MAA OMWATI DEGREE COLLEGE HASSANPUR (PALWAL)

Notes

BBA 3rd Sem

Enviroment Studies

1

Environmental Studies : An Introduction

The term Environment is derived from the French word *Environner,* which means to encircle or surrounded. All the biological and non-biological entities surrounding us are included in environment. The concept of environment is defined in the Environment (Protection) Act, 1986, according to which all our living and non-living surroundings are included in it. The following figure explains the environment in a better way :

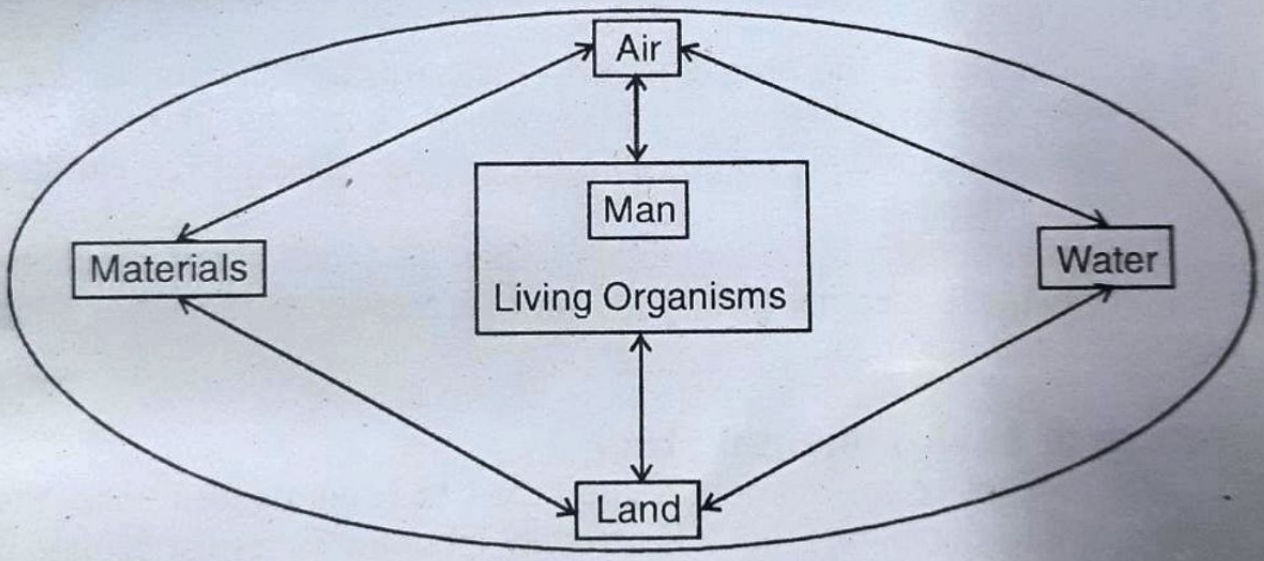


Fig. 1.1 : Our Environment

But the above explanation refers to the one side of the coin, *i.e.,* the environment of human beings only. In broader concept, the term environment can be used in two ways. In one sense, it refers to what surrounds an entity. Any entity, say a person, a living organism, a citizen, a company, etc., has its environment. That is why, we talk of the home environment, the business, the political environment, and the natural environment. In the second way, we use the word environment by itself. Here we mean the natural environment : the air, water, soil, living beings, plants, trees, mountains, oceans, etc.

An entity interacts with its environment, that is, it influences and is influenced by its environment, either positively or negatively. For example,

the natural environment affects human beings. We in turn have an impact (often a negative impact) on the natural environment.

Environment has been defined in various ways by different scholars and scientists :

- According to **Hersch Kovitus,** "Environment is the totality of all those external conditions on the surface of earth, which influence the evolutionary cycle of the living beings."
- According to **Dr. D.H. Davis,** "In the context of human beings, environment means all those physical features on land which influence them continuously."
- According to **E.J. Ross,** "Environment is the external factors that influence us."
- According in the **Universal Encyclopaedia,** environment is "the sum total of all conditions, agencies and influences which affect the development, growth, life and death of an organism, species or race."
- According to the **Encyclopaedia Britannica,** "The entire range of external influences on an organism, both the physical and biological forces of nature, surrounding the individual", constitutes environment.

Thus environment is the sum total of water air and land and the inter-relationship that exist among them and with the human beings, other living organisms and materials.

Nature of Environmental Studies

The concept of environment is too broad to understand. Hence, the subject of Environmental Studies is no doubt inherently interdisciplinary. It has close relationship with all other subjects of study. The interconnections are numerous and involve many different disciplines. We need inputs from biology, botany, zoology, soil science, technology, oceanography, atmospheric science, economics, sociology, anthropology, law, ethics and so on. The nature of the subject is multi-disciplinary because we go through the complex relationships that exist in our natural environment among people, animals, other organisms, water, soil, air, trees and the ocean. This can be summed up in the following lines :

- For the understanding of the biotic components and their interactions we take the help of various life sciences like zoology, botany, genetics, biochemistry and microbiology.
- In view of increasing environmental problems we try to find solutions to them with the help of genetics and biotechnology.
- We study physics, chemistry, geology, atmospheric science, oceanography and geography in order to define the physical and

chemical structure of a biotic components of environment along with mass and energy transfers.

- In order to deal with the socio-economic aspects associated with various development activities we have to study some other subjects like economics, sociology and management.
- Subjects like mathematics, statistics and computer science are emerging as useful tools in environmental modeling.
- To find the technical solutions to environmental pollution control and waste treatment a synthesis of civil engineering, hydraulics, chemical engineering and nanotechnology is necessary.
- For disseminating environmental awareness two subjects are very effective which are environmental education and mass communication.
- For effective management and protection of various aspects and activities of the environment we study environmental laws.

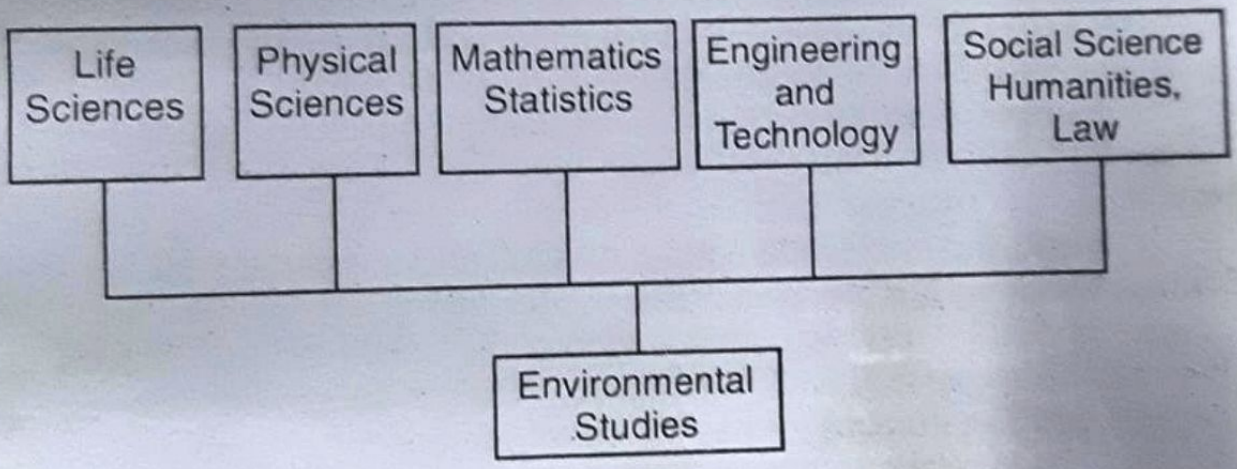


Fig. 1.2.

Scope of the Subject

The subject encompasses a large number of areas and aspects which have a direct relevance to each and every section of the society. Its scope is expanding dramatically day-by-day. Natural resources, ecological aspects, runway growth, imperilled ecosystems, disappearing forests, endangered species, escalating pollution, growing population, dangerous toxies, green laws, social issues in relation to development and environmental and all other such issues come within the preview of Environmental Studies. A close look on these issues, topics and concerns is, hence, necessary here.

1. **Natural Resources.** We study about the nature, availability, conservation and management of natural resources in this subject. The subject describes how humans are using and abusing the natural resources : water, energy sources, forests, land and minerals. Here we discuss the degradation caused to these natural resources through human activities and possible measures for reversing the decline.

2. **Ecology.** This branch of science also comes within the scope of Environmental Studies. This includes the study of the distribution and abundance of living organisms and the interaction between organisms and their environment. The environment of an organism includes both its physical habitat which can be described as the sum of local abiotic factors like climate and geology as well as the other organisms which share its habitat.

3. **Bio-diversity.** It refers to the variety of forms—the different plants, animals and micro-organisms. It includes the genes they contain and the ecosystem they form. It deals essentially with dynamic processes and increases when new genetic variation is produced and decreases on the loss of genetic variation or species extinction. Thus, it is a concept laying emphasis on inter-related nature of the living world with its processes.

4. **Environmental Pollution.** The study of environmental pollution, forms of environmental crisis, their causes and conservation measures also comes within the ambit of Environmental Studies. Here we learn about the possible dangers of pollutions—water, air and land. Effects of global warming, degradation of forest and role of government and civil society in combating pollution are the major thrust areas.

5. **Human Population.** In Environmental Studies, we study human population and their inter-connection with the environment. The over-exploitation of natural resources, the pressure of population explosion on environment, the man-made natural hazards and the perfect solutions of various problems are the main areas of interest.

6. **Social Issues.** We cannot ignore the social issues involved in environmental perspective. Our technological development has strong impacts on the natural as well as the social components. When we talk of social issues in relation to development an environment, we focus on the complex relationships between people, environmental conservation, governments and environmental laws. Environmental Studies explores the issues of development and employment and presents examples of 'green livelihoods' and community-based conservation. At the same time, it addresses the question of displacement of people due to environmental and other reasons.

7. **Crisis and Hazards.** Various forms of environmental crisis and hazards also come within the scope of this subject. Here we study deforestation, energy crisis, garbaze, hazardous waste and associated problems, earthquake, cyclonic storms, floods, drought, landslide etc.

Career Options

In the concerned field we have a number of career options as well. These can be categorised in the following way :

Green Technology. Increasing environmental concerns have increased the role of green technology at every level. By green technology we mean

environmental management and environmental engineering. These are emerging career options as trained manpower is greatly in demand for sustainable development and environmental protection. Moreover, in order to tackling such problems in a holistic manner there is a need of skilled and prolific scientists who can devise effective research and development models based on green technology.

The pollution control laws are becoming more stringent day by day and hence industries are finding it difficult to dispose off the wastes produced. They are now trying to adopt green technologies, which would reduce pollution. For this purpose they are in need of trained manpower and environmental professionals in order to avoid expensive litigation.

Green Market. Market for pollution control technology is increasing the world over. Cleaning up of the wastes produced is another potential market. It is estimated to be more than $100 billion per year for all American business. Germany and Japan having more stringent laws for many years have gained more experience in reducing effluents. Still there is a $200 billion market for cleaning up the former East Germany alone. The Green market for India is evolving rapidly to meet the prescribed standards.

Next point of discussion is ensuring the quality products with ISO mark. Environment friendly products are being given due preference which have ecomark of ISO 14000 certification. Environmental auditors and environmental managers would be in great demand in the coming years.

Green Advocacy. Emphasis is being given an appointing environment lawyers who can deal with laws and legal matters related to various stands of environment like water and air pollution, wildlife and forest Acts. So, the importance of Environmental Studies in increasing rapidly.

Green Media. Persons well-trained in environmental affairs are being engaged in the field of print and electronic media. The sole purpose is to spread awareness amongst the mass through various modes like radio, television, magazines, advertisements etc.

Consultancy Service. Environmentally educated persons can pursue the career of consultants as many non-government organisations (NGOs), government bodies and industries have opened the door of a plethora of such options. The role these consultants is to devise systematic ways of tackle issues related to environmental problems.

Importance of Studies

We cannot live without nature. If we want to lead a healthy life and aspire for a clean earth for our next generations, it is essential to understand the basics of environment. Environmental Studies is very important since it deals with the most mundane problems of life where each individual matters, like dealing with safe and clean drinking water, hygienic living conditions, clean and fresh air, fertile land, healthy food and sustainable development.

The study of the Environmental Studies is important because there is a great need of public awareness for saving our earth which is facing a global environmental crisis. Our unsustainable way of consuming natural resources at a rate greater than that at which nature can regenerate them and the rapidity with which we are polluting the planet, can only lead to a catastrophe.

The crisis of today is rooted in our attitude of domination and exploitation of Nature, based on the 'Idea of Progress'. Many phenomena like population and consumption have been growing exponentially over the past 100-200 years. The concept of ecological footprint expresses the amount of land needed to sustain the lifestyle of an entity—a person, a city, a country, etc. Several international meetings have deliberated the issues of environment and development and have come up with agreements. The accepted approach is that of sustainable development.

The nature of Environmental Studies is equally important for global as well as local issues. For example, there are certain issues like global warming, depletion of ozone layer, dwindling forests and energy resources, loss of global biodiversity etc., which are going to affect the mankind as a whole are global in nature and for that we have to think and plan globally.

The world is heading for an environmental disaster, and like the three wise monkeys, we do not want to see, hear, or talk about it. What is even worse, we sometimes do talk about it, and then go about our business as if the environment and our lives were quite separate. Many environmental problems arise from the deliberate or inadvertent abuse, misuse, and overuse of natural resources by human beings. Land, water, energy resources, air and space have all been adversely affected by human intervention.

On the other hand, there are some environmental problems which are of localized importance. For dealing with local environmental issues, *e.g.*, impact of mining or hydro-electric project in an area, problems of disposal and management of solid waste, river or lake pollution, soil erosion, water logging and salinization of soil, fluorosis problem in local population, arsenic pollution of ground water etc., we have to think and act locally.

Need for Public Awareness

Dissatisfaction with the Idea of Progress began surfacing in the 1960s, when the adverse environmental impact of unbridled growth became clear. Books like Rachel Carson's Silent spring (Carson 1962) set the tone for an environmental movement.

The United Nations Conference on Human Environment in 1972 at Stockholm was the first international initiative to discuss environmental problems. Later, the World Commission of Environment and Development (WCED) was set up in 1983 with Gro Harlem Brundtland of Norway as its Chairperson. The WCED report, our Common Future, emphasized the need for an integration of economic and ecological systems. The commission

supported the concept of sustainable development and defined it as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

The idea of sustainable development has been criticized for being interpretable in many ways. Yet, it has caught the attention of many people, since it seems to imply that development and environmental conservation can go together.

Besides Stockholm, the other major effort was the United Nations Conference on Environment and Development (UNCED) held in 1992 in Rio de Janeiro. Attended by more than a hundred heads of state and 30,000 participants, UNCED came up with several documents including :

- 'The Rio Declaration on Environment and Development', listing 27 principles of sustainable development,
- 'Agenda 21', a detailed action plan for sustainable development in the twenty first century, and
- 'The Convention on Biological Diversity'.

The next conference, popularly known as Rio +10, was held in Johannesburg, South Africa, in 2002. This conference recognized that the implementation of the Rio agreements had been poor. It marked a shift from agreements in principle to more modest but concrete plans of action.

The 2004 Nobel Peace Prize was awarded to Kenyan Environmentalist Wangari Maathai for her contribution to sustainable development, democracy and peace. This is the greatest recognition given to the cause of environment at international level. The Norwegian Nobel Committee, while awarding the prize, expressed the views "Peace on Earth depends on our ability to secure our living Environment."

Maathai, Kenya's Deputy Environment Minister is the founder of Kenya based Green Belt Movement. This movement comprising mainly of women has planted about 30 million trees across Africa. This has helped in slowing desertification, perserving forest habitats for wildlife and food for future generations and has helped combat poverty.

Maathi has given a beautiful slogan "When we plant new trees, we plant the seeds of peace."

But to make our environment clean and green we need public awareness for environmental issues. This is possible only when people of all classes are aware about these concerns. There are many factors that limit our awareness of environmental issues. To the millions of poor people, the problems of daily existence are more important than environmental degradation. The more prosperous are afraid that, in the name of the environment, their comforts may be taken away. In any case, most of us do not pay the real costs of exploiting nature.

There is also false anti-environment propaganda by vested interests like the large corporations, for whom constant growth is vital. At the political

level, parties are more interested in short term gains and will not adopt unpopular measures to conserve the environment. Further, in this age of extreme specialization very few can look at the larger picture of what is happening to the world. There is also a paucity of reliable and clear information on the environment. To make matters worse, indicators like Gross Domestic Product (GDP) give us a misleading picture of what is desirable.

In fact, the public has to be educated about the fact that if we are degrading our environment we are actually harming our own selves. This is because we are a part of the complex network of environment where every component is linked up. It is all the more important to educate the people that sometimes the adverse impact of environment are not experienced until a threshold is reached. So we may be caught unawares by a disaster.

Environment belongs to all and there is an urgent need to create awareness amongst people that we have no other option but to follow sustainability principles. Only then life of mankind on this earth would be secure and our future generations would be safe. Environmental awareness is needed to change the mindset of modern society for an earth-oriented approach.

Model Questions

1. Define environment. What is the crisis of environment?
2. How could we define environmental studies and related terms?
3. Discuss the multidisciplinary nature of Environmental Studies?
4. Why is the need for studying environmental issues important?
5. How would you define the scope of environmental education?
6. Why is there a general lack of public awareness about environmental issues?
7. How would environmental awareness help to protect our environment?

2
Natural Resources

Man's living solely depends upon the gifts of nature. The gifts of nature include Nature's endowments, resources and reserves. Before dealing with resources in detail, it becomes imperative to know about endowments, resources and reserves. The gifts of nature which are useful to us for our living are natural endowments. They include rocks, minerals, soils, water, plants and animals. But these natural endowments have no meaning unless man tries to work on them and gets something useful out of them. Only when man recognises the value of natural endowments, they become natural resources. Before knowing the use of iron, during the stone age there were large quantities of iron in the earth, but they were mere natural reserves or endowments. After man started using them, the mineral endowments became mineral resources. The stocks of natural resources that are available for use by man are termed as reserves, such as reserves of timber, coal, petroleum and natural gas etc.

