergone various processes of legislation over the last two centuries. Some forests have been declared as Reserve Forests, the first being the Corbett National Park (1936). The National Forest Policy was framed in 1988 for forest management in view of the rapidly vanishing forests which now stand at about 15 per cent forest cover. The Forest Policy aims at 33 per cent forest cover. In the hilly regions most of the major rivers originate and the ecosystem is fragile-the new Policy targets at 67 per cent of land under forest cover, encourages massive afforestation and prohibits deforestation. The role of tribals living in the forests and on forest products has been recognised and their symbiotic (i.e., intimate association) relationship with forests since ancient times has been respected.

Biosphere Reserves

In different regions of the country several Biosphere Reserves have been declared for conservation of different ecosystems. At present 13 Biosphere Reserves have been recommended.

Flora and Wildlife

The total area under mangroves in India is about 6750 sq. km., which is about 7 per cent of world's mangroves. Among these the Sunderbans of West Bengal has the largest area under mangroves, 4200 sq. km., the next being Andaman and Nicobar islands, 1190 sq. km., together accounting for 80 per cent of the total mangroves in the country. The mangroves have suffered severe deforestation, which must be checked.

India is rich in biodiversity with about 75,000 species of animals and 45,000 species of plants. The fauna (animals) include 340 species of mammals, 1200 species of birds, 420 species of reptiles, 140 species of amphibians, 2000 of fishes, 4000 of molluscs and 5000 of insects besides other invertebrates (those without backbones/spines). The flora include 15000 species of flowering plants, 5000 algae, 1600 lichens, 20,000 fungi, 2700 bryophytes, etc. Rich biodiversity is also observed in wetlands and mangroves which serve as treasure houses of genetic resources and also as active protective systems. There is cause for alarm when we notice overexploitation of biodiversity and continued habitat (shelter) destruction (deforestation). Extinction of species is on the increase—everyday we are losing one animal and one plant species. Already a large number of plant and animal species are in the list of the endangered species.

11.3 ENVIRONMENTAL LAWS/ACTS

There are more than 200 Central and State Laws today that can be interpreted one way or another to protect the environment. Only the more important Laws/Acts are tabulated below.

11.3.1 Forests

1927- Indian Forest Act—Forests were classified as

- Reserve Forest
- Protected Forest
- Village Forest
- Restriction on hunting and authorised establishments of Sanctuaries.

1976- 42nd Amendment to the Constitution of India—Forests were transferred from State list to the Concurrent list (i.e., all India basis).

1980- Indian Forest Act—National Forest Policy

- Prohibits State Governments for declaring any portion of forest as non-reserved without approval of Central Government.
- Prohibits State Government for allotting any forest land or any portion there of for any non-forest purpose.

1988- Indian Forest Act—Welfare of forest-dwellers is the major objective

- Prohibits lease of forest land to anybody other than Government.
- Conservation, planting and increase of forest cover to an average of 30 per cent across the country.

11.3.2 Wildlife

1927- Indian Forest Act—Restriction on hunting and authorised

- establishment of sanctuaries.

1936- Corbett National Park—First Wildlife National Park Act

- establishment, of Sanctuary-Tiger reserve.

1972- Wildlife Protection Act—Action Plan for wildlife objectives

- management of protected areas and habitat,
- rehabilitation of endangered and threatened species,
- National Conservation Strategy,
- collaboration with voluntary bodies and NGOs,

11.3.3 Water

1927- Indian Forest Act—Prohibits poisoning of water in forests

1948- Indian Factories Act—Restrictions on discharge of effluents into water bodies

1974- Water (Prevention and Control of Pollution Act)—Setting -up of Pollution Control Boards at Centre and States

- Industries required to submit discharge data for effluents,
- Penal provision for non-compliance.

1986- Environment Protection Act (EPA) (Act introduced in the wake of Bhopal Disaster, 1984)— Protection and improvement of human environment and prevention of hazards to humans, plants, animals and property.

The Environment Protection Act (EPA) empowered the Central Government to issue orders for closing down industries for non-compliance, imposing on them heavy penalty, etc.

Under the provision of EPA, every State set up "Green Bench" courts to attend to Public Interest Litigation (PIL) cases concerning environmental hazards affecting the quality of life of the citizen. The "Green Bench" courts have been empowered to settle the cases quickly and provide legal redress to the citizens: (See Sec. 10.6).

11.3.4 Air

1948- Indian Factories Act–Protection to workers against hazardous processes.

1981- Air (Prevention and Control of Pollution Act) Act—Ambient air quality specified.

- monitoring stations established.

1987- Air Act—Empowers Government to close down polluting industries and stop their supply line of water and electricity.

1989- Motor Vehicles Act—Emission standards of carbon monoxide and hydrocarbons specified.

11.3.5 Environment Impact Assessment (EIA)

Analysis of any possible change in the environmental quality, adverse of beneficial, caused by a devlopmental project of Government or private company is known as Environmental Impact Assessment (EIA). As a matter of Government policy, it is compulsory for any enterprise (Government/private) to include EIA in the planning stage of any developmental project and submit it to the Central Government for clearance. All major and minor irrigation projects and all highly polluting industries are subjected to ElA for their initiation.

11.4 ENVIRONMENTAL ETHICS AND AWARENESS

India has a rich tradition of environmental ethics since the Vedic era some 5000 years ago. The spirit of conservation ethics was inherent in our history, culture, religion and philosophy. The message of *Isho-Upanishad* underscores the philosophy:

"The Universe has been created and nurtured by God. Man can enjoy the bounties of Nature by giving up greed."

The sublime concept of living harmoniously with Nature was practised by our *seers* (*rishis*); their *Tapovan ashramas* (forest hermitages for meditation) and *gurukul education* (teacher-based education) are models for all ages. The compassion for animates and inanimates is the keynote of Indian culture. Buddha and Mahavira preached *non-violence* ("Ahimsa Paramo Dharma") 2500 years ago, which was also introduced in the 20th Century by Mahatma Gandhi. The Nobel laureate World Poet, Tagore presented to the nation the concepts and practices of Vriksharopana (Tree Plantation) ceremony in 1927 and Ashrama Model Open Air School at Santiniketan (1902), that is, long before the world woke up to the alarming environmental issues.

But we failed to sustain our heritage of environmental ethics and lead the world in this matter. We were swept by the western world approach of establishing supremacy over nature and exploiting the natural resources, instead of utilising them as per our old tradition. Again our concern for environment started only two decades after the western world took note of it and worked seriously for handling the environmental issues.

Environmental Awareness

The International Conference on Environmental Education in 1981 stressed the need for environmental education at all levels to help arouse social and community consciousness about the environment. The Bhopal disaster of 1984, the worst environmental disaster in history, focussed very bluntly on the need of environmental education and awareness in India.

The disaster took toll of 10,000 lives in one week; 1000 people turned blind and more than 1 lakh people continue to suffer from various disorders. This tragedy was possible in third world country like India due to negligence and lack of awareness at all levels—Central Government, State Government, industry, public and hospital doctors.

In this context it is important to note the Chinese proverb relating to education:

"If you plan for one year, plant rice;

If you plan for ten years, plant trees;

But if you plan for 100 years, educate the people."

So people's education is important in the long-term interest of a country.

People must be made aware of the present state of environment and crisis and also the remedies. Both formal and non-formal education should be the instruments of education and awareness. Formal education (school/college/university) is meant for students in the educational system. Non-formal education (adult education, literacy mission, etc.) is meant for those who are outside our educational institutions, that is, the majority of Indian population. In other words, the basic or elementary concepts of environment should reach out to the entire population all over the country. The University Grants Commission recently urged the Universities to introduce the syllabus on Environment for under-graduates in all streams (Arts/Science/Commerce). The present book has been designed as a textbook for Polytechnic students.