Defining Natural Resources

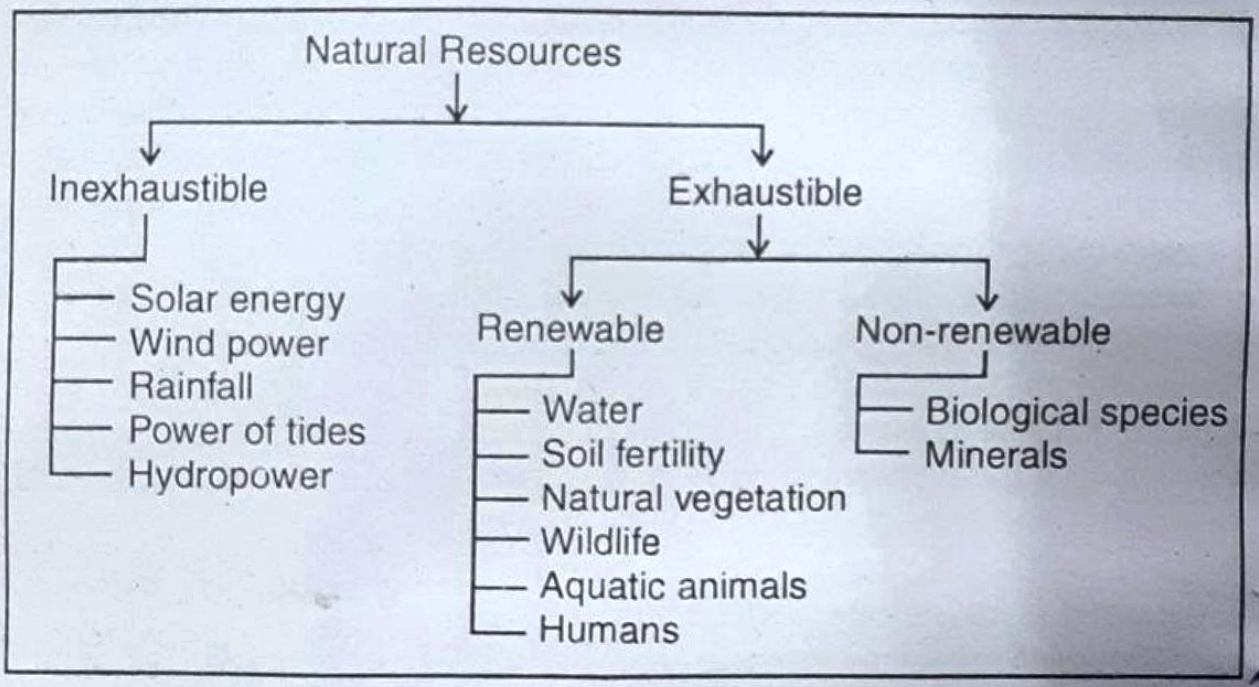
The word resources is made up of two words : Re+source. 'Re' means again while 'source' implies basic or original place of birth. Therefore, resource literally means resurgence of a thing from its original place of birth. According to dictionary, "Those things of human life and environment which are essential for survival of human being are known as resource." The most important natural resources are water, soil, sunlight, air, forests, animals and minerals as man depends upon them for satisfying his needs of food, clothing and shelter. The meaning of the word 'Resources' has undergone a change in recent times, as a result of interaction among nature, man and his culture. During the early days of twentieth century the most valuable natural endowments were known as natural resources but due to man's advancement of science and technology the concept of natural resources has broadened. Now-a-days the natural resources couple the whole natural environment as each and every part of it is well equipped with the natural gifts or natural endowments for use by man. In this respect all the living and non-living elements of lithosphere, atmosphere and hydrosphere have become natural resources as they are capable of providing comforts to man.

Resources can be classified into two main categories :

(i) **Renewable Resources.** These are enexhaustive in nature and can be regenerated within a given span of time *e.g.,* forests, wildlife, wind energy, biomass energy, tidal energy, hydro power etc. Solar energy is also a renewable form of energy as it is an inexhaustible source of energy.

(ii) **Non-renewable Resources.** These cannot be regenerated *e.g.,* Fossil fuels like coal, petroleum, minerals etc. Once we exhaust these reserves, the same cannot be replenished.

Table 2.1.



Conservation

The word 'conservation' is derived from two Latin words, 'con' meaning 'together' and 'servare', meaning to 'keep' or 'guard'. Therefore 'to keep together' is the literal meaning of the word conservation. The word conservation was coined by Gifford Pinchot shortly after the White House Conference of 1908. In general, the concept of conservation was started for non-renewable resources but for renewable resources also proper management is necessary, which is a part of conservation.

The conservation of natural resources is a concept that deals with the rational use of resources so that a harmony between man's resources requirements and its availability can be established. While renewable resources need a proper resources management system, the non-renewable resources require a long-term strategy for their proper use. This is not only essential to certify long-term resource utilization but also to guard the ecosystem. Nowadays each country is very specific with its natural resources and tries to openly favour conservation policies.

Apart from national efforts by each country, efforts on global level have also been started under United Nations. Different agencies of the UN are now playing a key role in setting the world on the long road towards conservation of natural resources and protection of the environment. The increase in public support for conservation measures both at international and local levels has given this movement a new life, but still there is a long way to go.

In this chapter we will study about the status and conservation of the following major natural resources :

(a) Forest Resources
(b) Water Resources
(c) Mineral Resources
(d) Food Resources
(e) Energy Resources
(f) Land Resources.

Forest Resources

The word 'Forest' is derived from Latin word *'Foris'* which means a thing outside home or the land undistributed by man. In other words, natural cover of grass, plants and trees is called as forests. In the beginning almost 75% of the earth's surface was covered with forests, but in course of time with increase in population and added requirement of land for its settlement and other activities, the forest area went on depleting and, at present, it covers only 30% of the surface. Former USSR accounts for about a 5th of the world's forests, Brazil for about a 7th and Canada and USA each for 6-7%. Now man sees the depletion of forest resources with concern and is making efforts to conserve them. The greatest losses have occurred in tropical Asia where one third of the forest resources have been destroyed. However, latest reports reveal that maximum loss of forest cover is currently taking place in Brazil.

Uses of Forests

Forests are an important renewable natural resource. Forest ecosystem is dominated by trees, their species-content varying in different parts of the world. Forests contribute substantially to the economic development of our country by providing goods and services to the people and industry. They also play an important role in enhancing the quality of environment by influencing the life supporting system. Forests are also linked with our culture and civilisation. Forests help man in several ways. They provide numerous products and also many indirect advantages to him.

Food. Man especially aborigins depend on forests for food. Forests provide him fruit, nuts and roots which are directly and indirectly satisfy his food needs.

Clothing. Forests are responsible for satisfying clothing needs of man in a big way. They provide chemicals and wild animals living in forests provide him for chemicals and fir are used for making clothes.

Housing. Man builds houses with materials obtained from forests. Even the modern houses in big cities get timber for wood work. One third of the wood harvest is used for building materials as lumber, plywood and hardwood, particle board and chipboard.

Fuel. Half of the timber cut each year is used as fuel for heating and cooking. Forests were major source of power. They still hold this status, though some what subdued. Wood is used in houses and factories as a means of power. Actually forests are the basis of coal and petroleum.

Industrial Raw Materials. Innumerable products such as rubber, gum, cork, raisin, tunning materials, gataparcha and terpentine, woodpulp, sabai grass, tree branches and timber etc., are obtained from forests. We use them in factories and industries as raw materials to produce new products, which satisfy our needs and make our life comfortable.

Non-Wood Products. In many poorer countries, especially in Asia, non-wood forest products (NWFPs) such as food, fibre, honey, and medicinal form an important source of income and a critical component of food security and well-being. Some forests are also sources of minerals. Forests provide employment and income, recreation, education, scientific study, protection of natural and cultural heritage, aesthetic pleasure, and spiritual solace.

Increase in Fertility of Soil. Tree leaves fall into soil and get decayed. Decayed leaves produce humus and increase soil fertility.

Prevention of Soil Erosion. Forests control water speed during rains and allow water to percolate into the earth. Roots of trees keep soil compact and do not allow soil to become loose. Intensity of water decreases. All these factors prevent soil from being eroded. Forests also break wind speed, thus controlling deserts from spreading.

Moisture Attraction from Atmosphere. Leaves of trees attract moisture present in the atmosphere. This leads to cause rains and provide enough water for irrigation.

Production of Oxygen. The trees produce oxygen by photosynthesis which is so vital for life on this earth. They are rightly called as earth's lungs.

Reducing Global Warming. The main greenhouse gas carbon dioxide (CO_2) is absorbed by the forests as a raw material for photosynthesis. Thus forest canopy acts as a sink for CO_2 thereby reducing the problem of global warming caused by greenhouse gas CO_2.

Pollution Moderators. Forests can absorb many toxic gases and can help in keeping the air pure. They have also been reported to absorb noise and thus help in preventing air and noise pollution.

Place of Shelter to Wild Animals. Forests provide shelter to wild animals. They live, roam and grow in forests without fear and harm. Man also obtains numerous animal products from animals and birds living in forests.

State of World's Forests

It is difficult to assess the extent of the world's forests. Data supplied by countries is often unreliable, though satellite imagery is increasingly being used to verify data from ground surveys. The definition of a forest also varies from one assessment to another.

The highlights of two global forest assessments are presented below, one from the World Commission on Forests and Sustainable Development (WCFSD), and the other from the Food and Agricultural Organization (FAO) of the UN.

Table 2.2 :
Change in Forest Resources of World (1990-2000)

Areas of the world	Total forests (Forest area in million hectares)		Change 1990-2000
	1990	2000	Percentage
Africa	702	650	–7.8
Asia	551	548	–7.0
Australia and other island	201	198	–1.8
Europe	1030	1039	+0.8
Northern & Central America	555	549	–1.0
Southern America	923	886	–4.1
Total of World	3962	3869	–2.2

Source : UNO Food and Agriculture Organization, State of the World Forest, 2001.

In its 1999 report, WCFSD came to the following conclusions about the state of the world's forests :

- The world's remaining forested areas amounted to about 3.6 billion hectares in 1999, down from about 6 billion hectares 8000 years ago.
- Fifty six countries have lost between 90 and 100 per cent of their forests.
- Over the last two decades of the twentieth century, 15 million hectares of forest were lost annually, largely in the tropics.
- About 14 million hectares of tropical forests have been lost each year since 1980 due to conversion into cropland.

- Forest decline threatens the genetic diversity of the world's plants and animals. About 12.5 per cent of the world's plant species and about 75 per cent of the world's mammal species are threatened by forest decline.
- In developing countries alone, some US$ 45 billion per year is lost through poor forest management.
- In Europe, forests are declining due to drought, heat, pests, and air pollution. The number of completely healthy trees in European forests fell from 69 per cent in 1988 to 39 per cent in 1995.

The WCFSD concluded, 'The decline is relentless. We suspect it could change the very character of the planet and of the human enterprise within a few years unless we make some choices'. The Global Forests Resources Assessment 2000 (FRA 2000) of the FAO was primarily based on information provided by countries, supplemented by state-of-the-art technology to verify and analyse the information. More than 200 countries and areas were presented in the assessment. For the definition of a forest, FRA 2000 adopted a threshold of 10 per cent minimum cover, for both natural forests and forest plantations.

The main findings of FRA 2000 were :

- The world's forest cover in 2000 was about 3.9 billion hectares, or approximately 0.6 hectare per capita. About 95 per cent of the forest cover was in natural forest and 5 per cent in forest plantations.
- The distribution of forest area by ecological zone, in terms of percentage, was 47 per cent in the tropics, 33 per cent in the boreal zone, 11 per cent in temperate areas, and 9 per cent in the subtropics.
- Deforestation in the 1990s was estimated at 14.6 million hectares per year. The figure represents the balance of annual losses of natural forests minus the area replaced through reforestation with forest plantations. Expressed in another way, during the 1990s, the world lost 4.2 per cent of its natural forests, but gained 1.8 per cent through reforestation (with plantations), afforestation, and the natural expansion of forests.
- Overall, however, the loss of natural forests is still high in the tropics, and increases in plantation establishment and the natural expansion of forests have not been able to compensate for the losses incurred.
- Despite the high losses of the world's natural forests at the global level, new forest plantation areas are being established at the reported rate of 4.5 million hectares per year. The countries with the largest plantation development are China, India, Russia, the US, Japan and Indonesia.
- Initiatives to promote sustainable forest management have stimulated many countries into implementing forest management

plans. At least 123 million hectares of tropical forests were reportedly subject to management plans. In industrialized countries, the majority of the forests are under some form of protection or sustainable management.

- Of the world's forests, 12.4 per cent were estimated to be in protected areas according to the categories defined by the World Conservation Union (IUCN).

Table 2.3 :
Comparison of Forest Cover

Country	Percentage of Total Forest Area	Country	Percentage of Total Forest Area
Finland	69.23	France	24.45
Brazil	65.91	Australia	18.87
Sweden	62.22	China	13.40
Malaysia	53.33	India	11.73
Canada	45.43	England	9.79
Nepal	35.46	Bangladesh	5.51
America	31.61	Pakistan	2.38
Sri Lanka	25.76		

Source : World Development Report,1997

Over Exploitation

Exploitation of forests has been continued since early times for their vast potential. It was the growing demand of the cities that also destroyed our forests. Besides this local cattle, goats, sheep etc., not only destroy the vegetation but also pull out the roots of plants. After denudation of our Himalayas, the process of deforestation started in the Shivalik range (extending parallel to the Himalayas). Shivalik sal forests were over-exploited for industrial use (railway sleepers etc.). Thus foot hills of the Shivaliks once covered with dense forests, are facing an acute water scarcity and semi-desert conditions. When forests die, ecological balance maintained by nature breaks away; and floods or drought are the terrible consequences. The trees not only increase rainfall of an area, but also conserve the water which falls on the ground as rain. Plants also reduce evaporation thus allowing water to remain in soil for a long time.

Forests are being destroyed to meet human demands in the following ways :

(a) Commercial logging methods directly and indirectly lead to deforestation. In many places, to obtain one cubic metre of log wood, two cubic metres of standing trees are destroyed. New extractive technologies

can cut trees very quickly. When some species are selected for logging, non-target species are also damaged.

(b) Logging companies create infrastructure, especially roads, in forests to make their task easier. However, roads provide easier access to the interiors of forests and encourage the entry of invasive species, hunters, poachers, tourists, plant collectors, and people in general. This, in turn, leads to further exploitation of the forest resources.

(c) Another area of concern is the depletion of forest-based wildlife due to commercial harvesting and trade of bushmeat. This practice of killing wild animals for meat is prevalent in Africa, where many species of primates and antelopes are threatened.

(d) The construction of dams in forests invariably causes enormous damage. Dam reservoirs inundate and destroy forests and their biodiversity.

Deforestation

In day-to-day language, uncontrolled felling of forests is known as deforestation. In official language deforestation is a continuous loss of forest area resulting from cutting of forests than planting. Extensive and unabated deforestation, over-grazing and the growing hunger for land have hit the ecology of the world. The total forest area of the world in 1990 was estimated to be 7,000 million hectares which was reduced to 2,890 million ha in 1975 and fell down to just 2,300 million ha by 2000. Deforestation rate is relatively less in temperate countries, but it is very alarming in tropical countries where it as high as 40-50 per cent and at the present rate it is estimated that in the next 60 years we would lose more than 90 per cent of our tropical forests.

Despite increasing awareness of importance of forest, deforestation rates continue to increase.

- Each day about 32,300 ha of forest disappear from the Earth and another 32,300 ha of forest suffers degradation.
- During 2000-2005, the tropical deforestation rate has increased by 8.5% as compared to 1990's deforestation rates.
- Loss of primary forests have increased by an alarming 25%.
- Further, primary forests are being replaced by plantations with much less biodiversity.

Indian Scenario

India today is the poorest in the world as per capita land is concerned. The per capita forest land in India is 0.10 hectare compared to the world average of 1 hectare, Canada 14.2 hectare, Australia 7.6 ha and USA 7.30 ha. Indian forests comprise only 0.50 per cent of the world forest area. India is losing about 1.5 million hectares of forest cover each year. If this trend continues we may in the next 20 years or so reach to zero forest

value in our country. During a period of 25 years (1951-1976) India has lost 4.1 million hectares of forest area.

Large-scale deforestation has been done for fuel, fodder, valley projects, industrial uses, road construction etc. India consumes nearly 170 million ton of firewood annually, and 10-15 million hectares of forest cover is being stripped every year to meet fuel requirements. Actual fuelwood consumption went up from 86.3 million ton in 1953 to about 135 million ton in 1980, indicating pressure on forests. During a period of 20 years (1951 to 1971) forests have been cut for agriculture (24.32 lakh hectares), river valley projects (4.01 lakh hectares), industrial uses (1.24 lakh hectares), road construction (0.55 lakh hectares) and miscellaneous uses (3.88 lakh hectares).

Thus a total of 3.4 million hectares of forests were lost during this period. Nearly 1 per cent of the land surface of India is turning barren every year due to deforestation. In the Himalayan range, the rainfall has declined 3 to 4 per cent due to deforestation.

Table 2.4

Forest Statistics : Indian Perspective

• Total forest area	: 67,701,000 ha
• Percent of land area	: 22.8%
• Deforestation Rates	
Total forest loss (since 1990)	: 3,762,000 ha
Annual forest loss (2000-2005)	: 29,400 ha
• Break down of forest area	
Natural	: 32,943,000 ha
Semi-natural	: 31,532,000 ha
Production plantation	: 1,053,000 ha
Plantations (2005)	: 3,226,000 ha
• Forest classification	
Public Forest	: 98.4%
Private Forest	: 1.6%
• Forest use	
Production	: 21.2%
Protection	: 14.8%
Conservation	: 21.7%
Multiple purposes	: 42.4%

Source : MoEF (Annual Report 2005-06)

Causes of Deforestation

The causes of deforestation and denudation are well known. The principal causes have been the population explosion in man and livestock

leading to enhanced requirement of timber and fuelwood, and grazing respectively. Following are some of the important causes of deforestation :

1. **Natural Causes.** Natural causes have always been responsible for forest destruction but nature counters the damage by producing more forests itself. Secondly, natural causes affect a limited forest area. All forests on the earth are not affected by it. Some the causes are :

(*a*) **Forest Fire.** During summers, dry leaves and twigs catch fire due to friction and heat; sometimes lightning is also responsible for forest fire. Due to this, many times the forests of an area are damaged.

(*b*) **Natural Disasters.** Many times natural calamities like earthquakes, floods, cyclones etc. also destroy or damage the forests.

(*c*) **Biological Factors** : Biological factors also play a role in deforestation. They include pet animals, microbes, bacteria and insects etc. which can damage the trees.

2. **Human Factors.** The man-made factors far exceed the natural causes in their destructive power *e.g.* in deforestation at present. The main human factors are following :

(*i*) **Expansion of Agricultural Land.** With the development of human civilization a large scale deforestation took place to meet the demand for agricultural land. With further increase in population, the demand for food increased and therefore the land for agriculture was largely expanded by damaging a large area of forests. In India only, in the last two decades, approximately 35 lac hectares forest land has been converted into agriculture land.

(*ii*) **Shifting Agriculture.** The practice of shifting agriculture has continued for thousands of years in the North-Eastern states of India (Assam, Arunachal Pradesh, Mizoram, Nagaland, Meghalaya. Manipur and Tripura). It is called as Jhum cultivation. In this type of agriculture, the farmers clear an area of forest by cutting or fire and use it for agricultural practices. After some years, when the fertility of that land is reduced, they leave it and clear other area in the same way. This practice of agriculture is proving fatal for environment and forests for the past 40-50 years. Earlier, only survival of a family was the main concern for agriculture and the methods of agriculture were traditional; a family did not have to clear a new area before 20-30 years. But now, market and profit motive is spreading; therefore, the frequency of land clearing has increased and land has to be cleared within 4 or 5 years or even 3 years. It means every third or fourth year new land is to be cleared, which is causing heavy losses of the forests. Population increase is also a reason for this change.

It is also worth mentioning that shifting agriculture was practised in states like Kerala, Andhra Pradesh, Orissa, Madhya Pradesh, Himachal Pradesh and Rajasthan.

(*iii*) **Plantation and Horticulture.** Another important cause of deforestation is commercial plantation. In this, for the crops like apples, rubber, coco, coffee, coconut etc. the hill slopes are cleared of forests by cutting or burning. For this kind of agriculture, the forest or hilly slopes are cut on a large scale for plantation in countries like Malaya, Indonesia, Sri Lanka and India. Moreover, the wooden boxes for packing the products of these plantation are also made by destroying the forests. For example, in Himachal Pradesh, approximately 50,000 trees are cut annually to meet packing demands.