Environmental ethics can be cultivated from now on so that it can be part of the lifestyle of the present and future generations. The following guidelines are meant for the government/institutions and individuals in their daily lives:

For the Government (National Policy) [Action Plan]

1. Reduce population growth rate by 30 per cent (from 3.0 to less than 2.0 per cent) over the next five years.
2. Reduce livestock population by 30 per cent over the next five years in order to cut down methane (green house gas) emissions.
3. Shift from coal-fired thermal power stations to gas-fired power stations, solar energy, wind power and hydel power as alternative sources of energy.
4. Impose heavy penalties for motor vehicles exceeding emission levels.
5. Introduce CFC-substitutes in all air-conditioners and refrigerators to reduce ozone hole.

For Individuals and Groups [Action Plan]

1. Keep your home and surrounding areas clean and also working places (offices/institutions) clean.
2. Enforce "No Smoking" in as many public places (offices/institutions/banks/post offices/public transports/public halls, etc.) as possible besides own homes.
3. Promote literacy and environmental campaigns among the masses.
4. Organize environmental brigades in every block consisting of young and old people including girls and women for protection and conservation of environment.

5. In critical situations where environment is on the point being destroyed, organize environmental movement along the lines of the Chipko and Silent Valley Movements involving teachers, students and people.
6. Let us take the solemn pledge in our day-to-day life that we shall do our best to make this world a better place to live in for our next and future generations.

Non-Government Organisations (NGOs)

These play important roles in environmental awareness and education. Out of about 200 NGOs, 130 are engaged in these areas, 50 in Nature conservation, 50 in Pollution Control, 45 in Afforestation and Social Forestry, 15 in Rural Development and 10 in Eco-development. Most of these are academically oriented activities. In critical situations they also launch environmental movements. Among the pioneer NGOs, mention should be made of Kerala Sastra Sahitya Parisad (KSSP) which piloted the silent valley movement and successfully stalled the state government Hydel project.

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12 Feedback Exercises

The Feedback Exercises are intended to help the students to test their own understanding of the subject matter of this book which in turn will sustain their interest in Environment.

Put a tick mark (√) within the bracket against the correct answer(s). If there are more than one correct answer, both should be marked. Some answers are given at the end indicating the serial number.

1. Environment means
   (a) a beautiful landscape ( )
   (b) industrial production ( )
   (c) sum total of all conditions that effect the life and development of all organisms on earth ( )
   (d) air and water ( )
2. The elements of environment are
   (a) nitrogen, oxygen and carbon dioxide ( )
   (b) nitrogen, oxygen and sulphur dioxide ( )
   (c) oxygen, ozone and carbon dioxide ( )
   (d) atmosphere, hydrosphere and lithosphere ( )
3. Environment has two major components [NEHU, 2000]
   (a) plants and animals ( )
   (b) man and nature ( )
   (c) biotic and abiotic ( )
   (d) physical and chemical ( )
4. Atmosphere has the main constituents
   (a) nitrogen, oxygen and water vapour ( )
   (b) argon, neon and helium ( )
   (c) carbon dioxide, methane ( )
   (d) nitrogen oxides and sulphur oxides ( )

5. Troposphere has altitude range
   (a) 11-50 km ( )
   (b) 0-11 km ( )
   (c) 20-80 km ( )
   (d) 80-200 km ( )
6. Stratosphere contains an important species which protects life on earth
   (a) oxygen ( )
   (b) nitrogen ( )
   (c) ozone ( )
   (d) carbon dioxide ( )
7. Hydrological cycle provides us with
   (a) supply of fresh water ( )
   (b) irregular rainfall ( )
   (c) fresh oxygen ( )
   (d) electricity ( )
8. Hydrosphere denotes
   (a) water ( )
   (b) plants ( )
   (c) microorganisms ( )
   (d) soil ( )
9. Lithosphere means
   (a) air ( )
   (b) water ( )
   (c) rocks and soil ( )
   (d) organisms ( )
10. A zone consisting of land, water and air which supports life is called
    (a) biosphere ( )
    (b) atmosphere ( )
    (c) lithosphere ( )
    (d) hydrosphere ( )
11. Ecosystem denotes
    (a) seas and oceans ( )
    (b) functional unit in ecology ( )
    (c) forests ( )
    (d) natural cycles ( )
12. The three major living components of an ecosystem are
    (a) producers, phototrophs and consumers ( )
    (b) producers, decomposers and consumers ( )

(c) proteins, carbohydrates and humic acids ( )
(d) micro-consumers, bacteria and fugi ( )

13. For manufacturing their own food, plants are classified as
(a) consumers ( )
(b) producers ( )
(c) decomposers ( )
(d) food web ( )

14. In an ecosystem there is dynammic balance between
(a) man, animals and birds ( )
(b) minerals, water and soil ( )
(c) plants, bacteria and micro-organisms ( )

15. Bacteria and fungi are
(a) decomposer ( )
(b) producers ( )
(c) consumers ( )
(d) none of the above ( )

16. The most important organisms of an ecosystem are
(a) herbivores ( )
(b) carnivores ( )
(c) green plants ( )
(d) protozoa ( )

17. Forests bring about
(a) air pollution control ( )
(b) soil erosion ( )
(c) cyclones ( )
(d) increase in soil fertility ( )

18. Deforestation leads to
(a) heavy rainfall ( )
(b) enhanced soil erosion ( )
(c) balance of ecosystem ( )
(d) none of the above ( )

19. Afforestation is necessary for
(a) soil conservation ( )
(b) soil erosion ( )
(c) weed control ( )
(d) low humidity ( )

20. In the hills forest cover is affected by
    (a) overgrazing by cattle ( )
    (b) soil erosion by rain ( )
    (c) leaching of soil ( )
    (d) soil pollution ( )

21. Social forestry is meant for
    (a) supplying goods and services to people ( )
    (b) providing services to industries ( )
    (c) putting pressure on forests ( )
    (d) improvement of degraded lands ( )

22. Extinction of species is due to
    (a) natural process ( )
    (b) man-made activities ( )
    (c) animal pollution ( )
    (d) industrial pollution ( )

23. How many living organisms on earth are on record?
    (a) 1.7 million ( )
    (b) 16 million ( )
    (c) 30 million ( )
    (d) nil ( )

24. Biodiversity means
    (a) the living natural resources ( )
    (b) micro-organisms only ( )
    (c) seas and oceans ( )
    (d) lithosphere ( )

25. The energy flow through the ecosystem is (NEHU 2000)
    (a) cyclic ( )
    (b) linear and one way ( )
    (c) both cyclic and linear ( )
    (d) linear and two-way ( )

26. The transfer of food energy takes place in some hierarchical order called
    (a) Ecosystem ( )
    (b) Trophic levels ( )
    (c) Ecological pyramids ( )
    (d) Ecological niche ( )

27. Primary producers produce their own food by
    (a) converting solar energy into chemical energy ( )
    (b) hydroelectricity ( )
    (c) osmosis ( )
    (d) mechanical energy ( )

28. A food chain is
    (a) a group of organisms which eat the same type of food ( )
    (b) animals eating the plants ( )
    (c) series of plants and animals which are interrelated in the process of eating and being eaten up ( )
    (d) none of the above ( )
29. A food chain always starts with
    (a) photosynthesis ( )
    (b) respiration ( )
    (c) nitrogen fixation ( )
    (d) decay ( )
30. A food web
    (a) increases variety of food at each trophic level ( )
    (b) delicately balances the interrelations among organisms ( )
    (c) increases the quantity of food at each trophic level ( )
    (d) increases variety as well as quantity of food at each trophic level ( )
31. A group of interconnected food chain is called
    (a) complex food chain ( )
    (b) food cycle ( )
    (c) food web ( )
    (d) none of the above ( )
32. The current world population is [NEHU 2001]
    (a) 4 billion ( )
    (b) 5 billion ( )
    (c) 6 billion ( )
    (d) 8 billion ( )
33. The average number of persons living per sq. km. is known as
    (a) community ( )
    (b) population density ( )
    (c) population growth rate ( )
    (d) population explosion ( )
34. It is estimated that the world population may stabilise around 2050 at [NEHU 2000]
    (a) 10 billion ( )
    (b) 12 billion ( )
    (c) 14 billion ( )
    (d) 20 billion ( )

35. The largest metropolitan city in India (1991) was
    (a) Greater Mumbai ( )
    (b) New Delhi ( )
    (c) Kolkata ( )
    (d) Chennai ( )
36. The number of 1-million plus cities in India in 1991 was
    (a) 20 ( )
    (b) 23 ( )
    (c) 25 ( )
    (d) 28 ( )
37. The state with the highest population growth rate between 1981 and 1991 is
    (a) U.P. ( )
    (b) Bihar ( )
    (c) Assam ( )
    (d) Nagaland ( )
38. At the present growth rate India's population in 2010 will reach
    (a) 1050 million ( )
    (b) 1100 million ( )
    (c) 1200 million ( )
    (d) 1500 million ( )
39. High fertility in India is associated with
    (a) early marriage ( )
    (b) low literacy level ( )
    (c) mother's malnutrition ( )
    (d) high infant mortality ( )
40. India has doubling time for population
    (a) less than 25 years ( )
    (b) 50 years ( )
    (c) 60 years ( )
    (d) 75 years ( )
41. Population explosion occurs
    (a) when natural disaster strikes ( )
    (b) when population size exceeds the carrying capacity of a country ( )
    (c) under conditions of low fertility ( )
    (d) when infant mortality is low ( )
42. Population pressure affects
    (a) food and natural resources ( )
    (b) has no effect on livestock ( )

(c) has no effect on fuel stock ( )
(d) poverty and pollution ( )

43. Primary air pollutants are
(a) oxygen, nitrogen and water vapour ( )
(b) carbon monoxide, nitrogen oxides, sulphur oxides and hydrocarbons ( )
(c) carbon dioxide, sulphur dioxide and ozone ( )
(d) halogens and methane ( )

44. Automobile exhausts consist of
(a) hydrocarbons, carbon monoside and nitric oxide ( )
(b) lead vapour ( )
(c) sulphur dioxide ( )
(d) carbon dioxide ( )

45. Auto emissions are controlled by
(a) using oxygen stream in the exhaust pipes ( )
(b) using catalytic converters in the engines ( )
(c) substituting petrol by alcohol ( )
(d) using less fuel and more air ( )

46. Acid rain originates from
(a) acetic and phosphoric acids ( )
(b) hydrogen chloride, nitric and sulphuric acids ( )
(c) sulphuric acid ( )
(d) leather industries ( )

47. The source of acid rains are
(a) steel plants ( )
(b) nuclear reactors ( )
(c) thermal power plants ( )
(d) coke oven plants ( )

48. Fine particles (0.01–1.0 μ size) cause
(a) typhoid ( )
(b) dysentery and diarrhoea ( )
(c) asthma, bronchitis, tuberculosis ( )
(d) cholera ( )

49. The source of soot particle in air is
(a) burning of paper ( )
(b) fuel combustion ( )
(c) evaporation of water from seas ( )
(d) coke oven plants ( )

50. Particulate emissions from gas streams can be removed by
    (a) lightning discharge in air ( )
    (b) electrostatic precipitator ( )
    (c) air jet ( )
    (d) acid spray ( )

51. Meteorology of the earth is affected by
    (a) natural disasters ( )
    (b) human activities ( )
    (c) earth's rotation ( )
    (d) tidal waves ( )

52. Fresh water available for use is
    (a) less than 10 per cent of total water resources ( )
    (b) less than 5 per cent of total water resources ( )
    (c) less than 1 per cent of water resources ( )
    (d) more than 2 per cent of total water resources ( )

53. Ocean water, vast water resource (97 per cent), is
    (a) good for agriculture ( )
    (b) unfit for human consumption ( )
    (c) useful for coastal vegetation ( )
    (d) useful for inland fisheries ( )

54. Ground water, compared to sea water and lake water, has
    (a) same minerals salts ( )
    (b) less mineral salts, nitrate and bicarbonate ( )
    (c) more mineral salts, nitrate, carbonate ( )
    (d) is fit for our use ( )

55. The symptoms of polluted water are
    (a) no change in physical appearance ( )
    (b) no external matter on the surface ( )
    (c) foul smell, bad taste, dead fish floating on the surface ( )
    (d) none of the above ( )

56. Arsenic contamination of ground water arises from
    (a) excessive withdrawal by shallow tube wells ( )
    (b) leakage of surface water ( )
    (c) leaching of arsenopyrite mineral into ground water ( )
    (d) dumping of industrial wastes on ground ( )

57. Arsenic poisoning symptoms are
    (a) diarrhoea, dysenetery etc. ( )
    (b) loss of hair, brittle nails, gangrene and cancer ( )
    (c) pneumonia, typhoid etc. ( )
    (d) chest congestion ( )
58. The Ganga river is heavily polluted at
    (a) Rishikesh and Haridwar ( )
    (b) Kanpur, Varanasi and Kolkata ( )
    (c) Patna and Allahabad ( )
    (d) Hyderabad ( )
59. The Ganga pollution is due to dumping of
    (a) domestic and industrial sewage ( )
    (b) food wastes ( )
    (c) waste from forests ( )
    (d) industrial gases ( )
60. For drinking water supply, water treatment requires
    (a) filtration through sand bed ( )
    (b) chlorination for killing viruses ( )
    (c) sedimentation ( )
    (d) aeration ( )
61. The important water quality parameters are
    (a) pH, dissolved oxygen, chemical oxygen demand, chloride, arsenic ( )
    (b) calcium and magnesium ( )
    (c) lead, zinc and mecury ( )
    (d) all the above ( )
62. Desalinization of sea water means
    (a) removal of salts from sea water ( )
    (b) dumping of oil into sea water ( )
    (c) removal of suspended matter from sea water ( )
    (d) aeration of sea water ( )
63. Toxic wastes are handled by conversion into less hazardous product(s) by treatment with
    (a) acids ( )
    (b) alkalies ( )
    (c) aeration ( )
    (d) chlorination ( )

64. Non-hazardous wastes are managed by
   (a) dumping on roads ( )
   (b) sanitary landfill ( )
   (c) composting process ( )
   (d) accumulation at the site ( )

65. Radioactive substances emit radiations
   (a) alpha and beta ( )
   (b) alpha, beta and gamma ( )
   (c) cosmic rays ( )
   (d) ultra-violet ( )

66. Radioactive radiations have
   (a) ionizing power ( )
   (b) penetrating power in air ( )
   (c) no effect on matter ( )
   (d) no effect on health ( )

67. The radioactive disintegration series have the same end product but different isotopes
   (a) copper ( )
   (b) iron ( )
   (c) lead ( )
   (d) bismuth ( )

68. Atom bomb explosions destroyed
   (a) Moscow ( )
   (b) Hiroshima and Nagasaki ( )
   (c) Bangkok ( )
   (d) Manila ( )

69. Excessive radiation exposure leads to
   (a) cancer and death ( )
   (b) typhoid ( )
   (c) bronchitis ( )
   (d) genetic damage ( )

70. Chernobyl disaster occurred due to
   (a) gas leakage ( )
   (b) nuclear reactor explosion ( )
   (c) steel plant accident ( )
   (d) forest fire ( )

71. Noise pollution becomes hazardous above
   (a) 90 decibel ( )
   (b) 100 decibel ( )

(c) 120 decibel ( )
(d) 150 decibel ( )

72. Noise levels in residential areas should not exceed
(a) 100 decibels ( )
(b) 150 decibels ( )
(c) 70 decibels ( )
(d) 85 decibels ( )