(*iv*) **Over-grazing** : With increase in population, the need for dairy products increased. For fulfilling this need the number of cattle was enhanced and under dairy farming industry forests were cleared and developed into pastures. With continuous over-grazing the vegetation is vanishing. Specially, grazing causes a harm to newly germinated plantlets in the forest area. The natural development of forests is thus stopped this way. In the areas with mediterranean climate and in temperate areas, grazing on a large scale has damaged the forests.

(*v*) **Mining.** Due to mineral extraction, the land in mining area is disturbed. The vegetation cannot grow in this land and if vegetation is to be restored, it takes a lot of time. An irreparable loss is taking place of the forest resources due to mining activities in West Bengal, Jharkhand, Orissa, Madhya Pradesh, Uttar Pradesh, Rajasthan and Uttrakhand etc.

(*vi*) **Dam-projects.** The forests have been destroyed on a large scale for constructing multipurpose river valley dam projects in almost all countries of the world. Due to these projects a lot of forest areas have been flooded. In India, only Narmada Sagar Dam project has resulted in loss of 40,322 hectares of forests.

(*vii*) **Commercial Purposes.** Forests provide raw materials for many industries. For example, paper and pulp industry, match boxes, board, packing, railway compartments, boats and timberwood are the industries or products for which raw material is obtained from forests. For this purpose, forests are cut very unscientifically taking into consideration only the benefits of contractors. On the other side, due to increase in population, the need for raw material is continuously increasing. Consequently, the demand of wood for commercial purposes is increasing. In the areas of equatorial line 20 million hectares of forests are cleared annually only on commercial grounds. In the same way, a forest area of around 14.6 lac hectares has been cleared for industrial purpose in India in only last three years according to an estimate.

(*viii*) **Development of Road and Rail Transports.** Deforestation done for construction of railway tracks and roads is also not less significant. For millions of kilometres of railway tracks and roads millions of hectares of forests are destroyed worldwide. For example, in the last three decades 73

thousand hectares of forests have been destroyed in India only for road construction.

(*ix*) **Urbanization and Tourism.** Due to increase in population and many other reasons, urban area is expanding. Forests are cleared to supply land for habitation. Forest area is contracting. In the era of modernity, very large residential houses, beautiful hotels and community homes are being constructed in which much more wood is used than in simple residential houses. Tourist activities have also harmed forests. Specially in hilly regions, hotels are constructed to attract the tourists. Even the places at very high altitudes like Gangotri are not spared.

(*x*) **Firewood and Fodder.** In rural areas, the forests are cut for the purposes of firewood and fodder also. Mainly in deserts people use green leaves of trees as fodder. The moisture loss in atmosphere due to this results in low amount of rain. According to an estimate, for only using as firewood, 23 crore 50 lac cubic metre fuelwood is cut annually in India. Some specialists believe that the wood used for fuel is mainly derived from branches and twigs thereby causing no great harm to forests.

Impacts of Deforestation

Deforestation exposes soils and shade species to wind, sunlight, evaporation and erosion. Soil fertility goes down due to the rapid leaching of essential mineral nutrients. The topsoil is eroded and this accelerates siltation in dams, rivers, and the coastal zone. The increased sedimentation harms downstream fisheries.

(1) Deforestation, degradation and fragmentation of forests affect many species and lead to the extinction of some. In particular, migratory birds and butterflies suffer due to the loss of their habitat.

(2) Local and global climate changes may also result from deforestation. Studies have shown that about 97 per cent of the water absorbed from the soil by the roots of plants, evaporates and falls back on the land as precipitation. When a large forest is cut down, the regional rainfall pattern may be affected.

(3) Deforestation may also lead to global warming by releasing carbon stored in the trees. It the trees burn, the carbon is released immediately. If the trees are cut and removed, half the carbon remains in the form of branches, twigs, etc. When they decompose, the carbon is slowly released.

(4) Deforestation has increased land erosion a lot, which causes fertile soil flows to sea alongwith water. Due to absence of trees on an average 6,000 million tonnes of fertile soil in India flows to sea annually.

(5) Clearing of forests affects local communities, who lose their source of food, fuel, construction materials, medicines, and areas for livestock grazing. What is more, they lose their culture and way of life.

Forest Fires

Wildfires, usually started by lightning, have an ecological role. The combustion frees the minerals locked in the dry organic matter. The mineral-rich ashes are necessary for the growth of plants. The vegetation usually flourishes after a fire.

Fires remove plant cover and expose the soil, which stimulates the germination of certain types of seeds. They also help control pathogens and harmful insects. Occasional fires burn away some of the dry organic matter and prevent more destructive fires from occurring later on. For all these reasons, prevention of fires is not necessarily good for a forest.

Intentional or accidental human-induced fires do however cause damage. Such fires have become a major problem in large forests, especially in countries like Canada and the US. In a number of developing countries, fires continue to be used for land clearing with adverse consequences.

Climate change also causes more fires than usual. In many countries, there was an increase in wildfires during the 1990s as compared with previous decades. The climate phenomenon El Niño was implicated as a major contributing factor to the severe forest fires in the 1990s (as well as in the 1980s). El Niño is an occasional phenomenon that causes change in climate patterns worldwide (see Chapter 14 for a more detailed account). This phenomenon provokes severe droughts in generally humid or temperate areas, enhancing the propensity for devastating fires.

Big Dams

Big dams and river valley projects have multi-purpose uses, however, these dams are also responsible for the destruction of vast areas of forests.

India has more than 1550 large dams, the maximum being in the state of Maharashtra (more then 600), followed by Gujarat (more than 250) and Madhya Pradesh (130). The highest one is Tehri dam, on river Bhagirathi in Uttarakhand and the largest in terms of capacity is Bhakra dam on river Satluj in Himachal Pradesh.

Big dams have been in sharp focus of various environmental groups all over the world which is mainly because of several ecological problems including deforestation and socio-economic problems related to tribal or native people associated with them. The Silent Valley hydroelectric project was one of the first such projects situated in the tropical rain forest area of Western Ghats which attracted much concern of the people.

For building big dams, large scale devastation of forests takes place which breaks the natural ecological balance of the region. Floods, droughts and landslides become more prevalent in such areas. Forests are the repositories of invaluable gifts of nature in the form of biodiversity and by destroying these (particularly, the tropical rain forests) we are going to lose these species even before knowing them. These species could be having

marvellous economic or medicinal value. This storehouse of species which have evolved over millions of years get lost due to deforestation in a single stroke.

Forest and Climate Change

Forests both influence and are influenced by climate change. They play an important role in the carbon cycle and the way we manage forests could significantly affect global warming.

Forests hold more than 50 per cent of the carbon that is stored is terrestrial vegetation and soil organic matter. Hence, deforestation contributes significantly to net emissions of carbon dioxide into the atmosphere.

If the predicted global warming occurs, the impact on forests is likely to be regionally varied, dramatic, and long-lasting. Even now, we can see how any extreme weather has great impact on forests. For example, the 1999 storms in Europe caused heavy damage to forests and also to trees outside forest areas.

The Kyoto Protocol on climate change may have a great impact on forest management. Under the Protocol, a country with forests emission credits, since its forests absorb carbon dioxide. These credits are tradable, that is, a developing country can sell its credits to an industrialized country that has exceeded its quota of emissions. The latter would invest in afforestation and reforestation projects in the developing country.

Forest Conservation

Sustainable forest management was first discussed at the international level at the Earth Summit held at Rio de Janerio, in 1992. These were major differences between the industrialized countries and the developing countries and the Summit could only come up with a set of non-binding principles.

The International Tropical Timber Organization (ITTO) was set up in 1983 under the United Nations Commission for Trade and Development (UNCTAD). ITTO brings together the producer and consumer countries and is a major platform for issues concerning sustainable forest management. In 1985, FAO, UNDP, the World Bank, and the World Resources Institute came up with the Tropical Forestry Action Plan, later revamped and renamed as the National Forest Action Programme.

The Kyoto Protocol, Convention on Biological Diversity, and the Convention to Combat Desertification are three of the international agreements that have a bearing on forests. The UN Forum on Forests, created in October 2000, is a permanent high-level intergovernmental body with universal membership.

Declaring forests as protected areas or as biosphere reserves is a measure adopted by most countries. This is also supported by initiatives like the UNESCO Man and the Biosphere Programme.

Sustainable Forest Management

Sustainable Forest Management (SFM) is the use of the world's forests in such a way that they continue to provide resources in the present, without depriving future generations of their use. One of the principles of SFM is to fully involve local communities in forest management. Implementing this principle is, however, difficult since forest departments are usually very reluctant to lose their control over forest resources.

SFM has also become an element of climate change negotiations. As mentioned earlier, the Kyoto Protocol would compensate countries for the benefits their forests provide to the world. The industrialized countries are ready to support SFM in developing countries so that they can buy the credits and continue to pollute the atmosphere.

By 2000, 149 countries were engaged in nine international initiatives to develop and implement criteria and identify indicators for SFM, covering 85 per cent of the world's forests. There are 140 countries with national programmes in various stages of development.

Communities Involved

Many local communities have lived in or near forests and have used them in a sustainable manner. In the twentieth century, however, there were two developments in this regard.

- First, due to an increase in population and poverty, new groups migrated into the forest areas and began over-exploiting the forest resources.
- Second, when governments began protecting forests and declaring them as protected areas, they viewed the local people as enemies of the forests and tried to prevent them from even entering the forest area.

The result was an increase in the illegal use of forest resources and conflicts between government representatives and the local people.

It is now increasingly being realized that local people should be regarded as partners in conservation. Most programmes now involve local communities in planning, decision-making, and implementation. In return for controlled access to the forests, the locals can provide labour and help in conservation. They can become excellent guides in ecotourism ventures.

Extractive Reserves. Extractive reserves are protected forests in which local communities are allowed to harvest products, such as fruits, nuts, rubber, oil, fibres, and medicines, in ways that do not harm the forest. The objective is to improve the lives of the people, while conserving biodiversity.

This approach believes that local people would have a greater stake in conservation if they continue to get the benefits that they previously enjoyed. It recognizes the fact that, in many instances, we have to use the land and forests in order to preserve them.

In India and some other countries, communities living in or near the forest are involved in conservation in three ways : joint forest management, social forestry, and sacred groves.

Joint Forest Management. Around the 1980s, the Government of India came to recognize the important role of local communities in forest conservation. They introduced the concept of Joint Forest Management (JFM), with a view to working more closely with local user communities in the protection and management of forest resources.

In JFM, the local communities are involved in planning the conservation programme. They are allowed controlled access to the forest areas and permitted to harvest the resources in a sustainable manner. In return, they become the guardians of the forest.

The Tamil Nadu Afforestation Project (TAP), implemented with Japanese aid, is cited as a successful example of JFM. During the first phase (1995-2003) of implementation, Rs. 6.5 billion was spent and one million acres of degraded forest land and upgraded, involving 400,000 people in 1800 villages.

In the TAP villages, 2500 self-help groups comprising 25,000 women were formed. The basic needs of the people of the TAP villages such as drinking water and roads were met by integrating the development schemes of several departments.

Social Forestry. Social forestry refers to the planting of trees, often with the involvement of local communities, in unused and fallow land, degraded government forest areas, in and around agricultural fields, along railway lines, roadsides, river and canal banks, in village common land, government waste land, and panchayat land.

The term 'social forestry' was first used in India in 1976 and the idea has been adopted in many Asian Countries. A major controversy has been the planting of eucalyptus trees under social forestry projects. Eucalyptus was chosen for the majority of social forestry projects because it survives on difficult sites and out-performs indigenous species in growth, producing wood very rapidly. However, it has some adverse ecological impacts on soil nutrients, water hydrology, biodiversity, and wildlife.

The traditional sacred groves of India play an important role in community participation and conservation of biodivesity. The sacred groves of India are a unique traditional institution devoted to the conservation of forests and biodiversity. Over time, hundreds of these groves have disappeared under the twin pressures of population and development. However, according to one survey, over 13,000 groves still survive as patches

across the country. Other estimates put the number at between 100,000 and 150,000. Only groves in remote areas remain undisturbed, while others need protection.

In recent years, there has been an increasing interest in documenting and conserving the sacred groves. In 1999, the Indira Gandhi Rashtriya Manav Sangrahalaya (the National Museum of Mankind) and several other institutions established a museum for sacred groves in Bhopal, with the goal of raising awareness of the important role these ancient forests play in conservation. The museum celebrates the communities, festivals, and rituals associated with the gloves of different states.

Role of Individuals and Groups

There are remarkable stories from all over the world of individuals and groups going to great lengths to save or plant trees. Some examples are :

Chipko Movement. It was born in a small hilly village of the upper reaches of Himalayas. The illiterate tribal women commenced this unique movement in December 1972 that became famous as the Chipko (means to embrace) movement. It questioned the development based on the ruthless butchery of nature to achieve short term gains. It challenged the old belief that forests mean only timber, and emphasized their role in making soil, water and pure air which are the basis of life.

On March 26, 1974, a group of men arrived stealthily in the forest next to Renni village in the Garhwal District of the Himalayas. They had been set by a contractor to begin cutting down 2500 trees in the forest. Anticipating resistance from the people, the contractor had ensured that all the men of the village were away on that day.

Word of the arrival of the axe-men spread in the village and the women came out of their houses. About 25 of them, led by Gaura Devi, confronted the contractor's men. They pleaded with the men not to start the felling operations, but the men responded with threats and abuses. As the confrontation continued, more women joined the protest. Ultimately, the men were forced to leave, since the women would not budge.

The movement continued under the leadership of Shri Sunderlal Bahuguna in various villages like Advani and Budhekar of Tehri-Garhwal. Mr. Bahuguna presented the plan of this movement for protection of soil and water through ban on tree-felling in the Himalayas at the UNEP meeting held in London in June 1982. Every standing green tree in the forest is a sentry to protect us from avalanches and landslides, to save our soils and conserve our water. Important gift of three to us is not timber, but soil, water and oxygen.

The Chipko's plan is infact a slogan of planting five Fs—food, fodder, fuel, fibre and fertiliser trees to make communities self sufficient in all their basic needs. It should generate a decentralized, self renewing and long term prosperity. It will protect the environment and bring permanent peace,

prosperity and happiness to mankind. Mr. Bahuguna alongwith a team of dedicated workers later undertook marches of 300 km from Srinagar (Kashmir) to Siliguri.

Appiko Movement. Chipko reached to Karnataka as Appiko. Like a migrating bird the idea of Chipko flew south to Salkani village of Sirsi taluka in North Kanara district of Karnataka on September 8, 1983. The Chipko movement put on new feathers to become the Appiko Chaluvali of Kannada. Some 160 men and women marked eight km to the Kelase forest where the contractor's axemen under orders from the forest department has turned the area into a slaughter house. They hugged the trees and compelled the axeman to stop tree felling.

As the movement started spreading, political parties jumped forward to monopolise it. Mr. Pandurang Hegde, a student of Delhi School of Social Work went to Navjeevan Ashram in Tehri Garhwal in 1979. This was centre of Chipko movement. He participated in the movement and later joined the Kashmir-Kohima Chipko foot march in Bhutan. The Appiko movement was launched in other talukas of the district. Due to this local contractors became much nervous. The movement organisers received much support from many other quarters. For instance, Prof. Madhav Gadgil of Indian Institute of Science, Bangalore could conclude "that contentions of Yuvak Mandalis *i.e.,* excessive damage in the course of felling and excessive concentration of trees marked for felling were true." He went on to recommend that such Mandalis be involved in conservation programmes. Indian Plywood Co., the West Coast Paper Mill, Harihar Polyfibres, WIMCO etc., can never undo the incalculable harm caused by depletion of forests in Western Ghats.

Green Belt Movement. Wangari Maathai is a social and political activist of Kenya. She studied in the US and also received a doctorate in biology from the University of Nairobi, the first woman in east and central Africa to do so. She was a Professor at the Nairobi University in Kenya when she launched the Green Belt Movement (GBM) in 1977.

Her objective was to empower the people and to show them that they could choose to destroy or build the environment. GBM encouraged poor women to plant millions of trees to combat deforestation, in return for which they received sufficient fuelwood.

The movement has set up 5000 tree nurseries run by women and disabled persons. Seedlings are given away free to groups and individuals. For every tree that survives for three months, the planter receives a small payment. By 1988, 40,000 people were planting trees and in due course the movement spread to many other African countries.

Wangari came into the limelight when she led a protest against the building of a 62-storey building in the middle of Freedom Park, Nairobi's most popular public space. The then President, Daniel Arap Moi, labelled her and the GBM subversive. Faced with intense persecution, she had to leave the country for a while. Her marriage also broke up.

When Wangari returned to Kenya, she took up the cause of political prisoners. She criticized the President for allowing deforestation and displacing people. Once, when she and a group of women were on a hunger strike demanding the release of political prisoners, the riot police came in and knocked her unconscious. Through all the persecution, Wangari stood solid and unbowed, like the trees she had planted.

The political climate changed in Kenya in 2002, when Mwai Kibaki came to power. Wangari became a Member of Parliament and the new President appointed her as Assistant Minister for Environment. In October 2004, she was awarded the Noble Peace Prize.

Chico Mendes. The efforts of Chico Mendes cannot be forgotten. As a leader of the tappers' union, Chico campaigned for extractive forest reserves for tappers, who would use and maintain the rainforest in its natural state for generations. He ran into a conflict with powerful groups interested in clearing the forests for raising cattle. Chico argued that this would destroy valuable forests and that overgrazing would reduce soil fertility. Ranching would only bring short-term gains.

In 1988, the Xapuri Rural Workers' Union led by Chico successfully prevented the powerful cattle rancher, Darli Alves, from deforesting an area that the tappers wanted as a reserve. On December 22, 1988, Chico was shot dead. Darli was later convicted of Chico's murder.

Chico's death brought international attention to the question of saving the Amazon forests. His name has become synonymous with the worldwide fight to save forests. In 1990, the Chico Mendes Extractive Reserve was established and so also the Chico Mendes Foundation.

Model Questions

1. What is natural resource? Give examples.
2. What are renewable and non-renewable resources? Explain in brief.
3. Write a short note on the concerns resulted due to over-exploitation of natural resources.
4. What is the state of the world's forests?
5. Discuss the major uses of forests.
6. What are the products and services provided by forests?
7. Explain the causes and consequences of deforestation.
8. What is the role of forest lines?
9. Discuss the relationship between forests and climate change?
10. What are the international and national initiatives in forest management? Explain in brief.
11. Write a note on the sustainable forest management.
12. How can local communities be involved in forest conservation?
13. How can we save the remaining forest of the world?
14. Write a note on the effects of big dams on forests.

3
Water Resources

Water is a prerequisite for the existence of life. Human beings, animals, and plants cannot survive without water; in fact, the human body is mostly water. We can go without food for up to 30 days or more, but we cannot go without water even for a few days. When the water content in the body by just 1 per cent, we experience thirst. If it drops by 10 per cent, there is danger of death.

Water is the most critical limiting factor for many aspects of life, such as economic growth, environmental stability, biodiversity conservation, food security, and health care. In most cases there is no substitute for water. An energy source can be replaced by another, but water as a resources is largely irreplaceable.

The good news about water is that we can reuse it. It may change its form, but we can always retrieve it. In fact, the molecules in the water we use have been around for millions of years. The Earth holds the same quantity of water as it did when it was formed.

The paradox of the water situation is that there is scarcity amidst plenty. As we shall see, there is a lot of water on Earth and yet there are millions of people facing acute water scarcity.

World Water Scenario

The total water in the world is estimated to be 1400 million cu. km. If all this water were spread over the surface of the earth, it would be 3 km deep. This is a lot of water. Unfortunately, 97 per cent of this water is found in the ocean, and is too salty to drink.