73. Noise pollution hazards include
(a) ear damage, nausea and dizziness ( )
(b) high fever ( )
(c) stomach pain ( )
(d) chronic exhaustion and tension ( )

74. Silicosis is caused by
(a) dust containing free silica ( )
(b) coal dust ( )
(c) asbestos dust ( )
(d) mica dust ( )

75. Asbestosis causes
(a) respiratory problems ( )
(b) influenza ( )
(c) stomach disorder ( )
(d) none of the above ( )

76. Water-borne diseases are
(a) malaria and filaria ( )
(b) dysentery and cholera ( )
(c) typhoid ( )
(d) arthritis ( )

77. Air-borne diseases are
(a) asthma, bronchitis, pneumonia etc. ( )
(b) cholera and dysentery ( )
(c) malaria ( )
(d) jaundice ( )

78. Renewable resources are
(a) coal, natural gas ( )
(b) forests, plants, water ( )
(c) agricultural crops ( )
(d) all the above ( )

79. Non-renewable resources are
    (a) petroleum and natural gas ( )
    (b) solar energy ( )
    (c) forests ( )
    (d) rains and lightning ( )

80. Minerals mined to the maximum extent are
    (a) coal, petroleum, iron ore ( )
    (b) copper, zinc ( )
    (c) chromium, limestones ( )
    (d) sodium chloride, magnesium chloride ( )

81. Green Revolution resulted from
    (a) high-input high-output technique of agriculture ( )
    (b) use of fertilisers in agriculture ( )
    (c) excessive afforestation ( )
    (d) production of green vegetables ( )

82. Green Revolution concerned
    (a) production of wheat ( )
    (b) production of maize ( )
    (c) production of fish ( )
    (d) production of cotton ( )

83. Fossil fuel means
    (a) paper and wood ( )
    (b) hydroeletricity ( )
    (c) coal, petroleum and diesel ( )
    (d) food waste ( )

84. Conventional energy resources are
    (a) fossil fuel, wood, natural gas ( )
    (b) tidal wave energy ( )
    (c) storms and lightning ( )
    (d) nuclear energy ( )

85. The most abundant energy resource is
    (a) diesel ( )
    (b) coal ( )
    (c) solar energy ( )
    (d) electricity ( )

86. The major renewable natural energy resource is
    (a) nuclear fuel ( )
    (b) wood ( )
    (c) coal ( )
    (d) dry batteries ( )

87. Sunlight may be converted into electricity through
    (a) galvanic cell ( )
    (b) carbon electrodes ( )
    (c) photovoltaic cell ( )
    (d) glass blocks ( )

88. The clean pollution free energy resource is
    (a) coal ( )
    (b) solar energy ( )
    (c) petroleum ( )
    (d) nuclear power ( )

89. Sustainable development means
    (a) development without considering its impact on environment ( )
    (b) balance between development and environment with due emphasis on conservation of resources ( )
    (c) development at the cost of environment ( )
    (d) none of the above ( )

90. Chipko movement succeeded in
    (a) preventing deforestation of hill forests in Uttarakhand ( )
    (b) land protection ( )
    (c) wildlife conservation ( )
    (d) promoting timber business ( )

91. Silent Valley Movement succeeded in
    (a) coastal management ( )
    (b) promoting fishery industries ( )
    (c) cancelling the state govt. hydel project and saving the bioreserve ( )
    (d) boosting coconut cultivation in Kerala ( )

Answers to the Multiple Choice Questions

1. (c)	2. (d)	3. (c)	4. (a)	5. (b)	6. (c)	7. (a)	8. (a)
9. (c)	10. (a)	11. (b)	12. (b)	13. (b)	14. (c)	15. (a)	16. (c)
17. (a)	18. (b)	19. (a)	20. (b)	21. (a)	22. (b)	23. (c)	24. (a)
25. (b)	26. (b)	27. (a)	28. (c)	29. (a)	30. (d)	31. (c)	32. (c)
33. (b)	34. (c)	35. (a)	36. (b)	37. (d)	38. (c)	39. (a,b)	40. (a)
41. (b)	42. (a,d)	43. (b)	44. (a)	45. (b)	46. (b)	47. (c)	48. (c)
49. (b)	50. (b)	51. (b)	52. (c)	53. (b)	54. (b,d)	55. (c)	56. (a)
57. (b)	58. (b)	59. (a)	60. (b)	61. (a)	62. (a)	63. (a)	64. (c)
65. (b)	66. (b)	67. (c)	68. (b)	69. (a)	70. (b)	71. (a)	72. (c)
73. (a)	74. (a)	75. (a)	76. (b)	77. (a)	78. (b)	79. (a)	80. (a)
81. (a)	82. (a)	83. (c)	84. (a)	85. (c)	86. (b)	87. (c)	88. (b)
89. (b)	90. (a)	91. (c)					

MODEL TEST PAPER

NEHU (2000)

Man and Environment

Full Marks: 100 *Pass Marks: 30*

The figures in the margin indicate full marks for the questions.

SECTION-A

Tick (✓) the correct answer: *1 × 50 = 50 Marks*

1. The greatest cause of species extinction is
   (a) destruction of natural habitats (b) too much hunting
   (c) wildlife trade (d) none of the above

2. By 'resource' we mean
   (a) a source of supply (b) a means of meeting needs
   (c) materials available (d) natural substance

3. Resource conservation is essential to
   (a) protect the resources
   (b) ensure regular supply of resources
   (c) serve needs of the present generation
   (d) all of the above

4. Which of the following is an alternative technology?
   (a) use of coal (b) use of hydel power
   (c) use of solar energy (d) use of gas

5. Due to increase in human population there is
   (a) rise in consumption of energy and food
   (b) increase in resources
   (c) development of resources
   (d) conservation of resources

6. The UN Conference on Environment and Development was organised in
   (a) 1965 (b) 1970
   (c) 1972 (d) 1980

7. The most well-known leader of the Narmada Bachao Andolan is
   (a) B.D. Sharma (b) Jashbhai Patel
   (c) Medha Patekar (d) Vandana Shiva

8. The Narmada debate is primarily associated with
   (a) Doyang Dam Project (b) Damodar Valley Project
   (c) Ganga Basin Project (d) Sardar Sarovar Project
9. The Tehri Dam Project is located in
   (a) Kumaon Hills (b) Garhwal Hills
   (c) Chota Nagpur Hills (d) Saramati Hills
10. The most important people's movement for the protection of environment in India is
   (a) Jharkhand Movement (b) Tebhaga Movement
   (c) Kisan Movement (d) Chipko Movement
11. The world's largest river island is
   (a) Subansiri (b) Dibang
   (c) Majuli (d) Pashighat
12. Shifting cultivation has been the most common method of agricultural practice among the tribes of
   (a) Chota Nagpur region (b) Chhatisgarh region
   (c) North-Eastern region (d) Southern region
13. From which part of the country do maximum migrants come to the North-East?
   (a) Rajasthan (b) Punjab
   (c) Bihar (d) West Bengal
14. Which one of the following has the highest percentage of tribes in 1991?
   (a) Tripura (b) Manipur
   (c) Assam (d) Nagaland
15. Which one of the following is most diverse in terms of languages?
   (a) Mizoram (b) Nagaland
   (c) Arunachal Pradesh (d) Tripura
16. The term ecosystem was coined by
   (a) E.P. Odum (b) E.F. Blackman
   (c) G.E. Hutchinson (d) A.G. Tansley
17. Habitat
   (a) tells about the function of the organisms in the ecosystem
   (b) tells about the place where the organisms are found
   (c) tells about the size of the organisms
   (d) tells about the life span of the organisms
18. Environment has two major components
   (a) plants and animals (b) man and nature
   (c) biotic and abiotic (d) physical and chemical