Of the remaining 3 per cent, two-thirds is locked up in relatively inaccessible Icecaps and glaciers. That leaves a mere 1 per cent or 14 million cu. km. Again, half of this is ground-water and most of it lies too far underground. About 200,000 cu. km. can be found in rivers and lakes and 14,000 cu. km. in the atmosphere.

- A key element of the water cycle helps us get a regular supply of fresh water. Annually, about 430,000 cu. km. of water evaporates from ocean and only about 390,000 cu. km. returns as precipitation. The remaining 40,000 cu. km. moves from the ocean and falls on

the land as rain and snow. The first advantage is that we get this supply every year. Second, as the water evaporates from the ocean and falls on land it loses its salt content and thus becomes potable.

- We need water for domestic purposes (drinking, bathing and sanitation), agriculture, industrial processes, and energy production. The water needed for each activity varies with climate, lifestyle, culture, tradition, diet, technology, and wealth. Also, the more accessible the water, the more it is used.
- The absolute minimum requirement for domestic use is 50 litres per person per day, though 100-200 litres is often recommended.
- Adding the needs of agriculture, industry, and the energy sector, the recommended minimum annual per capita requirement, according to the World Health Organization (WHO), is about 1700 cu. m.
- The annual supply of fresh water is 40,000 cu. km. and this amounts to about 6600 cu. m. per person per year (for a population of 6 billion). This appears to be plentiful, since the minimum annual needs of a person are only about 1700 cu. m. By this token, we should be comfortable with regard to the world water situation. Yet, there is worldwide scarcity of water.

Water Scarcity

If a country has about 1700 cu. m. of fresh water per person per year, it will experience only occasional or local water problems. If the availability falls below this threshold value, the country will begin to experience periodic or regular water stress. If the availability of water further falls below 1000 cu. m. per person per year, the country will suffer from chronic water scarcity. The lack of water will then begin to adversely affect human health and well-being as well as economic development. If the annual per capita supply of water falls below 500 cu. m., the country will reach the stage of absolute scarcity.

In India, the per capita water availability was 5177 cu. m. 1951, but the figure dropped to 2464 cu. m. in 1990 and further down to 1820 cu. m. in 2001. India will be the next major country to move into the water-stressed category.

In 1990, 28 countries, with populations totalling 335 million, experienced water stress or scarcity. By 2025, about 50 countries (including India) will fall into one of the categories mentioned above, with water scarcity affecting more than 3 billion people worldwide. China, the most populous nation in the world today, will only narrowly miss the water stress benchmark in 2025. In the North China Plain, however, water shortages are already acute, with demand outstripping supply. By the middle of the twenty-first century, only a few countries will escape a major water crisis.

Even how, in the developing world, about 30 per cent of the population or 1.2 billion people are without a safe and reliable supply of water. It is also estimated that 80 per cent of all illnesses in developing countries can be traced to contaminated water.

Causes of Water Scarcity

There are a number of reasons behind this increasing water scarcity :

(a) Distribution of available water is uneven over space and time. Some areas of the world get too much water while other places get too little. Moreover, transporting water over long distances is impractical.

(b) In some regions rainfall occurs over a short period in the year, leading to floods during the monsoon and drought in summer. The run-off, because of deforestation, flows quickly into the ocean before it can be used. Much of the rainfall is in remote and inaccessible places. Some of the rain is also needed to maintain special ecosystems, such as wetlands, lakes, and deltas. Additionally, global warming is now changing rainfall patterns.

(c) The rapidly increasing pollution of rivers, lakes, and ground-water is also reducing the usable supply of water. In many places, available water is polluted and has become unfit for use. Incredibly small amounts of substances like oil can pollute huge amounts of water.

(d) In many places the rates of extraction of groundwater for irrigation are so high that aquifers are getting depleted. As a result, water tables are falling, notably in India, China, and the US (which together produce half the world's food). The major rivers of the world are drained dry before they reach the sea. The Yellow River in China, the Ganga in India, the Amu Darya in Central Asia, the Nile in Egypt, and the Colorado in the US are some examples.

(e) There is gross inequity in allocation of water resources. In general, the richer groups corner a large portion of the available water. Again, urban areas draw a great deal of water from the surrounding areas, depriving the poorer rural people.

Summer Scarcity in Cities

The megacities of the world, many of them in the poorer countries, need a lot of water. This water is often drawn from the neighbouring villages and far off rivers and lakes. For example, during summer, the water for Chennai comes from many surrounding agricultural villages. The farmers find it more profitable to sell the water than to cultivate the fields. This clearly constitutes an unwelcome shift in water use that will ultimately threaten our food security.

There are also plans to bring water to Chennai from distant sources like the Krishna River and the Veeranam Lake. Bangalore gets its water from 90

km away. Such practices, apart from increasing the cost of supply of water, also deprive the rural areas of much needed water.

Even if a city gets good rain, the water is not retained in the area. Buildings, paving, and roads cover most of the land and the rainwater does not percolate into the ground. Chennai, for example, has an average rainfall of 1290 mm per year, which is more than the national average. Yet, 90 per cent of this rain is lost as run-off, through evaporation, or flows into the sewage system.

Megacities also pollute the water. They release large amounts of wastewater into the rivers and the ocean. Worldwide, less than 20 per cent of urban wastewater is at present treated. Another issue is that the urban poor often pay a greater part of their income for water than the rich do.

Leaking taps in cities (and other places) waste enormous amounts of water. In many cities, more than half the available supply is lost through leaks and rotting pipelines. There is an urgent need to devise water-efficient toilets, taps, washing machines, dishwashers, etc.

Accessibility of Water

Human beings use about 54 per cent of all accessible fresh water supplies. By 2025, this share will increase to 70 per cent. This will have serious implications for all other life forms, including plants.

It is significant that domestic consumption accounts for only 8 per cent of available water and yet there is world-wide scarcity of drinking water. Agriculture continues to consume the major portion of available fresh water. However, there is a clear difference in water use between developing countries and industrialized countries. While agriculture consumes the bulk of available water in the former, industry consumes more than agriculture in the latter. This shows that there will be a severe problem in developing countries once they industrialize to the level of rich, industrialized countries.

We have no reliable figures on water consumption by Indian industry. The estimates range between 10 billion cu. m. and 67 billion cu. m. per annum. We are sure, however, that this requirement is increasing rapidly. It is estimated that the demand for water by Indian industry will triple over the next 20 years. The same will be true of China and many other developing countries.

Since, the total available water supply is limited, as increase of supply to one user means taking away from another user. In the Indian case, irrigation and drinking water for the local community will both be affected.

In India, the thermal power plants are the water guzzlers, accounting for about 87 per cent of total industrial consumption of water. Across the board, the efficiency of water use in India is way behind international standards. There is tremendous scope for reduction of consumption by the Indian industry.

There is no incentive for Indian industry to reduce consumption, since it gets water at ridiculously low prices. In order to attract industrial units to an area, state governments often offer assured water supply at low rates. The pricing in most cases ignores the opportunity cost of water (that is, the benefit from possible alternate use) as well as the damage caused, such as pollution of water supplies by the discharge of wastewater.

The amounts paid by the industry to the pollution control boards under the Water Cess (Prevention and Control of Pollution) Act of 1977 are also meagre. In contrast, industries in Europe pay much more for water. In addition, some European countries have introduced the principle of 'Polluter Pays' where industries are charged for the amount of pollution contained in their wastewater discharge.

This leads us to another important aspect of the use of water by industry—the pollution of water bodies by wastewater discharge.

Table 3.1 :
India's Position in Population and Water Availability

Year	Population (in crore)	Water Availability (Cubic metre per person per year)
1947	40	5,000
2000	100	2,000
2025	139	1,500
2050	160	1,000

Source : Yojana, June 2004, p. 31.

Water for Irrigation

There has been a five-fold increase in the use of water for irrigation over the course of the twentieth century. The situation in India has worsened since the adoption of the Green Revolution package. In 1992, only 16 per cent of cropland was irrigated, but it produced 36 per cent of the food harvest. In many countries 50 per cent or more of the food production comes from irrigated land. These include countries such as India, China, Egypt, Indonesia, Israel, Japan, Korea, Pakistan, and Peru. By 2025, up to four billion people will live in countries that will have insufficient water to produce their own food.

Even now, inefficient and outdated irrigation practices continue, leading to much wastage of water. When fields are flooded with water, often only half of it gets to the root zone helping the growth of the plant. The other half is wasted as it percolates, evaporates, or runs off. Drip irrigation, the lining of canals, and precision sprinkling must be introduced immediately.

Most new land brought under agriculture uses groundwater resources that are fast depleting. Meanwhile, available agricultural land is also lost

due to salinization, reservoir siltation, shift of water use, etc., salinization is often the result of a rising water table, which can result form the practice of flooding the fields. As the water evaporates it leaves behind a deposit of salt on the topsoil. The siltation of reservoirs in big dams has often cut their lives to a mere 20 or 25 years. Finally, a shift in water use occurs when cultivation is stopped in some places in favour of selling water to a nearby city. As a result of these cropland losses, the total irrigated area may in fact be decreasing.

The agricultural fields in countries like are often over-irrigated. This is primarily because the farmers get free electricity and subsidized pumps and thus do not pay the real economic price of water. Moreover, the Green Revolution has doubled the amount of water used for irrigation.

Globalization and industrialization have led to an increased demand for water, from industry and urban areas, in different parts of the world. The rapid increase in population also means that more water is needed for drinking and for agriculture.

In many places, irrigation depends on water from dams. The world over, large dams and canal systems are going out of fashion due to spiralling costs, environment concerns, and displacement of people. Protest movement in many places have stalled the construction of dams.

All these facts seem to indicate that there is not much scope for increasing irrigation at the same rapid rate of the last century. It is also a sobering thought that all irrigation-based societies have failed in the past.

Conflicts Over Water

The next world war may well be fought over scarce resources such as oil and water. In fact, there is a long history of conflicts over water. Such conflicts may arise from the desire to possess or control another nation's water resources, thus making the possession of water systems and resources a political or military goal.

Inequitable distribution and use of water resources, sometimes arising from development projects, may lead to disputes. Conflicts may also arise when water systems are used as instruments of war, either as targets or as tools. Worldwide, there are conflicts brewing over many rivers and river basins, with more than 200 water bodies, around the world, being shared by two or more countries.

Strife over water is erupting throughout the Middle East, from the watersheds of the Nile to the Euphrates and Tigris Rivers. Likewise, there is a problem in South Asia's Ganga-Brahmaputra Basin, where Bangladesh, India and Nepal are disputing the use of water. India and Nepal want to exploit the basin's huge hydroelectric power-generating potential whereas Bangladesh wants the water managed in a way that will minimize flooding during the monsoon season and water shortages during the dry season.

Of equal concern are the water conflicts between states in India that share river basins, such as Karnataka and Tamil Nadu, which share the Cauvery River. There are water shortages during the dry season in every major city in South Asia: During the dry season, urban water pipes are often empty, creating situations where water must be delivered by truck to desperate people.

The third category of conflicts is between industries and local communities on several issues : excessive water consumption by industry resulting in reduced availability for irrigation; preferential treatment for industry in pricing; and pollution of groundwater, rivers, and local water bodies by wastewater discharges.

Agitations and public interest litigation on water issues are increasing and more conflicts at all levels are expected in the future.

- **Water Conflict in the Middle East.** Three river basins, namely the Jordan, the Tigris–Euphrates and the Nile are the shared water resources for Middle East countries. Ethiopia controls the head waters of 80% of Nile's flow and plans to increase it. Sudan too is trying to divert more water. This would badly affect Egypt, which is a desert, except for a thin strip of irrigated cropland along the river Nile and its delta.

The population of Egypt is likely to double in the next 20 years, thereby increasing its water crisis. Likewise, there is a fierce battle for water among Jordan, Syria and Israel for the Jordan River water share.

Turkey has abundant water and plans to build 22 dams on Tigris–Euphrates for Hydroelectric power generation. But, it would drastically reduce the flow of water to Syria and Iraq, lying downstream. Turkey dreams to become the region's water super power. It plans to transport and sell water to starved Saudi Arabia, Kuwait, Syria, Israel and Jordan. Probably, the next war in the Middle East would be fought over water and not oil.

- **The Indus Water Treaty.** The Indus, one of the mightiest rivers is dying a slow death due to dams and barrages that have been built higher up on the river. The Sukkur barrage (1932), Gulam Mohammad Barrage at Kotri (1958) and Tarbela and Chasma Dams on Jhelum, a tributary of Indus have resulted is severe shrinking of the Indus delta. In 1960, the Indus water treaty was established by which Indus, the Jhelum and the Chenab were allocated to Pakistan and the Satluj, the Ravi and the Beas were allocated to India. Being the riparian state. India has pre-emptive right to construct barrages across all these rivers in Indian territory. However, the treaty requires that the three rivers allocated to Pakistan may be used for non-consumptive purposes by India *i.e.*, without changing its flow and quality. With improving political relations between the two countries it is desirable to work out techno-

economic details and go for an integrated development of the river basin in a sustainable manner.

- **The Cauvery Water Dispute.** Out of India's 18 major rivers, 17 are shared between different states. In all these cases, there are intense conflicts over these resources which hardly seem to resolve. The Cauvery river water is a bone of contention between Tamil Nadu and Karnataka and the problem is almost hundred years old. Tamil Nadu, occupying the downstream region of the river wants water-use regulated in the upstream. Whereas, the upstream state Karanataka refuses to do so and claims its primacy over the river as upstream user. The river water is almost fully utilized and both the states have increasing demands for agriculture and industry. The consumption is more in Tamil Nadu than Karnataka where the catchment area is more rocky. On June 2, 1990, the Cauvery Water Dispute Tribunal was set up which through an interim award directed Karnataka to ensure that 205 TMCF of water was made available in Tamil Nadu's Mettur dam every year, till a settlement was reached. In 1991-92 due to good monsoon, there was no dispute as there was good stock of water in Mettur, but in 1995, the situation turned into a crisis due to delayed rains and an expert committee was set up to look into the matter which found that there was a complex cropping pattern in Cauvery basin. Sambra paddy in winter, Kurvai paddy in summer and some cash crops demanded intensive water, thus aggravating the water crisis. Proper rationing, rational sharing patterns and pricing of water are suggested as some measures to solve the problem.
- **The Satluj-Yamuna Link (SYL) Canal Dispute.** The issue of sharing the Ravi-Beas waters and SYL issues between Punjab and Haryana is being discussed time and again and the case is in the Supreme Court. The Eradi Tribunal (1985) based the allocation of water on the basis of the time-inflow data of 20 years (1960-80), according to which 17.17 MAF (million acre feet) water was available. However, now it is argued by Punjab that in the last 17 years there has been consistent decline reducing the quantity to 14.34 MAF. The Supreme Court on January 15, 2002 directed Punjab to complete and commission the SYL within a year, failing which the centre was told to complete it. However, two years have passed, but neither the SYL has been completed nor the conflict over sharing of Ravi-Beas water is resolved.

The conflict is that Punjab being the riparian state for Beas, Ravi and Satluj stakes its claim. Haryana has faced acute shortage of water after it became a state in 1966 and has been trying to help it out by signing on

MoU (Memorandum of Understanding) with UP, Rajasthan and Delhi for allocation of Yamuna waters. The Yamuna basin covers the state of Haryana while the Indus basin covers Punjab.

The conflict revolving around sharing of river water needs to be tackled with greater understanding and objectivity.

Traditional Water Management System

In India, even today, there are several villages where water management is done not by the Irrigation Department, but by local managers.

- In South India, a neerkatti manages the traditional tanks very efficiently based on his/her knowledge of the terrain, drainage and irrigation needs. They usually give preference to the tail end fields and decide per capita allocation of water based on the stock of available water in the tank and crop needs.
- In Maharashtra, the water managers are called havaldars or jaghyas who manage and resolve conflicts by overseeing the water channels from main canal to the distributory canals.
- In Ladakh, the water manager is known as churpun who has got complete charge with full powers over allocation of available water. The major source of water is melt water from glaciers and snow supplementary by water from springs and marshes. The water is distributed to different fields through an intricate network of earthern channels.

In traditional water management, innovative arrangements ensure equitable distribution of water, which are democratically implemented. The 'gram-sabhas' approve these plans publicly. While water disputes between states and nations often assume battle like situations, our traditional water managers in villages prove to be quite effective.

Indian Situation

India and China are counted amount the water hotspots, primarily because of their large populations that have to be provided with food and drinking water. In India more than 60,000 villages did not have a source of drinking water in 1994 and by now this number must have increased further. Diarrhoea, caused by consuming contaiminated water, claims the lives of one million children every year. In addition 45 million people are annually affected by poor quality water.

While the increasing population is one cause of India's water crisis, the problem has been compounded by the steady deterioration, disuse, and disappearance of traditional tanks and ponds. A large number of such local water sources had been created by ancient kings all over India. Local communities exercised control over these resources and there were set

procedures for the maintenance of such tanks through community participation.

With the arrival of the British, however, the Public Works Department took over the control of water resources and this started a steady decline in their condition. This has continued even after India's independence leading to the disuse of thousands of such sources of water. These tanks and ponds were very effective in retaining rainwater and recharging the groundwater. Deforestation of the hills coupled with the absence of tanks has increased the run-off into the sea.

In recent years the extraction of groundwater using bore wells operated by electric or diesel pumps has reached gigantic proportions. One estimate is that the extraction rate is already twice the recharge rate. In many states water tables have been dropping at alarming rates.

The Way Out

Even in this grim situation, there are optimists who believe that there will be dramatic solutions that will solve the water problem once-and-for-all. Such dreams include :

- Transport of water in huge bags by sea : American and Norwegian companies are developing huge bags for this purpose.
- Towing of iceberg to places needing water : There are formidable technological problems involved in putting this into practice.
- Discovery of new, deep aquifers full of water : This is similar to the hope of finding huge oil wells and is an unlikely event.
- A new, cheap energy source that will make desalination affordable : This is likely to remain a dream.

Most experts, however, believe that there are real limits to the availability of water and that we are fast reaching them. Perhaps a realistic solution would be to find ways of using water more efficiently.

Inter-Linking of Rivers

The idea of linking rivers has been around for a long time. In 1972, Dr. K.L. Rao, the then Minister for irrigation, proposed a plan to link the Ganga and the Cauvery. In 1974, Capt. Dastur came up with a plan for a garland canal. The government set up the National Water Development Agency (NWDA) in 1982 to carry out studies on the question.

There was no much progress till 2002, when the Supreme Court of India, acting on a public interest petition, directed the government to interlink rivers within 10 years. In response, the government set up a Task Force to build national consensus, work out the detailed plans, and complete the entire work by 2016.

Three major advantages are being cited in favour of the scheme : droughts will never occur, floods in the Ganga and Brahamaputra will cease

to be a problem, and an additional 30,000 MW of hydropower will be generated. However, the NWDA has not conducted any detailed assessment of the financial feasibility, technological capability, ecological sustainability, and political feasibility of the project.

The budget for the project ranges from Rs. 5,600 to 10,000 billion. Even the lower estimate equals 25 per cent of our GDP, 2.5 times our tax collection, and double our present foreign exchange reserves. Obviously, funds of this magnitude will have to be raised from international sources. Even if we succeed in raising the funds, the annual interest alone would amount to Rs. 200-300 billion. The water will have to be priced high to meet such a burden. Will the farmers and other users be ready to pay the charges?