19. Lithosphere denotes
    (a) air
    (b) water
    (c) rocks and soil
    (d) organisms
20. Which of the following has maximum biological diversity?
    (a) agricultural fields
    (b) fish ponds
    (c) estuaries
    (d) pine plantations
21. Energy flow through the ecosystem is
    (a) cyclic
    (b) linear and one-way
    (c) both cyclic and linear
    (d) linear and two-way
22. The base of a food chain is always formed by
    (a) carnivore
    (b) herbivores
    (c) autotrophs
    (d) primary consumers
23. Community is
    (a) a group of people living in an area
    (b) people belonging to a particular sect
    (c) organisms living in a particular type of habitat
    (d) mode of interacting populations developed over a period of time
24. Energy pyramids are
    (a) always inverted
    (b) sometimes inverted
    (c) always upright
    (d) all of the above
25. Autotrophs
    (a) are self-nourishing organisms
    (b) cannot make their own food
    (c) depend on other organisms for food
    (d) derive their food from producers
26. Currently the world population is estimated at
    (a) 5 billion
    (b) 6 billion
    (c) 7 billion
    (d) 8 billion
27. It is estimated that the world population may stabilise around 2050 at
    (a) 10 billion
    (b) 12 billion
    (c) 14 billion
    (d) 20 billion
28. Malthusian doctrine implies
    (a) world population will go on increasing without a limit
    (b) world population will slow down due to positive checks
    (c) world population will rise more than the rise in world food production
    (d) world population will decrease due to preventive checks

29. Most of the high population growth countries of the world are located in
    (a) Asia, Africa and Europe
    (b) Africa and South America
    (c) Asia, Africa and South America
    (d) Asia, South and North America
30. The highest population density per area is found in
    (a) South Asia and South-East Asia
    (b) South Asia and Europe
    (c) Europe and North America
    (d) South Asia and Japan
31. The decadal population growth of India during 1981 to 1991 was
    (a) 23 per cent
    (b) 23.56 per cent
    (c) 23.85 per cent
    (d) 24 per cent
32. The State that observed the highest decennial growth of population between 1981 and 1991 is
    (a) Arunachal Pradesh
    (b) Mizoram
    (c) Assam
    (d) Nagaland
33. The State with the highest level of urbanisation in India is
    (a) Uttar Pradesh
    (b) Mizoram
    (c) Nagaland
    (d) Maharashtra
34. The life expectancy at birth of the Indian population is
    (a) 50 years
    (b) 55 years
    (c) 62 years
    (d) 65 years
35. In India's population the share of the scheduled tribe population (1991) is
    (a) 5 per cent
    (b) 7 per cent
    (c) 8 per cent
    (d) 10 per cent
36. Which one of the following is a greenhouse gas?
    (a) nitrogen dioxide
    (b) sulphur dioxide
    (c) carbon dioxide
    (d) sulphur trioxide
37. Global warming is the cause of
    (a) rise in sea level
    (b) natural disasters
    (c) forest fire
    (d) loss of soil fertility
38. Ozone holes are best seen over
    (a) The Equator
    (b) South Pole
    (c) Tropic of Cancer
    (d) Tropic of Capricorn
39. Deforestation causes
    (a) loss of biological diversity
    (b) siltation of water courses
    (c) disruption in wildlife corridors
    (d) all of the above
40. Desertification is most common in
    (a) tropical region
    (b) temperature region
    (c) gangetic plains
    (d) none of the above

41. Maximum air pollution in India is recorded in
    (a) Hyderabad (b) Bangalore
    (c) Delhi (d) Guwahati
42. Carbon dioxide level in the air is increasing because of burning of
    (a) firewood (b) fossil fuels
    (c) charcoal (d) all of the above
43. DDT concentration in higher levels of food chain increases due to
    (a) eutrophication (b) water pollution
    (c) spray of herbicides (d) biomagnification
44. Maximum level of noise pollution emanates from
    (a) loud-speakers (b) automobiles
    (c) crackers (d) jet aircrafts
45. Soil pollution is caused by
    (a) agrochernicals (b) domestic effluents
    (c) automobile exhausts (d) cow dung
46. The basic source of energy into the biosphere is
    (a) coal (b) petrol
    (c) wind (d) sun
47. High biodiversity in an ecosystem brings in
    (a) stability (b) imbalance
    (c) disturbance (d) balance
48. The highest biodiversity on the earth is found in
    (a) temperate forest (b) tropical forest
    (c) alpine forest (d) tundra forest
49. The 'hot spots' are areas of
    (a) hot springs (b) warm places
    (c) hearths (d) high biodiversity under threat.
50. Extinction of species is
    (a) loss of genetic distinctiveness
    (b) termination of an evolutionary lineage due to demographic failure
    (c) disappearance of a particular species
    (d) all the above

Answers to the Multiple Choice Questions

1. (a)	2. (b)	3. (b)	4. (c)	5. (a)	6. (c)	7. (c)	8. (d)	9. (b)	10. (d)
11. (c)	12. (c)	13. (c)	14. (d)	15. (c)	16. (d)	17. (b)	18. (c)	19. (c)	20. (c)
21. (c)	22. (c)	23. (d)	24. (b)	25. (a)	26. (b)	27. (c)	28. (c)	29. (a)	30. (b)
31. (b)	32. (d)	33. (b)	34. (c)	35. (c)	36. (c)	37. (a)	38. (b)	39. (d)	40. (a)
41. (c)	42. (b)	43. (d)	44. (d)	45. (a)	46. (d)	47. (a)	48. (b)	49. (d)	50. (b).

ENVIRONMENTAL EDUCATION (2002)

Full Marks: 70 | *Pass Marks: 28*
Time: Three hours

The figures in the margin indicate full marks.
Answer Q. No. 6 and any *four* from the rest.

1. Define environment. How the environment is affected by—
   (i) Population Growth (ii) Industrialisation
   (iii) Urbanisation? 2 + 4 + 4 + 4 = 14

2. (a) 'Man himself is responsible for the environment he faces'.
   Explain it with suitable example. 7
   (b) What is eco-system? Discuss about the structure of eco-system. 7

3. (a) What is air pollution? What are the sources of air pollution? 7
   (b) How we can control the air pollution? Define air quality standard. 4 + 3 = 7

4. (a) Discuss about the energy flow in eco-system. 7
   (b) What is de-forestation? How de-forestation affects the environment? Discuss. 7

5. (a) What is epidemiology? What are the factors involved in causation of diseases? 2 + 5 = 7
   (b) How the epidemic can be controlled?
   (c) What are the different media through which the diseases can be transmitted?
   4 + 3 = 7

6. Write short notes on the following (*any two*): 7 × 2 = 14
   (i) Urbanisation (ii) Food-chain
   (iii) Green-house effect.

7. (a) What is land pollution? How it imbalances the environment?
   What are the different sources from which the land is polluted? 10
   (b) What is conservation of wildlife? Explain with example. 4

ENVIRONMENTAL EDUCATION (2003)

Full Marks: 70 | *Pass Marks: 28*
Time: Three hours

The figures in the margin indicate full marks for the questions.
Answer any *five* questions.

1. (a) What do you mean by environment? What are the various components of it? 5
   (b) What is population growth of any species? 3
   (c) Explain industrialisation and urbanisation. 6
2. (a) What is biosphere? Write down various components of ecosystem. $2 + 6 = 8$
   (b) Explain the cyclic process of carbon in ecosystem. 6
3. (a) What is water pollution? Describe the sources of water pollution. $2 + 6 = 8$
   (b) Describe the self purification process of natural water. 6
4. (a) What is air pollution? What are the causes of air pollution? $2 + 6 = 8$
   (b) How to control air pollution? 6
5. (a) Define noise. What are the effects of noise pollution? $2 + 5 = 7$
   (b) What are the measures available to control noise pollution? 7
6. (a) What is radioactive pollution? What are the sources of radioactive pollution? $2 + 5 = 7$
   (b) Define solid waste. Discuss any one method for disposal of solid waste. $2 + 5$
7. Write down short notes on any four: $3\frac{1}{2} \times 4 = 14$
   (i) Food chain in ecosystem
   (ii) Land pollution
   (iii) Formation and depletion of ozone
   (iv) Eco-system
   (v) Conservation of wildlife
   (vi) Acid rain
   (vii) Occupational health hazards.