It is doubtful if a political consensus can ever be achieved on the project. Would the states be willing to freely share all the river waters? Even the current inter-state water problems, such as the construction of the Sutlej-Jamuna Link Canal, the sharing of Cauvery waters between Karnataka and Tamil Nadu, and the height of the Sardar Sarovar Dam have all defined an amicable solution. It is not even clear whether rivers such as the Ganga, the Brahamputra, the Mahanadi, and the Godavari are water-surplus. The sources of such rivers are drying up and the rivers themselves are chocked with silt.

The likely ecological consequences of building over 200 reservoirs and a network of criss-crossing canals cannot even be assessed now. Judging from the experience of the Narmada Dam and other large projects, the consequences could be disastrous. Environmentalists and social activists fear large-scale submergence of habits, forests, and fertile land; extensive destruction and wildlife habits and biodiversity; displacement of large populations; and so on. In some places enormous amounts of energy will have to be spent pumping water uphill.

In the past, every single irrigation project in India has resulted in heavy cost and time overruns. The project to interlink rivers is likely to meet similar fate.

Water Conservation

In recent times a number of initiatives have been taken by individuals, communities, non-governmental organization (NGOs), and even by government agencies to implement measures for water conservation and management. Some of the well known cases are :

- **Auroville.** The spectacular results of the efforts of this international community near Pondicherry over the past 35 years in afforestation, water conservation, wastewater treatment, appropriate technologies, etc., have made it a model to follow. Auroville is now working with local communities and the government to rejuvenate the traditional ponds and let the people manage them.

- **Tarun Bharat Sangh, Alwar, Rajasthan.** The building of check dams in villages.
- **Ralegaon Siddhi, Maharashtra.** Through the efforts of Anna Hazare, the people have constructed bounds and percolation tanks and brought back greenery to the area.
- **Rajiv Gandhi National Drinking Water Mission, Madhya Pradesh.** This is one of the few successful government schemes in water conservation.
- **Gram Gaurav Pratishthan.** In an area in Maharashtra, the late Vilas Salunke introduced the idea of a Pani Panchayat for the fair-sharing of water.
- **Tamil Nadu.** The city of Chennai is blessed with a fresh water coastal aquifer, which was being over-exploited. In the early 1990s, the state government introduced controls and as a result the water table did go up.

Rainwater harvesting was first made compulsory in Chennai and was extended to the entire state of Tamil Nadu in 2003. It is estimated that rainwater is harvested in atleast 30 per cent of the structures in the state. Rainwater harvesting is actively promoted by voluntary organizations like Akash Ganga, which has set up a 'Rain Centre' in Chennai to demonstrate the methods of harvesting rainwater.

- **Efficient Water Use by Industry.** Faced with water scarcity, increasing costs, and protests by local communities, several industries, such as Arvind Mills, Chennai Petroleum Corporation, JK Papers, and Natural Sugar and Allied Industry have implemented water conservation measures and have benefited by them.

Model Questions

1. Why is water a unique natural resource?
2. What percentage of the total water in the world is actually accessible to us?
3. What are the levels of water availability that indicate water crisis?
4. What are the environmental impacts of ground water usage?
5. Discuss droughts and floods with respect to their occurrence and impacts.
6. What are the special problems that big cities face on the water issue?
7. Explain the main differences between the industrialised countries and the developing countries with regard to water use.
8. Discuss the major causes for conflicts over water? Write examples.
9. What are the major inter-state water conflicts in India?
10. How can we reduce the total demand of water?
11. Will the plan to inter-link Indian rivers solve our problems?
12. What is the good news from India on water conservation and management?

4
Mineral Resources

Mineral Resources are those resources which are extracted from the earth in the form of organic and inorganic substances. Man has been using minerals from early stages of human civilisation. Their use has increased immensely during the last one hundred years. As agriculture is the basis of human civilisation minerals provide base to modern industries.

Various Uses of Minerals

Minerals are used in various ways. Some of them are :

1. Construction of buildings.
2. Manufacturing machineries.
3. Railway coaches, engines, motor-cars and other means of transport and communication.
4. Minerals also provide fossil-fuels such as coal, petroleum and natural gas.

Minerals are found in earth's crust mixed with other substances. They are called Mineral Ore. Minerals are exhaustible resources, this means that the mines from which minerals have been extracted, become mineralless for ever. In this respect mining is called the Robber Industry. These are numerous desolated towns or settlements near abandoned mines. We call them Ghost Towns.

Classifications of Minerals

Mineral resources can be classified into two classes—metallic and non-metallic.

1. **Metallic Minerals.** Those minerals which have the following characteristics are put in the group of metallic minerals :

(i) Metallic minerals give metals which can be stretched in sheets or they can be converted into wires.

(ii) Iron, gold, silver, copper and aluminium are metallic minerals.

(iii) They have brightens.

(iv) Machines, defence weapons and implements can be made of these minerals.

2. **Non-Metallic Minerals.** This class of minerals lacks in brightness. These minerals break up when they are hit in order to stretch them. Coal, marble and mica fall in this category of minerals. Petroleum used as power resource is also non-metallic mineral.

Methods of Mining. Mining methods are of two types. They are open cast-mining and shaft mining.

Open Cast Mining. Open cast mining is applicable when mineral ore is obtained after removing the upper layer of soil or rock. Sometimes upper layer are removed resorting to explosions. Iron ore and coal are obtained by open cast mining.

Shaft Mining. Shaft mining is resorted to when minerals are found at great depths beneath the surface or under ocean water. In Bombay High petroleum is mined through this method of mining.

Distribution of Minerals Iron Ore

Iron is the most used mineral metal in the world because :

1. It can be converted into peat iron, wrought iron, magnetic iron and steel;
2. It can be stretched in the form of sheets and drawn into wires;
3. It has its magnetic characteristics;
4. It is firm and rigid;
5. It is strong and durable;
6. Almost all types of machines and machinery equipments and appliances are made of iron.

Thus iron has played an important role in the growth and development of our civilisation. It would not be exaggerated if we call the modern civilisation. 'The Iron Civilisation'.

It is not certain when man came across iron but it is certain that he came to known about iron by accident. The Iron Pillar of New Delhi near Kutub Minar is an evidence to that the Indian people had knowledge of iron from time immemorial, and how developed our metallic knowledge was even in the early periods of history.

Uses of Iron

1. Iron is also used in buildings, factories, refineries and canning of food stuffs.
2. Iron is the basis of our modern civilization. It is used in manufacturing machines, and manufactured goods.
3. Huges pipelines for carrying petroleum, natural gas and irrigation water from one place to another are made of iron.
4. Iron makes the modern transport and communication possible. Motor-car, rails, engines and vehicles all are made of iron.

After mining iron ore it is smelted in huge furnaces, mixing in it coal and dolomite in order to purify it. This process is turned as 'smelting'. Smelting of iron ore results in doing away 'impurities'. Thus pig iron or wrought iron is obtained. When carbon is extracted from the wrought iron, iron comes into being. From this iron sheets or iron wires are made. Steel comes into existence with the mixing of manganese, nickel, venedium, chromium and tungsten.

World Distribution

Distribution of iron ore reserves in the world are very uneven. The major iron ore producing countries include USSR, USA, Australia, Canada, Sweden, France, Spain and India.

USSR. USSR accounts first in the production of iron ore in the world. Major iron ore producing regions of the USSR are :

(i) Moscow and its adjoining region.
(ii) Kriboyrog (Ukraine).
(iii) Siberia.
(iv) Megnitogorsk and its adjoining region (Ural Region).
(v) Kustani (Kajakistan).
(vi) Angara Valley.

USA. The USA stands second after the USSR in the world in iron ore production. The major producing regions are :

(i) The Great Lake Region—Mesabi Range.
(ii) Bermingham city and adjoining region (in the south of Appalachian Mountains in Alabama).
(iii) The Western Region—Utah-Nevada, Wyoming and California states.

Canada. The major iron-ore producing region of Canada is situated in the Great Lake region and brings third in the world iron ore production. Iron ore has also started to be mined in Labrador and Eastern Quebec.

France. Produces 10% iron ore of the total world production. The major regions are :

(i) Pyraness.
(ii) Lorrain.
(iii) Central Masiff.
(iv) Normander.

Sweden. Sweden comes fifth in world and is the most leading iron ore producer of Europe. Kiruna and Gallivara are the major regions of iron ore.

The production of iron ore has suffered in Sweden as a result of the following problems :

(i) Non-availability of coal for smelting iron ore, resulting in its export to neighbouring countries.

(ii) Most of the reserves are situated in the northern parts which experiences severe cold and long winters, thus hindering mining operations.

Venezuela. High quality iron ore reserves are found on the Guinea Plateau. Elpao and Cerro-Bolwar are leading mines of the country. USA imports iron ore from here.

China. Iron ore reserves of China as found in Anshan region of Munchuria, other iron ore producing regions are : Maanshan (Lower Yangtese Valley), Tayeh and Chungkiang, adjoining Canton, and Honan islands.

Brazil. Iron ore deposits are situated in the south eastern Brazil. Iron and steel industry at Voltaridonda and Velohorrigento use this ore. The modern development of Brazil depends upon the huge deposits of iron ore.

Australia. Distribution of iron ore is found all over Australia, Mt. Yoldswortho, Mt. Bruce, Mt-tom, Prize and Yumpi Sound are the recently found regions of iron ore deposits. After satisfying its home demand, Australia exports some iron ore to Japan.

India. High quality iron is mined in India from Singhbhum, Keonjhar, Bonai, Mayurbhunj and Solapet. Besides these regions other important iron ore mines are Lohara and Sipalgaon region of Chanda Distt. of Maharashtra, Baliadila, Dally, Rajaharu and Buster in Madhya Pradesh, Salem and Tiruchirapalli in Tamilnadu, Hyderabad in Andhra Pradesh and Goa. The mining of iron are in Northern India have the following facilities :

(i) Iron and steel industries are situated in the region.

(ii) Most of the iron are deposits are located in the adjoining regions of coal.

(iii) Rail-road network is all over the region.

Africa. Iron ore producing countries of the 'dark continent' are mentioned below :

North Africa — Tunisia, Algeria and Morocco.

South Africa — Transval Province.

Copper

Man has been using copper from time-immemorial. It is perhaps because of its availability in pure form and work on it is problem-free. In the early days he used copper mainly in making utensils but since last 80 years with increase in electricity in domestic and industrial purposes demand of copper has increased manifoea, because of its good conductivity. Now-a-days it is used in powerhouses, telephones and electrical machines.

Copper, though found in its pure form on the surface or under the surface, it is generally found chemically mixed with iron, gold, silver, lead and sulphur.

World Distribution

The following description gives an understanding about the distribution of copper in the world.

United States of America is the chief producer of copper in the world, with its deposits in Michigan and Arizona regions. Utah province also produces copper in abundance. The industrial complex of the North-east utilises most of the copper production of the country.

The other copper producing countries and their deposit regions are :

Countries	Regions
Chile	Chukikmata
Zaire	Cotanga
Japan	Honshu and Shikoku islands
USSR	Balkan Peninsula

Besides Zambia, Spain, Mexico, Australia, India, Canada, Peru and China also extract some quantities of copper in their countries. India has her copper mines in Singhbhum and Hazaribagh districts of Bihar. Other important centres are Kehtri and Daribo in Rajasthan and Anantpur in Andhra Pradesh. Some upper deposits are also found in Karnataka and Himalayan regions.

Aluminium

Importance of aluminium has been increasing day by day due to the following characteristics :

1. The metal is very light.
2. It is a good conductor of heat and electricity.
3. It becomes hardest metal, when mixed with other metals.
4. We use aluminium in

(i) making electric wires and electrical machines.

(ii) building houses and transport vehicles.

(iii) making cooking utensils.

Aluminium is not extracted in its true form. It is obtained from Bauxite, Cryolite, Corundum and Kaolin.

Ore	Countries
Bauxite	Jamaica, France, Guinea, Surinam, Ghana, Hungary, Australia, India and USA.
Cryolite	Greenland

USA has very few deposits of bauxite but it manufactures 70% goods of aluminium of the total world manufacture. It is because USA imports large quantities of bauxite from Jamaica and Surinam. Ranchi (Bihar), Jabalpur and Katni (M.P.), Kaira (Gujarat), Selam (Tamilnadu) and Belgaon (Karnataka) produce bauxite in India. Most of the production of baxoxite in India is utilised in her industries.

Extraction of aluminium from bauxite and other mineral ores requires huge amount electricity. Hence its industries are situated near hydroelectric power stations where cheap hydro electricity is available Examples :

Countries	Aluminium Industries near Hydro-power Stations
Switzerland	Shake-Asen Waterfall
U.S.A.	Niagora Waterfall
France	Sevay Region
Germany and Italy	Mountain Regions
India	Renukoot (Mirzapur) Near Rehand Project

Table 4.1 : Major reserves and important uses of some of the major metals

Metal	Major world reserves	Major uses
Aluminium	Australia, Guinea, Jamaica	Packaging food items, transportation, utensils, electronics
Chromium	CIS, South Africa	For making high strength steel alloys, In textile/tanning industries
Copper	U.S.A., Canada, CIS, Chile, Zambia	Electric and electronic goods, building, construction, vessels
Iron	CIS, South America, Canada, U.S.A.	Heavy machinery, steel production transportation means
Lead	North America, U.S.A., CIS	Leaded gasoline, car-batteries, paints, ammunition
Manganese	South Africa, CIS, Brazil, Gabon	For making high strength, heat resistant steel alloys
Platinum group	South Africa, CIS	Use in automobiles, catalytic converters, electronics, medical uses.
Gold	South Africa, CIS, Canada	Ornaments, medical use, electronic use, use in aerospace
Silver	Canada, South Africa, Mexico	Photography, electronics jewellery
Nickel	CIS, Canada, New Caledonia	

Table 4.2 : Major uses of some non-metallic minerals

Non-metal mineral	Major uses
Silicate minerals	Sand and gravel for construction, bricks, paving etc.
Limestone	Used for concrete, building stone, used in agriculture for neutralizing acid soils, used in cement industry
Gypsum	Used in plaser wall-board, in agriculture
Potash, phosphorite	Used as fertilizers
Sulphur pyrites	Used in medicine, car battery, industry

Some Major Minerals of India

(a) **Energy generating minerals.**

Coal and lignite. West Bengal, Jharkhand, Orissa, Madhya Pradesh, Andhra Pradesh.

Uranium (Pitchblende or Uranite Ore). Jharkhand, Andhra Pradesh (Nellore, Nalgonda), Meghalaya, Rajasthan (Ajmer).

(b) **Other Commercially used minerals**

Aluminium (Bauxite Ore). Jharkhand, West Bengal, Maharashtra, Madhya Pradesh, Tamil Nadu.

Iron (haematite and magnetite ore). Jharkhand, Orissa, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Goa.

Copper (Copper Pyrites). Rajasthan (Khetri), Bihar, Jharkhand, Karnataka, Madhya Pradesh, West Bengal, Andhra Pradesh and Uttarakhand.

Impacts of Mining

A mineral is any substance that is naturally present in the Earth's crust and is not formed from animal or vegetable matter. The Earth's geological processes have formed these minerals over millions or billions of years and hence they are non-renewable.

Mining is the process of extracting and processing minerals. Over 100 minerals are mined and these include metals like gold, iron, copper and aluminium and non-metals such as stone, sand, and salt. Apart from minerals, another major material that is mined is coal.

Underground mining has little direct effect on the environment, but it can cause long-term problems like subsidence and pollution of aquifers. Moreover, workers are at great risk in underground mines. Accidents like

flooding and collapses are common and the work itself causes severe health problems like respiratory illnesses.

Surface mining destroys all vegetation in the area and pollutes the landscape with the dust that is thrown up. Once the available material is mined out, large craters are left behind. When hills that act as watersheds are mined away, the water tables go down, as in the case of the Aravallis in Rajasthan.

The processing of the mined material, often done on site, using in many cases mercury, cyanide, and large quantities of water, pollutes rivers and other water bodies. The waste material like slag is often far greater in quantity than what is usable, and is left behind as unslightly, unstable, and dangerous heaps.

The mining of precious metals is today more intense and widespread than in centuries past with far-reaching consequences. Of particular concern is heap-leach gold mining in which rivers of cyanide are poured over huge piles of low-grade ore to extract the metal.

Heap-leach mining is on the increase and has already caused several serious accidents. Two examples are :

- In 1984 on the OK Tedi Island in New Guinea, 1000 cu. m. of concentrated cyanide were released into a river and the ecosystem was devastated. This gold and copper project, which is tearing down a whole mountain, has already caused extensive environmental damage. It has also destroyed the culture and lifestyle of the native Wopkaimin people.
- In 2000, at the Baia Mare gold mine in Romania, the dam holding the heap-leach waste broke, releasing 80 million litres of cyanide into the Tisza River. The cyanide flowed 500 km. into Hungary and Serbia.

Indian Problem

Indian Scenario. India is the producer of 84 minerals the annual value of which is about Rs. 50,000 crore. At least six major mines need a mention here which are known for causing severe problems :

(i) **Sukinda Chromite Mines, Orissa.** Seeping of hexavalent chromium into river posing serious health hazard, Chromium (VI) being highly toxic and carcinogenic.

(ii) **Jaduguda Uranium Mine, Jharkhand.** Exposing local people to radioactive hazards.

(iii) **Kudremukh Iron Ore Mine, Karnataka.** Causing river pollution and threat to biodiversity.

(iv) **Jharia Coal Mines, Jharkhand.** Underground fire leading to land subsidence and forced displacement of people.

(v) **North-Eastern Coal Fields, Assam**—Very high sulphur contamination of groundwater.

(vi) **East Coast Bouxite Mine, Orissa**—Land encroachment and issue of rehabilitation unsettled.

Environmental Damage

The environmental damage caused by mining activities are as follows :

(i) **Groundwater Contamination.** Mining disturbs the natural hydrological processes and also pollutes the groundwater. Sulphur, usually present as an impurity in many ores is known to get converted into sulphuric acid through microbial action, thereby making the water acidic. Some heavy metals also get leached into the groundwater and contaminate it posing health hazards.

(ii) **Occupational Health Hazards.** Most of the miners suffer from various respiratory and skin diseases due to constant exposure to the suspended particulate matter and toxic substances. Miners working in different types of mines suffer from asbestosis, silicosis, black lung disease etc.

(iii) **Subsidence of Land.** This is mainly associated with underground mining subsidence of mining areas often results in tilting of buildings, cracks in houses, buckling of roads, bending of rail tracks and leaking of gas from cracked pipe-lines leading to serious disasters.

(iv) **Devegetation and Defacing of Landscape.** The topsoil as well as the vegetation are removed from the mining area to get access to the deposit. While large scale deforestation or devegetation leads to several ecological losses as already discussed in the previous section, the landscape also gets badly affected. The huge quantities of debris and tailings alongwith big scars and disruptions spoil the aesthetic value of the region and make it prone to soil erosion.

(v) **Surface Water Pollution.** The acid mine drainage often contaminates the nearby streams and lakes. The acidic water is detrimental to many forms of aquatic life. Sometimes radioactive substances like uranium also contaminate the water bodies through mine wastes and kill aquatic animals. Heavy metal pollution of water bodies near the mining areas is a common feature creating health hazards.

(vi) **Air Pollution.** In order to separate and purify the metal from other impurities in the ore, smelting is done which emits enormous quantities of air pollutants damaging the vegetation nearby and has serious environmental health impacts. The suspended particulate matter (SPM), Sox, soot, arsenic particles, cadmium, lead etc. Shoot up in the atmosphere near the smelters and the public suffers from several health problems.