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Appendix 1
The Time Scale of Evolution

Time	*Event*
6.5-7.00 billion years ago	The Big Bang
4.50 billion years ago	The Earth was born
3.50 billion years ago	The blue-green algae (plant) was formed
3.00 billion years ago	The animal appeared
0.0025-0.0030 billion (25-30 lakh) years ago	The man appeared

Appendix 2
The International SI Units

The modern textbooks have adopted the System International (SI) Units. However, these have not yet been accepted in toto. In this book some SI units, universally adopted, have been used while the more familiar units, e.g., Å atm, degree celsius, etc. are retained.

Physical quantity	*Name of Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Amount of substance	mole	mol
Energy	Joule	J
Temperature	Kelvin (1°C) = K-273)	K

Calorie (thermochemical) = 4.184 J

Appendix 3
Drinking Water Quality Standards

In this Table the permissible limits for water quality parameters, as laid down by the United States Public Health Standard (USPH) for drinking water and Indian Standards Institution (ISI), are listed for comparison. The ISI values, available for only a few parameters, are found to be much higher than those for USPH for no valid reasons. All the units, except for pH and *E.Coli*, are in ppm or mg/mL.

Parameters	*USPH Standard*	*ISI Standard*
pH	6.0-8.5	6.0-9.0
Dissolved Oxygen (D.O.)	4.0-6.0 (ppm)	3.0
Chemical Oxygen Demand (COD)	4.0	–
Total dissolved solids	500	–
Suspended solid	5.0	–
Chloride	250	600
Sulphate	250	1000
Cyanide	0.05	–
Nitrate + Nitrite	<10	–
Fluoride	1.5	3.0
Phosphate	0.1	–
Ammonia	0.5	–
Total hardness (as $CaCO_3$)	500	
Calcium	100	–
Magnesium	30	–
Arsenic	0.05	0.2
Cadmium	0.01	–
Chromium (VI)	0.05	0.05
Iron (filtrable)	< 0.3	–
Lead	0.05	0.01
Mercury	0.001	–
Zinc	5.5	–
Phenols	0.001	0.005
E.Coli (Coliform cells)/ 1000 ml (Bacteriological parameter)	100	–

Appendix 4

Toxic Chemicals in the Environment

There are a number of chemicals in the environment. Some of them are toxic while the rest are non-toxic. The toxic chemicals are discharged by industries into air, water and soil. They enter our biological system through food chain and disturb the metabolic processes, leading in some cases to fatal results.

At present there are four million known chemicals in the world and we are adding to the list 30,000 new compounds every year. Among these 60,000-70,000 chemicals are commonly used. Apart from their benefit to inceasing production, living standards and health, many of them are potentially toxic.

Toxic Chemicals in Air

- Acrylonitrile, Arsenic, Asbestos
- Benzene, Beryllium
- Cadmium, Chromium, Chlorinated solvents, Coke oven emissions, Chlorofluorocarbons.
- Ethylene dibromide, ethylene oxide.
- Lead, Mercury
- Ozone
- Polycyclic aromatic hydrocarbons
- Sulphur dioxide

Toxic Chemicals in Water

- Trace Elements: Arsenic
- Beryllium, Boron
- Cadmium, Chromium, Copper
- Fluoride
- Lead
- Manganese, Mercury, Molybdenum
- Selenium
- Zinc
- Pesticides (from agricultural run-off)

Appendix 5

The Haves and Have-nots (Developed and Developing Countries)

80: 20 Ratio 20 per cent of the world population (developed countries) consume 80 per cent of the world's resources (natural), generate 75 per cent of total solid wastes and are responsible for 70 per cent of global environmental damage.

USA, with about half of India's population and double of India's area, discharges 5000 million tons of carbon dioxide every year–five times more than India.

Al Gore, ex-Vice President of USA–UNEP magazine vol. 6, No.2, 1994–The North (developed countries) accounts for over consumption of resources while the south (developing countries), for population explosion and poverty.

Appendix 6

One Earth, One Family (Global Village)

The UNEP (United Nations Environment Programme) theme for 1994 was One Earth, One Family:

The Earth is not merely a “hotel”—it is our “home”.

It is a place, where we should not use the resources and then move to another spot for further exploration.

—it is a place that we should cherish and need to protect.

It is not merely a “resource” or “retreat”, which we use, enjoy and then leave.

—it is our **Mother.**

Appendix 7

India’s Rank in the World

Parameter	*Rank*
Population	2 (next to China)
Area	7
Value added in Agriculture	5
Electricity generation	8
Value added in manufacturing	14
Gross Domestic Product	15
Export of Goods and Services	30
Human Development Index	134

Appendix 8

Glossary (Key Terms and Concepts) (Chapterwise)

This Glossary is intended to reinforce the understanding of the subject (chapterwise) by the students.

CHAPTER 1

Atmosphere: Invisible blanket of odourless and tasteless mixture of gases which surround the earth and protect life forms on earth. It ranges from sea level to aout 500 km. above. The principal constituents are nitrogen (78%), oxygen (21 %) with water vapour and carbon dioxide as minor constituents.

Biosphere: Consists of the earth's surface, hydrosphere, atmosphere and various living species which exist 60 metres above the earth's surface and 10,000 metres below sea level.

Environment: Something that environs i.e., encircles or surrounds. It is the sum total of all conditions and influences that affect life and development of all organisms on earth.

Hydrological Cycle: Natural cycle based on evaporation of sea water, cloud formation and rainfall-this is the source of fresh water supply on earth.

Hydrosphere: All types of water resources—seas, oceans, rivers, lakes, ponds, streams, reservoirs and ground water.

Lithosphere: Earth's crust consisting of rocks and soil.

Mesosphere: Region of the atmosphere at an altitude of 50-85 km. just above the stratosphere.

Pollution: Any change in the properties of the environment—air, water, soil—due to the presence of external substances is the phenomenon of pollution.

Pollutants: The external substances which cause pollution in air, water, soil etc., are called pollutants.

Examples: carbon monoxide, sulphur dioxide etc. are air pollutants; domestic sewage is water pollutant.

Stratosphere: The region of the atmosphere at an altitude of 11-50 km just above the troposphere.

Here ozone is the important species which protects life forms on earth.

Thermosphere: Atmospheric region at an altitude of 85-500 km just above the mesosphere.

Troposphere: Bottom layer of the atmosphere, altitude range 0-11 km and temperature range 15°C to – 50°C; the important species are nitrogen, oxygen, carbon dioxide and water vapour.

CHAPTER 2

Biodiversity: Variety of living organisms within species, between species and ecosystems— wide range and variety of the living world, as manifested by numerous species of flora and fauna. Conservation of biodiversity is important for the functioning of the ecosystem and human welfare.

Decomposers: These are mainly bacteria, fungi etc., which break down dead tissues or absorb dissolved organic matter and thereby derive their energy.

Consumers: Man and animals live on plants and are known as consumers.

Ecology: Science that deals with the study of interactions between living organisms and their physical environment.

Ecosystem: Any unit that includes all organisms which function together in a given area where they closely interact with the physical environment.

Energy Budget: Record of the flow of energy through an ecosystem in each step from one organism to another.

Energy Flow: Movement of energy through an ecosystem—from the external environment through a series of organisms and back to the external environment.

Energy Path: Transfer of energy from one organism to another in the ecosystem is known as Energy Path. Food energy is transferred from green plants to animals and then to man—this is well-known as energy path.