Conservation of Minerals

In order to minimize the adverse impacts of mining it is desirable to adopt eco-friendly mining technology. The low-grade ores can be better utilized by using microbial leaching technique. The bacterium Thiobacillus ferroxidans has been successfully and economically used for extracting gold embedded in iron sulphide ore. The ores are inoculated with the desired strains of bacteria, which remove the impurities (like sulphur) and leave the pure mineral. This biological method is helpful from economic as well as environmental point of view.

Model Questions

1. What are the uses of various types of minerals?
2. Enlist some major minerals of India.
3. What are the environmental impacts of mineral extraction? Explain in the context of Indian scenario.
4. Explain the remedial measures to save mineral resources.

5
Energy Resources

Energy is an important input for development. It aims at human welfare covering household, agriculture, transport and industrial complexes. Like other natural resources, energy resources are also renewable as well as non-renewable. Renewable (inexhaustible) energy resources are mostly biomass-based and are available in unlimited amount in nature since these can be renewed over relatively short period of time. These include, firewood (or fuelwood) obtained from forests, petroplants, plant biomass (as agricultural wastes like bagasse), animal dung, solar energy, wind energy, water energy (hydro-electric and tidal energy), geothermal and dendrothermal energy etc. These can reproduce themselves in nature and can be harvested continuously through a sustained proper planning and management. Non-renewable (exhaustible) energy resources are available in limited amount and develop over a longer period of time. As a result of unlimited use, they are likely to be exhausted one day. These include coal, mineral oil, natural gas and nuclear power. Coal, petroleum and natural gas, the common sources of energy, being organic (biotic) in their origin are also called fossil fuels.

Classification of Sources of Energy

All the energy sources found on the earth are directly or indirectly related to solar energy. These sources can be classified into two categories :

1. **Conventional or Non-Renewable Resources.** Those resources which are being used on a large scale after industrial revolution (after year 1700), are known as conventional sources. Fossil fuels such as coal, oil and natural gas are such which are finite and exhaustible. They were created crores of years ago with extremely slow changes. As we are using these resources on a large scale (presently 95% energy need is met by them), they are expected to be depleted. Therefore, these resources are also known as non-renewable. It is estimated that known reservoirs of petroleum in India will be depleted till the year 2020. Coal reservoirs can probably run for 200-250 years but due to depletion of oil reserves, increase in population and increasing energy demands, these coal reserves may be depleted before long. Large scale use of fossil fuels is also a main cause of atmospheric pollution.

2. **Non-Conventional or Renewable Resources.** Sun rays, wind, flowing water, sea waves, oceanic tides and biogas provide energy which is also produced directly or indirectly from solar (sun) energy. Therefore, these resources can be exploited till earth is getting light and heat from the sun. Therefore, these resources are known as renewable resources. It is worth mentioning that geothermal energy will be available for a very long time. It will be useful to know that energy obtained from fuelwood is also renewable energy because fuelwood can be obtained by replantation of trees. But it takes more than 15 years for a plant to mature. Secondly, a large scale cutting of trees is destroying forests which is a reason of environmental imbalance. Therefore, use of wood as energy source will not be an intelligent decision. Renewable energy sources should be used on a large scale in place of fossil fuels. Success is being achieved in many areas in this regard.

Conventional Sources of Energy

Major sources of energy in this category are coal, mineral oil and natural gas, firewood and nuclear power.

Coal. About 6000 billion tons of coal lies under the earth and by now over 200 billion tons had been used.

Table 5.1 :
Coal Producing Countries of the World

1980		1986	
Country	**% of World Production**	**Country**	**% of World Production**
USA	26.04	USA	22.38
China	21.85	China	22.78
USSR	18.10	USSR	15.88
Poland	7.07	Poland	5.95
U.K.	4.77	U.K.	3.62
South Africa	4.25	South Africa	5.49
India	3.99	India	5.06
F.R. Germany	3.46	F.R. Germany	2.70
Australia	2.70	Australia	4.94
Czechoslovakia	1.07	Czechoslovakia	0.78
Total World	273 Crore metric tonnes		323 Crore metric tonnes

The total coal production in world has increased from 273 crore metric tons in 1980 to 323 crore metric tonnes in 1986, registering an increase of 18.4 per cent.

Coal, besides a prime source of industrial energy is also a raw material. Coal, including lignite even today accounts for 60 per cent of the country's

commercial power requirements. In developed world there is a trend of shift from coal to oil or gas. Major coal fields in India are Raniganj, Jharia, East Bokaro and West Bokaro; Panch-Kanham (Tawa Valley) Singrauli, Talchar, Chanda-Wardha and Godavari Valley. The major states known for coal reserves are Bihar, Orissa, West Bengal, M.P., A.P. and Maharashtra. By and large, the quality of Indian coal is rather poor in terms of heat capacity. This poor heat capacity can be converted into electricity and gas and even oil. This is the reason why many of our thermal and superthermal power stations are located on the coal fields to produce electric power to feed regional grids. Coal production in India which was just 35 million tons in 1951 has now gone to over 180 million tons in 1988-89. Per capita consumption of coal increased from 135 kg. to nearly 225 kg. Lignite (brown coal) is generally a low quality coal. But Indian lignite has less ash content than coal. The deposits at Neyveli (Tamil Nadu) are about 3,300 million tons, about 90 per cent of country's lignite reserves. It produces 600 mw of thermal power.

Oil and Natural Gas. Sedimentary rocks containing plants and animals remains—about 10 to 20 crore year old are the source of mineral oil. Mineral oil is very unevenly distributed over space like any other mineral. There are six regions in the world which are rich in mineral oil. USA, Mexico, former USSR and the West

Table 5.2 :
Major Oil Producing Countries of the World

1980		1986	
Country	**% of World Production**	**Country**	**% of World Production**
USSR	21.94	USSR	22.23
USA	16.64	USA	15.48
Saudi Arabia	14.24	Saudi Arabia	9.04
Iraq	4.36	China	4.71
Venezuela	3.85	U.K.	4.36
China	3.56	Venezuela	3.40
Nigeria	3.43	Iran	3.35
		Nigeria	2.63
Total	68.02	Total	65.20

Asian region (Iraq, Saudi Arabia, Kuwait, Iran, United Arab Emirates, Qatar and Bahrain) are the major oil producing countries of the world. Oil production has declined from 300 crore metric tonnes in 1980 to 275 crore metric tonnes in 1986.

India has a large proportion to tertiary rocks and alluvial deposits particularly in the extrapeninsular India. Such potential oil bearing area is

estimated to be over a million square km, one third of total area. It covers the northern plains in the Ganga-Brahamputra valley, the coastal strips together, with their off-shore continental shelf (Mumbai High), the plains of Gujarat, the Thar desert and the area around Andaman and Nicobar Islands.

Till Independence Assam was the only state where mineral oil was drilled. In India oil was first found at Makum (north-east Assam) but drilling of oil was started at Digboi in Lakhimpur district. After independence Gujarat plains and the major reserves were found off the Mumbai coast—the richest oil field of the country, known as Mumbai High (115 km. from the shore). The latest oil deposits have been found in off shore areas off the deltaic coasts of Godavari, Krishna, Kaveri and Mahanadi. The gas reserves are generally found in association with oil fields. However, exclusive natural gas reserves have been located in Tripura, Rajasthan and almost in all the off-shore oil fields of Gujarat, Maharashtra, Tamil Nadu, Andhra Pradesh and Orissa.

In 1951 our total mineral oil production was 269,000 tons. Total consumption at that time was only 3.1 million tons. By 1984-85, production increased to 29 million tons but consumption also jumped to 39 million tons. The net imports were 7 million tons of crude and 5 million tons of petroleum products. In 1986-87 oil production was 30.5 million tons and in 1988 nearly 36 million tons. It was only 10 million tons in 1980-81. The recoverable reserves of crude oil which were 366 million tons in 1980 rose to 580 million tons by 1987.

Natural gas production (million cubic meters) in 1980-81 was 2,358 that rose to 9,812 by 1986-87. The total gas reserves were estimated to be 5,41,000. In India gas is a natural gift. It can be used both as energy source and also an industrial raw material in petrochemical industry. It takes lesser time to build a gas based power plant. The gas is also used for fertiliser plants. Through pipe line, the gas from Mumbai and Gujarat gas fields is now taken to M.P., Rajasthan and U.P. Hazira-Bijaipur-Jagdishpur (HBJ) gas pipe line is 1,730 km long and carries 18 million cubic metres of gas every day. It feeds six fertiliser and three power plants. There are already 12 refineries in India. The liquefied petroleum gas (LPG), also called the cooking gas is now a very common domestic fuel in country.

Thermal Power. Hydro-electricity is obtained from a renewable source, water. But thermal power plants use coal, petroleum and natural gas to produce thermal electricity. These sources are of mineral origin and also called fossil fuels. They are exhaustible and polluting. Electricity, whether thermal, nuclear or hydro is the most convenient and versatile form of energy. This is in great demand in industry, agriculture, transport and domestic sectors. Installed capacity to produce thermal power in 1988-89 in India was about 40 million kw, a little more than twice the capacity to produce hydel power. The actual power generated in 1988-89 was 201 billion units. Against this hydel power accounted for 53.8 billion units and 5

billion units of nuclear power. In a single year it had arisen to about 10 per cent.

Both, big and small power stations are scattered all over the country. Electricity produced by them is fed into regional grids. It is proposed to have a single national grid. The grids receive electricity produced from all the four major sources—coal, oil, water and nuclear. Total length of lines was 10,000 circuit km in 1950 that rose to 1,71,000 circuit km in 1987. Besides there are high voltage transmission lines of 400 kv strength—16,000 km, and 55,855 km of 220 kv strength.

Firewood (Fuelwood). One must combine environmental supply of firewood and other biomass energy sources. Besides we need technologies for total utilisation of biomass and/or conversion to solid (densification), liquid (liquification) and gaseous (gasification) fuel. According to ABE (1985) the demand for firewood is likely to go to the order of 300-330 Mt in 2004/05 against the present level of 120-130 Mt. Table lists such demand state-wise.

Table 5.3 :
Estimated Fuelwood Consumption (Mt) in 2004/05 (ABE, 1985)

Region/State/UT	Fuelwood Consumption		
	Rural	Urban	Total
Northern Region			
1. U.P.	37.0	10.0	47.0
2. Rajasthan	17.0	4.0	21.0
3. Punjab	3.5	0.5	4.0
4. Haryana	2.0	0.5	2.5
5. Himachal Pradesh	3.0	0.5	3.5
6. J & K	2.5	0.5	3.0
Eastern & N.E. Region			
7. West Bengal	9.5	0.5	10.0
8. Bihar	19.5	1.5	21.0
9. Orissa	13.0	3.5	16.5
10. Assam	11.5	1.0	12.5
Southern Region			
11. Andhra Pradesh	26.5	8.5	35.0
12. Karnataka	17.5	7.5	25.0
13. Tamil Nadu	20.0	10.5	30.5
14. Kerala	11.5	4.5	16.0
Western Region			
15. Madhya Pradesh	20.5	6.5	27.0
16. Maharashtra	22.5	5.5	28.0
17. Gujarat	10.0	3.0	13.0
Total	247.0	69.0	316.0

Table 5.4 :
Estimated Fuelwood Requirements in 2004-05 to be met through plantations (ABE, 1985)

State	Quantity (Mt)
Northern Region	
1. U.P.	66.5
2. Rajasthan	22.5
3. Punjab	7.0
4. Haryana	6.0
5. Himachal Pradesh	2.5
6. J & K	2.0
Eastern & N.E. Region	
7. West Bengal	13.5
8. Bihar	20.0
9. Orissa	19.0
10. Assam	11.0
Southern Region	
11. Andhra Pradesh	35.0
12. Karnataka	27.5
13. Tamil Nadu	32.0
14. Kerala	15.5
Western Region	
15. Madhya Pradesh	28.0
16. Maharashtra	30.5
17. Gujarat	14.5

It may be seen that nearly 70 per cent of firewood demand pertains to the rural areas. Only 50 Mt. of the fuelwood may become available from natural forests. According to NCA for next 15 years or so the av. fuelwood contribution from natural forests would be 0.75 t/ha/yr year and the rest is to be met from plantations. Table 13.7 gives an idea about the same. Whole of the required plantations is to be non-agricuitural land, degraded forest land, culturable wasteland, barren/inculturable land, permanent pasture and grazing lands. Roughly 60 Mha of such land are available and it may be difficult to bring more than 50 per cent of this land under plantation.

Hydro Power. Water energy is most conventional renewable source of energy. Energy is obtained from water flow, water falling from a height. Hilly and highland areas are suitable for this purpose, where there is continuous flow of water in large amounts falling from high slopes. In the late 18th and early 19th century most industries were located near water-falls. Technology was also developed for use of steam energy. Hydro-power is a clean, non-polluting source of energy. It can be transmitted to long distance through wires and cables. But, this form of energy can not be

stored for future. Thus, markets are to be fixed before generation of this form of energy. Dams are constructed our rivers. Norway, Switzerland, Canada, Sweden and New Zealand harnessed their water resources for water energy. In South America, about 75 per cent of the total electricity consumption comes from water. Japan, USA and former USSR are the leading countries in production of hydro-power.

In India the generation of hydro-electric power was emphasised from the First Five Year Plan. A number of multipurpose river valley projects were launched, of which Bhakra Nangal project over Sutlej, Bokaro, Panchet and Tilaiya in Damodar Valley, Hirakund, Rihand, Nagarjuna Sagar, Kosi and Koyana etc., are the examples. A number of such project including construction of large dams as Tehri Dam on Bhagirathi river in U.P., Sardar Sarovar in Gujarat, and Narmada Valley Project (NVP) are also under different stages of development. The construction of these dams could generate at times much political and environmental controversies. We have referred to these dams earlier in chapter on "Natural Resources and their Conservation" under Land use Resource.

Nuclear Power. This is of course a principal source of energy, when the fossil fuel reserves are depleting very fast. A small quantity of radioactive material can produce an enormous amount of energy. For instance, one ton of Uranium 235 would provide as much energy as by three million ton of coal or 12 million barrels of oil. Besides electricity, atomic power is also used as fuel for marine vessels, heat generation for chemical and food processing plants and for spacecrafts.

For atomic energy, we need a nuclear reactor. The decay of fissionable matter produces enormous heat. This is used to make steam and channelled through a turbine connected to an electric generator. There are different types of nuclear reactors. Light water reactor (LWR), where we use ordinary water for cooling and moderation. These are of two basic types (i) boiling water reactor (BWR) and (ii) pressurised water reactor (PWR).

There are also high temperature gas cooled reactors (HTGCR) which are basically of LWR-type.

Heavy water reactor (HWR), where we use heavy water. The most popular one has been Canadian Deuterium-Uranium (CANDU) reactor. Here the design is different from that of LWR-type. The fuel is arranged horizontally rather than vertically as in LWR.

Liquid metal fast breeder reactor (LMFBR), where we use liquid sodium as the coolant.

There are over 300 atomic power plants, operating in the world. The maximum are in U.S.A. (83), followed by USSR (40), U.K. (35), France (34), Japan (25), F.R. Germany (15) and Canada (13).

India has been a leader in making peaceful use of nuclear power in medicine, agriculture and space. India is rich in certain atomic minerals.

Uranium mines are located in Singhbhum in Bihar and parts of Rajasthan. Most abundant source is monazite sands on the shores of Kerala. Thorium is derived from these sands. In India, Nuclear Power Corporation (NPC) is engaged with establishment of nuclear power plants. We are the seventh nation in the world to have mastered the nuclear fuel cycle. At present there are six nuclear power plants in operation generating 1230 MWe (individual plant capacity ranging 210 to 235 MWe). These plants are located in states of Maharhashtra (Tarapur), Rajasthan (Kota), and Tamil Nadu (Kalpakkam). Some more units are to come up in Gujarat (Kakarapor), Karnataka (near Karwar) and Uttar Pradesh (Narora) in near future increasing the present installed capacity of 1230 MWe to 10000 MWe by 2000 A.D.

Non-Conventional Sources of Energy

Coal, mineral oil, natural gas and nuclear minerals are non-renewable and are to last one day. Moreover, their use is invariably associated with environmental pollution problems. Large scale utilisation of wood may lead to deforestation. Moreover, centralised system in conventional source of energy, involves much expenditure on setting up infrastructure and management. There is now a trend towards decentralisation. It would provide greater initiative to local people who could assess their needs and resources and plan a strategy that suits best to them.

The energy crisis during 1970s forced scientists to develop alternative sources of energy that should be renewable and pollution free. Due to rapidly depletion of conventional energy sources, countries all over the world have been forced to concentrate over tapping the vast potential of non conventional energy source like dendrothermal, solar, wind, ocean (tidal), geothermal heat, biomass, farm and animal waste including human excreta. All these sources are renewable and inexpensive.

In India, while the responsibility for harnessing the potential for energy by conventional technology lies with the Department of Power/Central Electricity Authority and the State Governments the Department of Non-conventional Energy Source (DNES) is actively involved in R&D activity for developing non-conventional know-how technology. Non-conventional sources can augment power in specific areas in a decentralised manner. Their potential is actually for local use.

Solar Energy. Domestic heating and water supply can be met by this source. In Israel, such systems of heating homes and water supply are already in operation. In U.S.A., commercial solar heaters are available in Florida and California. In Asia, Africa and Australia where number of sunshiny days is high, this method has promising future. India receives abundant sunshine with about 1648-2108 kwh/m^2/year with nearly 250-300 days of useful sunshine in a year. The daily solar energy incidence is between 5 to 7 kwh/m^2 at different parts of the country. This enormous solar energy

resource may be converted into other form of energy through thermal or photovoltaic conversion routes. The solar thermal route uses radiation in the form of heat that in turn may be converted to mechanical, electrical or chemical energy. Solar thermal devices like solar cookers, solar water/air heaters, solar dryers, solar wood seasoning kilns and silicon systems have been developed. A solar cooker consisting of an aluminium reflector (10 sq. ft. in area) has been tried and introduced by DNES in extremely cold and remote areas of Ladakh. IITs have been successful in developing the technology to trap solar and wind energy on the icy continent of Antarctica and remote areas of Leh and Ladakh. In a solar cooker, nearly one m^2 collector area at 17.3 per cent efficiency would give a saving of 663 kg of wood at 4708×10^3 kcal/kg.

The photovoltaic conversion systems convert solar radiation directly into electricity through silicon solar cells. These may be single crystal silicon cell, polycrystalline cells, amorphic solar cells etc. Such systems are used for community lighting, radio and TV sets, light houses, offshore platforms and installation in remote areas. An important application of these systems in pumping of water of microirrigation and drinking purposes. Such systems are decentralised on the spot electricity generation systems and help to replace diesel utilising systems. Thus photovoltaics and totally without chemical and noise pollution. They may be installed in remote areas as forests, deserts etc. Under the National Solar Photovoltaic Energy Demonstration Programme (NSPEDP) the DNES has since 1980 installed a number of photovoltaic devices with a target of producting 1 MW of electricity. Such systems are used for pumping water, village electrification, use in TV sets etc.