Food Chain: Transfer of food energy from the source in green plants through a series of organisms with repeated process of eating and being eaten.

Food Web: Interlocking of food chains due to multiple sources

Heterotrophic Organisms: These depend on others for their nourishment e.g., animals which live on other organisms i.e. plants, small animals etc.

Primary Productivity: Rate of production of organic matter by photosynthesis (by green plants).

Specide: Extinction of species of plants and animals by man-made activities.

Sustainable Ecosystem: Degradation of ecosystem by man-made activities can be checked by including the elements of renewability e.g., afforestation with minimum deforestation, air and water pollution control, population stabilisation etc.

Trophic Levels: Food energy passes from one group of organisms to other groups at different levels called Trophic Levels (plants-animals-man): Green plants belong to Trophic level I, cattle, goat Trophic level II, carnivores Trophic level III and man Trophic level IV.

CHAPTER 3

Carrying Capacity: Maximum population size that an ecosystem can support.

Dependency Ratio: Ratio of people over 60 years of age and under 15 to the rest of the population.

Doubling Time: Period within which the population of a country doubles-100 years for developed countries and 25-30 years for developing countries.

Fertility Rate: Number of babies born to 1000 women of the reproductive age group—for India, the rate is 3.0 while for the developed countries, less than 1.5.

Infant Mortality: Number of infant deaths per 1000

Life Expectancy: Average number of years that a new-born baby is expected to survive. For India life expectancy is 59 years.

Population Density: Number of people per sq. km. of area.

Population Crash/Explosion: This occurs when population grows at a fast rate and population size exceeds the carrying capacity as in India and in other developing countries.

Population Stabilisation: Population kept within limit at controlled rate (0.5% as in the developed countries).

P-Triangle: Population-Poverty-Pollution form the P-Triangle as in India—this is serious setback for economic growth and welfare of India.

CHAPTER 4

Acid Rain: Acidic precipitation consisting of mixtures of hydrochloric, nitric and sulphuric acids—harmful for marble sculptures, lakes and forests.

Air Quality Standards: Each pollutant, present in air, has to be kept within threshold limit values beyond which it will cause public health hazard. These values set the air quality standards. Thus chlorine has threshold limit value 10 parts per million which must not be exceeded.

El Nino: Ocean warming phenomenon along south American coast in December-March every 3-5 years, causing rain, storms and affecting the climate over half the globe (south).

Global Warming (Greenhouse Effect): Increase of earth's surface temperature due to absorption of earth's infra-red radiation by greenhouse gases. This has adverse effect on the global climate, food production etc.

Greenhouse Gases: Gases such as carbon dioxide, methane, ozone, water vapour, nitrous oxide and chloflurocarbons absorb earth's infra-red radiation, return it to the earth's surface thereby raising its temperature.

Ozone Hole: Thinning of ozone layer in the stratosphere by interaction of ozone with nitrogen oxides, chlorofluorocarbons etc.

Particulate: Small solid particles (soot) and liquid droplets, suspended in air, are collectively called particulates. They play important role in the atmosphere-reduce visibility, help cloud, rain and snow formation and thereby influence the climate.

Photochemical Smog: Mixture of smoke and fog arising from photochemical reactions in which ozone, hydrocarbons and nitrogen oxides participate giving harmful products for our health.

Primary Pollutants: Pollutants which are of primary nature—e.g., carbon monoxide, nitrogen oxides, hydrocarbons, sulphur oxides and particulates.

Sinks: Media which receive and absorb a pollutant (air)—ocean is a great sink for carbon dioxide.

Gamma Rays: Radiation, without mass and charge, consisting of photons. Gamma rays have more penetrating power than alpha or beta-particles/rays.

Radiation Chemistry: The study of chemical and biological effects caused by radiations during their passage through matter.

Radioactive Decay: Radioactive elements undergo transformation from one to another element by emitting radiation (alpha, beta, gamma) and the process is known as Radioactive Decay.

CHAPTER 5

Arsenic Contamination: Ground water is pumped by shallow tube wells for irrigation. This causes leaching of arsenopyrite mineral (arsenic, iron, sulphide) and release of arsenic into ground water thereby leading to arsenic contamination. Prolonged use of arsenic-contaminant drinking water leads to arsenic-related diseases such as melanosis, keratosis, lungs and liver disorders, skin cancer and death. More than 20 lakh people in W. Bengal along the Hooghly river course are victims of arsenic poisoning. Similar calamity faces Bangladesh.

Desalinisation: Process of removing mineral salts from sea water.

Ganga Action Plan: The Government of India launched this Plan in 1986 and entrusted the task to the State Governments concerned-U.P., Bihar and W. Bengal for cleaning up the Ganga and bringing it back to life. The Plan included steps for diversion of sewage into separate diversion canals away from the Ganga, treatment of sewage by plants, use of clean water for agriculture (recycling), construction of low cost sanitary latrines away from the river and public awareness campaign.

Ground Water Pollution: Ground water, through relatively free from surface contamination, gets polluted due to contamination from leaching of minerals as in the case of arsenic pollution.

Inorganic Pollutants: This group consists of inorganic salts, mineral acids, metals, trace elements etc.

Organic Pollutants: These comprise domestic sewage, pesticides, synthetic organic compounds, plants nutrients, oil wastes etc. These reduce dissolved oxygen in water bodies.

Thermal Pollution: Thermal power plants (coal/nuclear) are sources of thermal pollution —hot waste water from these plants is dumped into water bodies where temperature rises by about 10°C.

Waste Water Treatment: Domestic and industrial sewages are sources of water pollution. Domestic waste water is treated in several steps—sedimentation, aeration, chlorination and the purified water is recycled for municipal water supply. Industrial wastes are purified by filtration using activated charcoal or ion exchange resins and the resulting effluent recycled for use by industries.

Water Quality: The extent of purity of water for drinking and other purposes is expressed by some parameters (pH, dissolved oxygen, hardness etc.).

Water Recycling: Reuse of water after treatment and purification.

CHAPTER 6

Composting: Biological process of decomposing organic wastes by means of micro-organisms.

Detoxification: Conversion of toxic wastes (industrial) into less hazardous products by oxygen, treatment with acids or micro-organisms (bacteria).

Incineration: Process of burning solid wastes to ashes in a special furnace (incinerator).

Sanitary Landfill: Disposal of solid wastes by dumping in a gravel pit and covering with soil.

CHAPTER 7

Alpha Particles: Positively charged particles carrying charge +2 units and mass 4 units, identical with helium nuclei.

Background Radiation: Radioactive minerals in the earth's crust and cosmic rays from upper atmosphere are sources of background radiation in the environment.

Beta Particles: Negatively charged particles, identical with electrons.

Chernobyl Disaster: Nuclear reactor explosion at Chernobyl, formerly USSR in 1986 which killed 200 people and damaged environment.

CHAPTER 8

Decibel: One tenth of a "bel"—the unit of sound intensity, abbreviated as *dB*. Mathematically, $dB = 10 \log I/I_0$ where I is the intensity of any sound and I_0 the intensity of a reference sound of the same frequency, just audible to the human ear. The faintest audible sound is taken as 1 *dB* while the audible range of human ear ranges from 1 to 130 *dB*.

Noise Pollution: High levels of unpleasant, disturbing sound or noise above 50 *dB* cause noise pollution and health hazards.

Noise Pollution Hazards: Noise pollution causes physiological and psychological disorders. These include ear damage and loss of ear sensitivity, nausea, dizziness, chronic exhaustion and tension, loss of sleep, lower working efficiency. Noise pollution also causes decline in the flights of migratory birds from winter to tropical climate.

Occupational Noise: Industrial workers are exposed to noisy working environment for 48 hours per week. They suffer from ear damage and low working efficiency.

CHAPTER 9

Asbestosis: Disease caused by inhalation of asbestos fibres in asbestos factries. Asbestosis leads to lungs and respiratory disorder (pneumonoconiosis) and lung cancer.