The Rural Electrification Corporation has identified 90,000 villages in remote areas where electric supply is very costly and physically tedious. In such cases photovoltaics can be used as also biomass-based systems. According to ABE (1985) nearly 30,000 villages would be benefited by photovoltaics, a demand for 75 MW. More than 300 villages in Rajasthan, Gujarat, U.P. and Haryana are supplied with street lighting units. India is to set up its first solar power station near Delhi very soon. The working groups of the Asian Solar Energy Network sponsored by the DNES/UNESCO had meetings for developing of technology for solar heaters, drying, desalination etc. The Department of Metallurgy, College of Engg., Pune designed a solar furnace that can generate temperature of 2,000°C. This can be used for heat treatments like surface hardening of steel and cost iron etc. In Haryana, first solar water heater was installed in 1982 at Haryana Breweries Ltd., Murthal. The systems is able to heat 15,000 litres of water per day at average temperature of 65°C. At Medical College, Rohtak, the system is capable of heating 25,000 litres of water at 65°C. at other places in Haryana, there are such systems in operation. The first solar desalination plant has

been installed at Haryana Tourist Complex at Dubchick. It will treat 2,000 litres of potable water daily. The first multipurpose solar dryer-cum warehouse is being constructed at Ganaur (Haryana) to be used for dry chillies, potato chips etc. More than 100 domestic solar heaters of 100 litre capacity are installed in different parts of Haryana. A photovoltaic irrigation pumpset has been installed at Haryana Agricultural University, Hisar.

Wind Energy. In the country there are areas which are quite windy. Average annual wind density of 3kw/m^2/day are prevalent at a number of places in Peninsular India as also along coast-line in Gujarat, Western Ghats and parts of Central India. The wind densities are even more than 10kw/m^2/day during winter and wind densities exceeding 2kw/m^2/day are available for 5-7 months in a year.

Wind energy may be converted into mechanical and electrical energies. To date wind energy has been utilised for pumping water in rural areas and may also be useful in remote areas. About 20,000 mw electricity can be generated in India from wind. According to DNES, the wind farms with a total capacity of 3.3 mw have already been set up in Mandvi; 1.1 mw in Kutch; 550 kW in Okha (Gujarat); 550 kw in Deogarh (Maharashtra); 550 kw in Tuticorin (Tamil Nadu) and 550 kw in Puri (Orissa). The types of the wind mills developed are, 12 PU-500, Sail Tpe, Vertical Axis type etc.

Wind energy is useful in remote areas, helps saving fossil fuels, would deliver on the spot small quantity of energy which is free from pollution and environmental degradation. DNES has installed 924 wind pumps (PU-500 type) with pumping capacity of about 20m throughout the country. Gujarat is the first state in the country to start using wind power.

Ocean (Tidal) Energy. Tidal power generation depends on the harnessing of rise and fall of sea level due to tidal action. Small tidal power plants have been constructed in China and USSR. The most important application of tidal power is in electricity generation. In 1966, France constructed the first major tidal electric plant. In India, prospective sites for exploitation of tidal energy are Gulfs of Kutch and Cambay and Sunderbans. In Kutch, French assistance has been received. Other suitable sites are near Lakshadweep Islands and Andaman and Nicobar Islands. At both these places, the cold water layers (20°C or lower) at 1,000 m depth are available near the shore. In India, tidal power potential of the order of 9,000 mw has been identified, of which 800-1000 mw in Gulf of Kutch; 7000-8000 mw in Gulf of Cambay and the rest in Suderbans.

India could intensify work on ocean thermal energy conversion (OTEC) and wind wave energy, that would go a long way in meeting the power requirements in remote oceanic islands and coastal towns. The country is already exercising with exploiting tidal energy. The Central Electricity Authority and the Gujarat Electricity Board carried out site studies for establishment of tidal plants in the Gulf of Kutch. India has an excellent

OTEC potential and some of the best sites in the world are kare known to be located off the Indian mainland and near the islands of Lakshadweep and Andaman and Nicobar. Total OTEC potential around India is nearly 50,000 mw which is about 150 per cent of the present total installed power generating capacity in the country.

OTEC. We may utilise the temperature difference existing between warm surface sea water (28-30°C) and the cold deep sea water (5-7°C) which is available at a depth of about 800 m to 1000 m in tropical waters. The advantage is that power is continuous, renewable and pollution free. A floating OTEC plant can generate power even at mid-sea and can be used to provide power for operations like off-shore mining and processing of manganese nodules. We have already designed a one mw plant for Lakshadweep islands.

Wind Wave Energy. The incessant motion of the sea surface in the form of wind waves constitutes a source of energy. About 1.5 per cent of the incoming energy from sun is converted to wind energy. Part of this is transferred to the sea surface resulting in the generation of waves. This then is carried to coastal lines where it is dissipated as the waves break. Extract of energy from waves is more efficient than direct collection of power from wind, since the wave energy is concentrated through the interaction of the wind and the free ocean surface. For India whose coastal line extends to about 6000 km in length wave energy potential is estimated to be around 60,000 mw. There are many other benefits in extraction of wave energy. A multipurpose wave regulator system (WRS) in the form of a long barrier results in the formation of a calm pool between the barrier and shore, and this can be used as a harbour, space for aquaculture, space for coastal transportation with lighter and faster crafts and shore protection against the erosion by sea. A WRS can be placed at a depth of about 10 m, a distance of about 500 m form the shore (available at most places along the Indian coasts). Gujarat may become the first state of the country to make use of tidal power.

Geothermal Energy. Here we utilise the heat in the interior of the earth for power generation. This is possible in volcanic regions or where hot springs and geysers occur. For developing countries the overall projected potential was estimated at 400×10^{18} joules for geothermal energy with a projected capacity at 2300 mw in 1990. The total potential worked out to be nearly 1/5th of 1971 recoverable resources of natural gas. Efforts are being made to use this energy for generating power and creating refrigeration etc. A cold storage unit and 5 mw power plant have been set up at Manikaran (H.P.) Geological exploration for prospective location for geothermal energy for electricity generation are to be undertaken. Drilling into deeper levels is necessary where there is a possibility of availability of geothermal fluids. At present nearly 350 geothermal springs have been located in the country.

Puga (Ladakh) geothermal area is a good site for power generation. Other areas to be screened are, Tattapani (Sarguja Distt., M.P.), Cambay Basin (Alaknada Valley, U.P.) and Parvati Valley (H.P.).

Bio-energy. Global requirements for energy have increased significantly during past few years and likely to continue during future also. Not only, human population growth increased, particularly in developing countries, but there has also been increase in per capita consumption. Depleting resources of fossil fuels and the gaseous emission problem associated with their use led to development of non-polluting renewable sources of energy. Energy produced from biomass is, therefore, a potential alternative energy for sustainable development. Biomass is a general term used for all materials originating from photosynthesis. Thus biomass includes all new plant growth, residues and wastes (wood, short rotation trees); herbaceous plants; freshwater and marine algae; aquatic plants; agricultural and forest residues (straw husks, bagasse, corn cobs, bark, sawdust, wood shavings, roots, animal dropping); wastes (garbage, night soil, sewage, industrial refuse etc.). Biodegradable organic effluents from industries like canneries, sugar mills, slaughter houses, meat packing plants, breweries, distilleries etc., are also included in this category. Biomass can also be produced from hydrocarbon plants, oils etc. Biomass energy systems are renewable and act as a sink for CO_2. They help in conservation of soil and water and halt water run off and desertification.

Biomass is considered to be one of the key renewable resources at both small and large-scale levels. It already supplies 14 per cent of the world's primary energy consumption. On average, biomass produces 38 per cent of primary energy in developing countries. Biomass is being increasingly used even in developed countries. The census of India, 1991, reported that of the 151 million households in India in 1991 (39.5 million in urban area and 111.5 million in rural areas), 92 per cent in rural areas and 39 per cent in urban areas were dependent on bio-fuels (Down to Earth, 2001). 3.2 per cent energy in India comes from non-conventional sources, of which 12.5 per cent non-conventional energy is generated in Tamil Nadu.

Biomass is already supplying roughly 15 per cent of the world's requirements of energy, i.e., 55KJ (55×10^{18}) per year (25 million barrels of oil/day). The various sources of bioenergy (biofuels) are hydrogen produced by some microorganisms, methane/biogas generated during biological gasification of organic wastes (anaerobic digestion of biomass by methanogenic microbes), energy plantations (dendrothermal energy), ethanol (by conversion of starch-rich biomass feed stocks into alcohol using microbes) and biodiesel from petroplants.

Hydrogen. Many experts believe that, as we run out of fossil fuels, we will move towards using the element hydrogen as the main fuel to run the world's economy. When hydrogen burns and gives us energy, it combines

with oxygen to produce water vapour. In this process, there is no air pollution or emission of carbon dioxide.

This is good news again! What are we waiting for? There is some bad news too. Hydrogen is not available in a free state : it is locked in water and in compounds like petrol and methane. We need to use energy and an effective method to split these compounds to get hydrogen. We can split water by heat or by a process called methanol. Thus the first problem is one of collection. As in the case of solar energy, we also have the problem of storage. Hydrogen is highly explosive and if it is stored as compressed gas, the tank needs to be large, heavy, and costly. Only large buses and trucks could hold the tanks. If we store it as a liquid, energy will be consumed in maintaining the very low temperatures that will be needed. Another method being tried out is storage as a solid metal hydride. Here again, energy is needed to release the hydrogen when we want it.

(*i*) **Fuel Cell.** A fuel cell is so called because it is an electrochemical unit like a battery. The fuel cell burns hydrogen to produce electricity. In the process, hydrogen combines with oxygen to produce water vapour. Thus there is no pollution and it runs continuously as long as there is input. Unlike a battery, the fuel cell draws its input (hydrogen and oxygen) from outside. Again, a battery requires recharging, but the fuel cell does not. Finally, there is no toxic output when a fuel cell is discarded.

Fuel cells were developed as far back as 1960 for space applications. The progress since then has, however, been slow. There are now experimental buses and cars running on fuel cells, but they are very expensive. Automobile companies like Daimler-Chrysler, Honda, and General Motors have made prototype fuel-cell cars.

(*ii*) **Problems with Using Hydrogen.** First, it takes energy to produce hydrogen. Obviously, against this input, we should get much more energy from the hydrogen we produce.

Second, if this input energy comes from fossil fuels, there will be environmental effects.

Third, the situation is even worse if we produce the hydrogen from fossil fuels themselves. Finally, we have not fully solved the problem of storing hydrogen.

(*iii*) **Hydrogen Economy.** We must first cost-effective ways of producing hydrogen from water using renewable energy like solar energy. We should solve all the storage problems too.

Increasing the efficiency of energy use will be equivalent to finding free sources of energy. There is tremendous scope for increasing energy efficiency in all our activities. The ordinary incandescent bulb has an efficiency of just 5-10 per cent. Most of the input electrical energy disappears as heat. Replacing it with a compact fluorescent lamp (CFL) will reduce consumption by 75 per cent. The initial cost is more, but over time it pays back. At the

same time, we are doing a service to society by consuming less energy. Incidently, the cost of CFLs has been steadily coming down.

The internal combustion engine that runs our automobiles is another device that wastes 90 per cent of the input energy. Driven by the first oil crisis, the fuel efficiency of American cars gradually increased between 1973 and 1985. Since then, however, it has levelled off primarily because of the consumer craze for the so-called Sport Utility Vehicle (SUV), minivan, etc., and because of the availability of cheap oil.

Makers like Toyota and Honda have introduced hybrid electric cars with much higher fuel efficiency. They run on petrol and a battery. The battery is kept charged by the petrol engine and an electric motor provides energy for acceleration and hill climbing. When the car is braked, part of the heat generated is used to charge the battery.

Whenever we use energy, some waste is inevitable. However, there is a large amount of avoidable waste in energy use. One estimate is that we waste more than 40 per cent of the commercial energy that we buy. Examples are vehicles and furnaces that waste fuel and poorly designed buildings that use up huge amounts of energy for heating and cooling. There is also the huge inefficiency of conventionally-fuelled power stations and large transmission losses.

Technology exists today for increasing the efficiency of most appliances by 50 per cent or more. As the demand for energy-efficient appliances increases, the prices will also come down. We must always consider the life cycle cost of devices, that is, the total of the initial cost and the operating costs over the lifetime of the device. Such an approach will make us take better decisions that will save cost and energy.

Model Questions

1. What is the main source of energy for this planet and how does it give us energy?
2. Which country consumes the maximum amount of energy and why is this fact relevant?
3. Why are fossil fuels non-renewable?
4. What are the special problems of nuclear power?
5. What are the prospects of getting more hydropower?
6. What are the hurdles in moving to a hydrogen economy?
7. How can we improve energy efficiency?
8. Give a brief account of non-renewable energy resources.
9. What are solar cells? Draw a diagram and enumerate its applications.
10. Discuss the merits and demerits of wind energy.
11. Comment upon the types of energy harnessed from oceans.
12. What is biogas? Discuss the structure and function of biogas plants.

6
Food Resources

We have thousands of edible plants and animals over the world out of which only about three dozen types constitute the major food of humans. The main food resources include wheat, rice, maize, potato, barley, oats, cassava, sweet potato, sugarcane, pulses, sorghum, millet, about twenty or so common fruits and vegetables, milk, meat, fish and seafood. Amongst these rice, wheat and maize are the major grains, about 1500 million metric tons of which are grown each year, which is about half of all the agricultural crops. About 4 billion people in the developing countries have wheat and rice as their staple food.

Meat and milk are mainly consumed by more developed nations of North America, Europe and Japan who consume about 80% of the total. Fish and sea-food contribute about 70 million metric tons of high quality protein to the world's diet. But there are indications that we have already surpassed sustainable harvests of fish from most of the world' oceans.

The Food and Agriculture Organization (FAO) of United Nations estimated that on an average the minimum caloric intake on a global scale is 2,500 calories/day. People receiving less than 90% of these minimum dietary calories are called undernourished and if it is less than 80% they are said to be seriously undernourished. Besides the minimum caloric intake we also need proteins, minerals etc. Deficiency or lack of nutrition often leads to malnutrition resulting in several diseases as shown in Table 6.1.

Table 6.1 : Impacts of Malnutrition

Deficiency	Health effect	No. of cases	Deaths per year (in millions)
Proteins and Calories	Stunted growth, Kwashiorkor, Marasmus	750 1 million	15-20
Iron	Anaemia	350 million	0.75-1
Iodine	Goitre, Cretinism	150 million, 6 million	
Vitamin A	Blindness	6 million	

World Food Problems

During the last 50 years world grain production has increased almost three times, thereby increasing per capita production by about 50%. But, at the same time population growth increased at such a rate in LDCs (Less developed countries) that it outstripped food production. Every year 40 million people (fifty per cent of which are young children between 1 to 5 years) die of undernourishment and malnutrition. This means that every year our food problem is killing as many people as were killed by the atomic bomb dropped on Hiroshima during World War II. These startling statistical figures more than emphasize the need to increase our food production, equitably distribute it and also to control population growth.

Indian Scenario. Although India is the third largest producer of staple crops, an estimated 300 million Indians are still undernourished. India has only half as much land as USA, but it has nearly three times population to feed. Our food problems are directly related to population.

The World Food Summit, 1996 has set the target to reduce the number of undernourished to just half by 2015, which still means 410 million undernourished people on the earth.

Chain of side effects on environment due to intensive practices for increased food production.

(A) Overgrazing

Livestock wealth plays a crucial role in the rural life of our country. India leads in livestock population in the world. The huge population of livestock needs to be fed and the grazing lands or posture areas are not adequate. Very often we find that the livestock grazing on a particular piece of grassland or pasture surpass the carrying capacity. Carrying capacity of any system is the maximum population that can be supported by it on a sustainable basis. However, most often, the grazing pressure is so high that its carrying capacity is crossed and the sustainability of the grazing lands fails. Let us see what are the impacts of overgrazing.

Impact of Overgrazing

(i) **Land Degradation.** Overgrazing removes the vegetal cover over the soil and the exposed soil gets compacted due to which the operative soil depth declines. So the roots cannot go much deep into the soil and adequate soil moisture is not available. Organic recycling also declines in the ecosystem because not enough detritus or litter remains on the soil to be decomposed. The humus content of the soil decreases and overgrazing leads to organically poor, dry, compacted soil. Due to trampling by cattle the soil loses infiltration capacity, which reduces percolation of water into the soil and as a result of this more water gets lost from the ecosystem along with surface run off. Thus overgrazing leads to multiple actions resulting in loss of soil structure, hydraulic conductivity and soil fertility.

(ii) **Soil Erosion.** Due to overgrazing by cattle, the cover of vegetation almost gets removed from the land. The soil becomes exposed and gets eroded by the action of strong wind, rainfall etc. The grass roots are very good binders of soil. When the grasses are removed, the soil becomes loose and susceptible to the action of wind and water.

(iii) **Loss of Useful Species.** Overgrazing adversely affects the composition of plant population and their regeneration capacity. The original grassland consists of good quality grasses and herbs with high nutritive value. When the livestock graze upon them heavily, even the root stocks which carry the reserve food for regeneration get destroyed. Now some other species appear in their place. These secondary species are hardier and are less nutritive in nature. Some livestock keep on overgrazing on these species also. Ultimately the nutritious, juicy fodder giving species like Cenchrus, Dichanthium, Panicum and Heteropogon etc., are replaced by unplatable and sometimes thorny plants like Parthenium, Lanthana, Xanthium etc. These species do not have a good capacity of binding the soil particles and, therefore, the soil becomes more prone to soil erosion.

As a result of overgrazing vast areas in Arunachal Pradesh and Meghalaya are getting invaded by thorny bushes, weeds etc., of low fodder value. Thus overgrazing makes the grazing land lose its regenerating capacity and once good quality pasture land gets converted into an ecosystem with poor quality thorny vegetation.

(B) Agriculture

In the early years of human existence on this earth, man was just a hunter gatherer and was quite like other animal species. Some 10,000 to 12,000 years ago he took to agriculture by cultivating plants of his own choice. He used the practice of Slash and burn cultivation or shifting cultivation, which is still prevalent in many tribal areas, as in the North East Hills of India. The type of agriculture practised these days is very different from the traditional ones and their outputs in terms of yield as well as their impacts on the environment show lots of differences.

1. Traditional Agriculture and its Impacts. It usually involves a small plot, simple tools, naturally available water, organic fertilizer and a mix of crops. It is more near to natural conditions and usually it results in low production. It is still practised by about half the global population.

The main impacts of this type of agriculture are as follows :

(i) **Soil Erosion.** Clearing of forest cover exposes the soil of wind, rain and storms, thereby resulting in loss of top fertile layer of soil.

(ii) **Depletion of Nutrients.** During slash and burn the organic matter in the soil gets destroyed and most of the nutrients are taken up by the crops within a short period, thus making the soil nutrient poor which makes the cultivators shift to another area.

(iii) **Deforestation.** The slash and burn of trees in forests to clear the land for cultivation and frequent shifting result in loss of forest cover.

2. Modern Agriculture and its Impacts. It makes use of hybrid seeds of selected and single crop variety, high-tech equipments and lots of energy subsidies in the form of fertilizers, pesticides and irrigation water. The food production has increased tremendously, evidenced by "green revolution". However, it also gave rise to several problematic off-shoots as discussed.

(i) **Pesticide related Problems.** Thousands of types of pesticides are used in agriculture. The first generation pesticides include chemicals like sulphur, arsenic, lead or mercury to kill the pests. DOT (Dichlorodiphenyl trichloroethane) whose insecticidal properties were discovered by Paul Mueller in 1939 belongs to the second generation pesticides. After 1940, a large number of synthetic pesticides came into use. Although these pesticides have gone a long way in protecting our crops from huge losses occurring due to pests, yet they have a number of side-effects, as discussed below :

(a) **Biological Magnification.** Many of the pesticides are non-biodegradable and keep on accumulating in the food chain, a process called biological magnification. Since human beings occupy a high tropic level in the food chain, they get the pesticides in a bio-magnified form which is very harmful.

(b) **Creating Resistance in Pests and Producing New Pests.** Some individuals of the pest species usually survive even after pesticide spray. The survivors give rise to highly resistant generations. About 20 species of pests are now known which have become immune to all types of pesticides and are known as "Super pests".