Byssionis: Lung disease caused by inhalation of cotton dust in cotton mills.

Epidemiology: Medical science of tracing the spread of an epidemic to its environmental factors. Epidemiological studies trace the source of a disease and provide information about the remedial measures to be taken. Thus contaminated water was identified as the source and spread of cholera and mosquito, for malaria.

Occupational Hazards: Health hazards faced by industry workers due to exposure to dust, vapours etc. during working hours.

CHAPTER 10

Bishnoi Tradition: A tribal community, known as Bishnois, in a Rajasthan village sacrificed their lives for protection of forests. Bishnois respected all life forms. According to them, cutting of trees and killing of animals is a sin. Finally the authorities prohibited cutting of trees and killing of animals in all the Bishnoi villages thereby respecting the Bishnoi tradition.

Chipko Movement: Most famous people's movement in Garhwal region (Himalayas) of Uttarakhand against deforestation in the hill areas. This was spearheaded by hill women under the leadership of Chandi Prasad Bhatt and Sunderlal Bahuguna.

Conventional Energy Resources: Conventional or traditional energy resources are fossil fuel (coal, petroleum, diesel), wood, natural gas, hydroelectricity etc.

Green Bench: Bench under a High Court, specially designated and constituted by the Supreme Court of India to deal with cases related to environmental issues.

Green Revolution: High agricultural yield achieved by application of high input-high output technology viz. use of fertilisers, pesticides and extensive irrigation. Punjab and Haryana showed record production of wheat since the sixties through Green Revolution.

Non-conventional Energy Resources: Solar energy, Biogas, Wind energy, Ocean and Tidal energy etc. are examples of non-conventional energy resources.

Resource: Form of matter and energy, useful for functioning of organisms, populations and ecosystems e.g., food, air, water, soil, plants, animals, minerals etc.

Renewable Resources are those which can be regenerated after use e.g., forests, water, solar energy etc.

Non-renewable resources are exhausted with time but cannot be renewed e.g., fossil fuel (coal, diesel, petroleum), natural gas and minerals.

Silent Valley Movement: The famous movement by Kerala environmental action groups and public for protection of the important bioreserve of the Silent Valley baffled the government plan of construction of dam in the valley for power generation. The movement attracted national and international attention and finally the government hydel project was shelved and the bioreserve was saved.

Sustainable Development: Balance between environment and development which satisfies the present needs without sacrificing the quality of environment for the future generations.

W.B. STATE COUNCIL OF TECHNICAL EDUCATION (WBSCTE)

Diploma in Civil Engineering

(Second Year Ist Samester)

January 2006

ENVIRONMENTAL ENGINEERING

Time Allowed: 3 Hours *Full Marks: 100*

Answer any five questions from Group-A, B, C & D, as directed.

Answer to Question 1 is Compulsory.

1. Fill in the blanks (any thirty): 1 × 30

i. The lowest layer of atmosphere is called_______.

ii. The chief output of greenhouse gas is_______.

iii. Natural fog is generally not classified as_______.

iv. An average man breathes_______times a day.

v. Sulfurdioxide is one of the principal constituents of_______.

vi. Smog is combination of_______.

vii. For dry and clean air approximate CO_2 content is _______ppm.

viii. The atmosphere is always acquiring oxygen from_______bearing plants.

ix. For all life_______necessary.

x. The unit of measurement of sound is_______.

xi. Raw sewage_______be used as soil fertiliser.

xii. Asiatic cholera is a_______disease.

xiii. BOD means amount of_______present in the liquid waste.

xiv. TSS stands for_______.

xv. COD stands for_______.

xvi. Coagulation has_______effect in waste treatment.

xvii. Sludge can be treated by_______method.

xviii. Sewage can be treated by_______process.

xix. Aluminium manufacturing process may emit_______.

xx. The bacteria are present in_______.

xxi. The gas produced by digesting sludge is mostly_______and_______.

xxii. Refuge consists of______________, etc.

xxiii. Aerobic bacteria cannot live without_______.

xxiv. Hardness of water due to the presence of_______.

xxv. Hard water is_______suitable for boiler.

xxvi. The point sources of water pollution are_______etc.

xxvii. The non-point sources of water pollution are_______etc.

xxviii. Agricultural pollutants are_______etc.

xxix. pH indicate_______and_______of water.

xxx. Water Pollution Prevention Act was passed in_______.

xxxi. Pathogenic bacter help in spreading_______.

Group-A

Answer any two questions.

2. What are the sources of air pollution? 14

3. How air pollution can be controlled in a city? 14

4. (a) What do you know about visibility?
   (b) What do you know about epidemiology? 7 + 7

5. (a) Describe the effect of air pollution on human health.
   (b) Describe the effect of air pollution on animal life. 7 + 7

Group-B

Answer any one question.

6. What are the characteristics of sewage? 14

7. Describe the effect of water pollution on human health. 14

Group-C

Answer any one question.

8. (a) What is soil pollution?
   (b) What are sources of soil pollution? 7 + 7

9. (a) What is solid waste?

   (b) Describe land fill method. 7 + 7

Group-D

Answer any one question.

10. (a) Define sound and noise.

    (b) When does noise pollution occur? 7 + 7

11. (a) Write the functions of WB Pollution Control Board.

    (b) What do you mean by ISO 14000? 12 + 2

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ENVIRONMENTAL ENGINEERING

Time Allowed: 3 Hours *Full Marks: 100*

Answer any five questions from Group-A, B, C & D, as directed.

Answer to Question 1 is Compulsory.

1. A. Fill in the blanks (any ten): $1\frac{1}{2} \times 10 = 15$

i. Electrostatic precipitators are used to control_______.

ii. The unit of noise measurement is_______.

iii. TSS stands for_______.

iv. BOD stands for_______.

v. ppm stands for_______.

vi. The bacteria are present in_______.

vii. Hard water is_______suitable for boiler.

viii. The lowest layer of atmosphere is called_______.

ix. For dry and clean air approximate CO_2 content is_______ppm.

x. TOC stands for_______.

xi. Aerobic bacteria cannot live without_______.

B. Answer the following questions (any ten): $1\frac{1}{2} \times 10 = 15$

i. What are the bad effects of noise pollution on human body?

ii. Name one natural source of air pollution.

iii. What is e-waste?

iv. What items in a city garbage can be recycled?

v. Which gas was responsible for Bhopal disaster?

vi. Which date is the World Environment Day of the year?

vii. In which year the Environment Protection Act was passed in India?

viii. Which is the Environment day of the year?

ix. Name a disease that is transmitted through soil.

ix. What is the full form of EIA?

x. What are the gases that are given off during purification process of sewage?

xi. The presence of which gas in air checks ultra violet rays from sunlight.

xii. Name some of the arsenic affected districts of your state.

Group-A

Answer any two questions.

2. a. What is acid rain? What are its causes?
   b. What are air pollutants? Name some of them.
   c. Explain the sources and effects of air pollutants on human being. 4 + 4 + 6
3. Name any two of the particulate matter control devices and explain them. 14
4. Describe the air pollution problem in a busy city and explain the control management strategies. 14
5. Write short notes on – (a) Kyoto protocol, (b) Ozone hole. 14

Group-B

Answer any one question.

6. What is biochemical oxygen demand? Describe the various types of liquid wastes that are generated in urban area. 14
7. Draw the flow sheet diagram of an activated sludge plant and explain. 14

Group-C

Answer any one question.

8. What is municipal solid waste? What are the options available for disposal of solid waste? 14
9. Describe soil pollution. How soil pollution can be prevented? 14

Group-D

Answer any one question.

10. What is noise pollution? How a human system is affected by noise pollution? 14
11. Write short note on – (a) Air (Prevention & Control of Pollution) Act, 1981, (b) Method of Control Noise Pollution. 14

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