(c) **Death of Non-Target Organisms.** Many insecticides are broad spectrum poisons which not only kill the target species but also several non-target species that are useful to us.

(ii) **Salinity Problem.** At present one third of the total cultivable land area of the world is affected by salts. In India about seven million hectares of land are estimated to be salt-affected which may be saline or sodic. Saline soils are characterized by the accumulation of soluble salts like sodium chloride, sodium sulphate, calcium chloride, magnesium chloride etc., in the soil profile. Sodic soils have carbonates and bicarbonates of sodium.

(iii) **Fertilizer Related Problems.**

(a) **Eutrophication.** A large proportion of nitrogen and phosphorus used in crop fields is washed off and along with runoff water reach the water bodies causing over nourishment of the lakes, a process known as Eutrophication (eu = more, trophic - nutrition). Due to eutrophication the lakes get invaded by algal blooms. These algal species grow very fast by rapidly using up the nutrients. They are often toxic and badly affect the food chain. The algal species quickly complete their life cycle and die thereby

adding a lot of dead organic matter. The fishes are also killed and there is a lot of dead matter that starts getting decomposition and very soon the water gets depleted of dissolved oxygen. This further affects aquatic fauna and ultimately anaerobic conditions are created where only pathogenic anaerobic bacteria can survive. Thus, due to excessive use of fertilizers in the agricultural fields the lake ecosystem gets degraded. This shows how an unmindful action can have far reaching impacts.

(b) **Micronutrient Imbalance.** Most of the chemical fertilizers used in modern agriculture have nitrogen, phosphorus and potassium (N, P, K) which are essential macronutrients. Farmers usually use these fertilizers indiscriminately to boost up 'crop growth. Excessive use of fertilizers cause micronutrient imbalance. For example, excessive fertilizers use in Punjab and Haryana has caused deficiency of the micronutrient zinc in the soils, which is affecting productivity of the soil.

(c) **Nitrate Pollution.** Nitrogeneous fertilizers applied in the fields often leach deep into the soil and ultimately contaminate the ground water. The nitrates get concentrated in the water and when their concentration exceeds 25 mg/L, they become the cause of a serious health hazards called "Blue Baby Syndrome" or methaemoglobinemia. This disease affects the infants to the maximum extent causing even death. In Denmark, England, France, Germany and Netherlands this problem is quite prevalent. In India also, problem of nitrate pollution exists in many areas.

(iv) **Impacts of High Yielding Varieties (HYV).** The uses of HYVs encourage monoculture i.e., the same genotype is grown over vast areas. In case of an attack by some pathogen, there is total devastation of the crop by the disease due to exactly uniform conditions, which help in rapid spread of the disease.

(v) **Water Logging.** Over irrigation of croplands by farmers for good growth of their crop usually leads to waterlogging. Inadequate drainage causes excess water to accumulate underground and gradually forms a continuous column with the water table. Under water-logged conditions, pore-spaces in the soil get fully drenched with water and the soil-air gets depleted. The water table rises while the roots of plants do not get adequate air for respiration. Mechanical strength of the soil declines, the crop plants get lodged and crop yield falls.

In Punjab and Haryana, extensive areas have become water-logged where adequate canal water supply or tube-well water encouraged the farmers to use it over-enthusiastically leading to water-logging problem.

Preventing excessive irrigation, sub-surface drainage technology and bio-drainage with trees like Eucalyptus are some of the remedial measures to prevent water-logging.

Causes. A major cause of salinization of soil is excessive irrigation. About 20% of the world's croplands receive irrigation with canal water or

ground water which unlike rainwater often contains dissolved salts. Under dry climates, the water evaporates leaving behind salts in the upper soil profile.

Thousands of hectares of land area in Haryana and Punjab are affected by soil salinity and alkalinity. Salinity causes stunted plant growth and lowers crop yield. Most of the crops cannot tolerate high salinity.

Remedy. The most common method for getting rid of salts is to flush them out of applying more good quality water to such soils. Another method is laying underground network of perforated drainage pipes for flushing out the salts slowly. This sub-surface drainage system has been tried in the experimental station of CSSRI at Sampla, Haryana. The Central Soil Salinity Research Institute (CSSRI) located in Karnal, Haryana has to its achievement the success story of converting Zarifa Viran village to Zarifa Abad *i.e.,* 'from the barren land to productive land' through its research applications.

Conservation of Natural Resources : Role of an Individual

Natural resources like forests, water, soil, food, mineral and energy resources play a vital role in the development of a nation. But the overuse of these resources in our modern society is resulting in fast depletion of these resources and several related problems. In order to save mankind there is a strong need to conserve these natural resources.

The word 'conservation' has derived from Latin words *'Con'* meaning 'together' and 'servare' meaning 'guard' which normally means safety or sustainance. Conservation does not mean that use of resources should be stopped. Actually the aim of conservation is the balanced and proper utilization of natural resources so that neither the environment is affected nor the coming generations are deprived of them.

Conservation efforts are going on at national as well as international level, but the individual efforts for conservation of natural resources can only solve the problem. Environment belongs to each one of us and all of us have a responsibility to contribute towards its conservation and protection. With our small individual efforts we can together help in conserving our natural resources to a large extent. Individuals help in conservation of different resources in the following way :

Conservation of Energy

- Building houses with provision for sunspace which will keep the houses warmer and will provide more light.
- Planting deciduous trees and climbers at proper places outside the home to cut off intense heat of summers and get a cool breeze and shade. This can cut off electricity charges on coolers and air-conditioners. A big tree is estimated to have a cooling effect equivalent to five air conditioners. The deciduous trees shed their

leaves in winter. Therefore they do not put any obstacle to the sunlight and heat.

- Lights, fans and other appliances should be turned off when they are not in use.
- Using solar cooker for cooking food on sunny days which will be more nutritious and will cut down on LPG expenses.
- Obtaining as much heat as possible from natural sources. Drying clothes in sun instead of drier if it is a sunny day.
- Recycle and reuse glass, metals and paper.
- It is better to lower the cooling load on an air conditioner by increasing the thermostat setting as 3-5% electricity is saved for every one degree rise in temperature setting.
- Drive less, make fewer trips and use public transportations whenever possible. You can share by joining a car-pool if you regularly have to go to the same place.
- Instead of using the heat convector more often wear adequate woollens.
- Riding bicycle or just walking down small distances should be preferred to using a car or a scooter.
- During winter we should close the windows at night. During summer we should close the windows during days if using an A.C. Otherwise loss of heat would be more, consuming more electricity.

Promoting Sustainable Agriculture

- We should fertilize our crop primarily with organic fertilizers.
- We should not waste food. Eat as much as we can.
- We should control pests by a combination of cultivation and biological control methods.
- We should use drip irrigation to water the crops.
- We should reduce the use of pesticides.
- We should eat local and seasonal vegetables. This saves lot of energy on transport, storage and preservation.

Conservation of Water

- We should use drip irrigation and sprinkling irrigation to improve irrigation efficiency and reduce evaporation.
- In washing machines we should fill the machine only to the level required for our clothes.
- We should build rain water harvesting system in our houses. Even the President of India is doing this.
- We should check for water leaks in pipes and toilets and repair them promptly. A small pin-hole sized leak will lead to the wastage of 640 litres of water in a month.

- We should not keep water taps running while brushing, shaving, washing or bathing.
- We should water the plants in our kitchen-garden and the lawns in the evening when evaporation losses are minimum. We should never water the plants in mid-day.
- We should install a small system to collect rain water and collect normally wasted used water from sinks, cloth-washers, bath-tubs etc., which can be used for watering the plants.
- We should reuse the soapy water of washings from clothes for washing off the courtyards, driveways etc.
- We should install water-saving toilets that use not more than 6 litres per flush.

Soil Protection

- We should better use sprinkling irrigation.
- We should use mixed cropping so that some specific soil nutrients do not get depleted.
- We should grow different types of ornamental plants, herbs and trees in our garden. Grow grass in the open areas which will blind the soil and prevent its erosion.
- We should not over-irrigate our fields without proper drainage to prevent water logging and salinisation.
- At the time of constructing our houses, we should avoid to uproot the trees as far as possible. It is better to plant the disturbed areas with a fast growing native ground cover.
- Using green manure and mulch in the garden and kitchen-garden can protect the soil.
- Making compost from our kitchen waste and using it for our kitchen-garden or flower-pots are best means of conserving natural resources.
- We should not irrigate the plants using a strong flow of water, as it would wash off the soil.

Model Questions

1. What are the sources of our food and is there enough food in the world for all?
2. What is overgrazing? How does it contribute to environmental degradation?
3. Write a note on equitable use of resources for sustainable life style.
4. What role can an individual play in conservation of natural resources?

7
Ecosystem

The term Ecology was coined by Earnst Haeckel in 1869. It deals with the study of organisms in their natural home interacting with their surroundings. The surroundings or environment consists of other living organisms (biotic) and physical (abiotic) components. The term ecosystem was proposed by the British environmentalist A.G. Tansley in 1935, who defined it as 'the system resulting from the integration of all the living and non-living factors of the environment'. Thus the ecosystem was regarded as including not only the organism-complex but also the whole complex of physical factors farming the environment.

Thus any unit that includes all the organisms i.e., the communities in a given area, interact with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycle (i.e., exchange of materials between living and non-living components) within the system, known as an ecological system or ecosystem. We may think of the earth, we live upon as a giant ecosystem where abiotic and biotic components are constantly acting and reacting upon each other bringing forth structural and functional changes in it. This vast ecosystem—biosphere is, however, difficult to handle and thus for convenience we generally study nature by making its artificial subdivisions into units of smaller ecosystems (terrestrial—forest, desert, grassland; man-engineered as a cropland; aquatic-freshwater, marine etc.) of different sizes.

Basic Concept

An ecosystem is a community of living organisms (populations of species) interacting with one another and with the non-living physical and chemical environment. The interactions are such as to perpetuate the community and to retain a large degree of stability under varying conditions.

A puddle of water, a stream, a clump of bushes, a thick forest, and a large desert are all ecosystems. The ecosystems of this planet are interconnected and interdependent and together they make up the vast biosphere.

To understand what the *biosphere* is, we should first know what the Earth is like. The Earth has several spherical layers. The atmosphere is a

thin envelope of air around the earth extending to about 50 km above its surface. That part of the atmosphere up to a distance of 17 km above sea level is called the *troposphere;* it contains the planet's air. Above the troposphere is the *stratosphere* that contains ozone. It is the ozone that supports life by filtering out the harmful ultraviolet radiation from the Sun.

The *hydrosphere* consists of the liquid water, ice and water vapour, while the *lithosphere* is the earth's upper crust containing fossil fuels and minerals. Then we have the biosphere, in which all the living organisms interact with each other and with their environment. The biosphere includes most of the hydrosphere, and parts of the lower atmosphere and upper lithosphere. Thus, the biosphere is that portion of the plant and its environment which can support life.

- According to **R.L. Lindman,** "Any system composed of physical-chemical-biological processes within a specific time unit of any magnitude is known as ecosystem."
- According to **P. Hagget,** "Ecosystems are ecological systems in which plants and animals are linked to their environment through a series of feedback loops."
- According to **E.P. Odum,** "In the study of ecosystem, we deal with body of nature, its construction and its functions."
- **Encyclopaedia Britannica** defines "Ecosystem is that unit of a particular area in which all the individuals of that area and their interactions with environment are included."

Kinds of Ecosystem

Different types of ecosystem may be categorized as follows :

(1) **Natural Ecosystem.** These operate by themselves under natural conditions without any major interference by man. Based upon the particular kind of habitat, these are further divided as :

(i) **Terrestrial,** as forest, grassland, desert, etc.

(ii) **Aquatic** (water-open), which may be further distinguished as :

(a) **Freshwater,** which may be lotic (running-water as spring, stream, or rivers) or lentic (standing-water as lake, pond, pools, puddles, ditch, swamp etc.).

(b) **Marine,** such deep bodies as an ocean or shallow ones as a sea or estuary etc.

(2) **Artificial (Non-engineered) Ecosystems.** These are maintained artificially by man where, by addition of energy and planned manipulations, natural balance is disturbed regularly. For example, croplands like maize, wheat, rice-fields etc., where man tries to control the biotic community as well as the physico-chemical environment, are artificial ecosystems. In addition to above the rapid progress made during recent years led to the recognition of some other such types of ecosystem as space ecosystem etc.

Structure of Ecosystem

An ecosystem has two major components :

1. **Abiotic (Non-living) Component.** Abiotic components are essential for biotic components. These can be divided into organic, inorganic and climatic factors :

(i) **Inorganic Matter.** It includes many nutrients and factors as calcium, carbon, oxygen, hydrogen, carbon dioxide, sulphur, phosphorus, mineral elements etc.

(ii) **Organic Matter.** This includes protein and carbohydrates. These mainly form biomass and link abiotic and biotic factors.

(iii) **Climatic Factors.** Sunlight, temperature, rainfall, water, vapours, moisture, land, soil, landscapes and geographical factors are included in it. These affect distribution, number and behaviour etc. of organisms.

2. **Biotic (Living) Component.** This is indeed the trophic structure of any ecosystem, where living organisms are distinguished on the basis of their nutritional relationships. From this trophic (nutritional) standpoint, an ecosystem has two components :

(i) **Autotrophic Components.** Autotrophic components are those which manufacture their own food for living. Plants are included in this category. Plants obtain their food with the help of roots and leaves. Roots provide moisture and minerals while leaves produce energy by a chemical reaction in the presence of sunlight. This process is known as photosynthesis. A green coloured pigment named chlorophyll present in leaves makes the process of photosynthesis possible. Some plants are chemotrophs which obtain food by oxidation of non-living inorganic elements. These remain alive even without light in the depths of oceans. Some bacteria and algae are included in such plants. It is worth mentioning here that many other organisms specially plant bacteria manufacture their own food and thus are included in autotrophs with green plants.

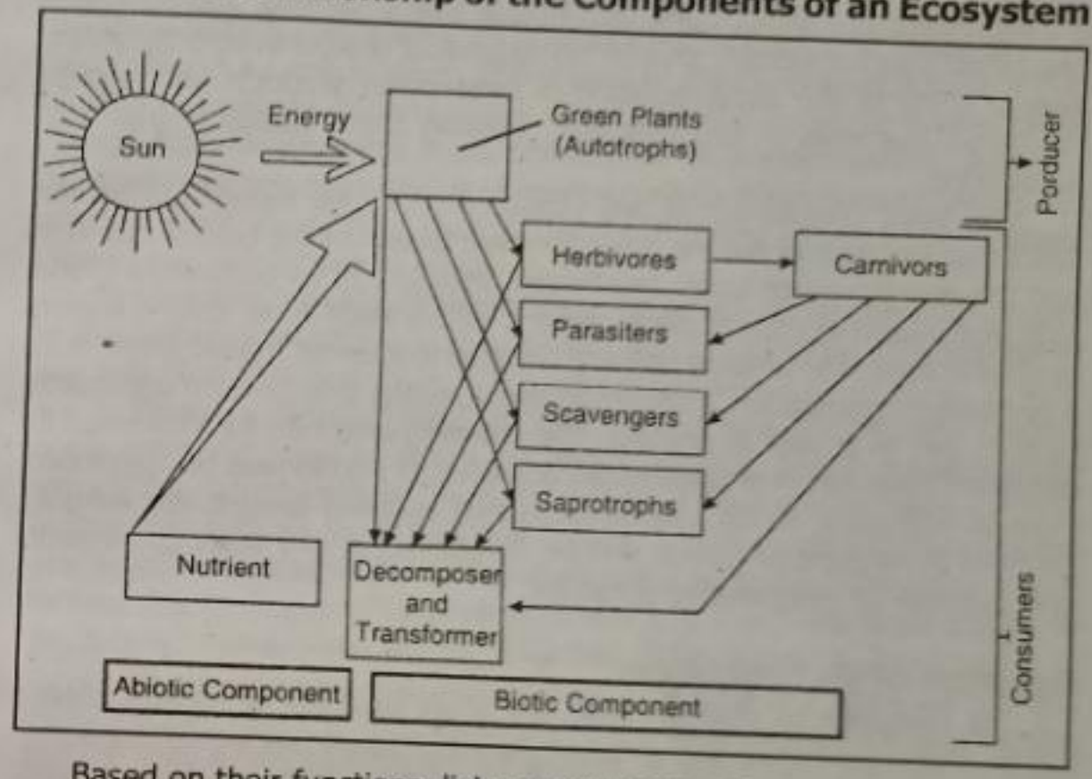
(ii) **Heterotrophic Component.** This category includes all those organisms which depend on plants or other organisms for their food. They use plants and other organisms for food, rearrange them and finally decompose them. Because they consume food from autotrophs or other heterotrophs, they are also known as consumers. Depending upon method of taking food, heterotrophs are divided into three sub-components :

(a) **Saprophytes.** These organisms live on organic matter obtained from dead plants and other organism. For example, bacteria, some fungi etc.

(b) **Parasites.** These organisms completely depend on other organisms for their living and food. For example, virus, amoeba, fungi, amarbel etc.

(c) **Holozoic.** These organisms take their food from mouth. All large organisms including man are included in this category.

Table 7.1 : Relationship of the Components of an Ecosystem



Based on their functions, living components of ecosystem are divided into three categories :

1. **Producers.** Autotrophic plants which use their green leaves for synthesis and storage of food from sunlight are included in this category. These producers are responsible for transferring solar energy to other organisms. The series of living organisms developed through this solar-energy transfer mechanism. Therefore, the plants are really termed "gods" (the givers), because they form the basis of food for all organisms.

2. **Consumers.** These are the heterotrophic organisms which depend on plants (producers) or other organisms for their food. When animals eat plants, the sugar and other components present in plants give them chemical energy, enabling them to run their physiological processes works. Consumers can again be divided into three categories :

(a) **Primary Consumers (Herbivores).** The organisms which obtain their food directly from plants or producers are known as primary consumers. These are also known as herbivores. For example, cow, horse, goat, squirrel, rabbit, some rodents and grasshoppers are all primary consumers.

(b) **Secondary Consumers (Carnivores).** These include the organisms which eat primary consumers for their food. These are also known as carnivores. Lion, tiger, frog etc. are carnivorous organisms.

(c) **Tertiary Consumers (Omnivores).** In this category are included the omnivores which take producers, primary consumers (herbivores) as well as secondary consumers (carnivores).

3. **Decomposers.** These are popularly known as microconsumers. They are saprotrophs (= osmotrophs) and include chiefly bacteria, actinomycetes and fungi. They breakdown complex compounds of dead or living protoplasm, absorb some of the decomposition or breakdown products and release inorganic nutrients in environment, making them available again to autotrophs.

The biotic component of any ecosystem may be thought of as the functional kingdom of nature, since they are based on the type of nutrition and the energy source used. The trophic structure of an ecosystem is one kind of producer-consumer arrangement, where each 'food' level is known as trophic level. The amount of living material indifferent trophic levels or in a component population is known as the standing crop, a term applicable to both, plants as well as animals. The standing crop may be expressed in terms of (i) number of organisms per unit area, or (ii) biomass i.e., organism mass in unit area, which can be measured as living weight, dry weight, ash-free dry weight or carbon weight, or calories or any other convenient unit suitable for comparative purposes.

Function of an Ecosystem

The foregoing account presents the gross structure of an ecosystem. But for a fuller understanding of nature, functions (particularly rate functions) must also be investigated. Both, structure and function, are best studied together, and now we shall consider a brief outline of gross function of an ecosystem i.e., how an ecosystem works or operates under natural conditions?

From the operational viewpoint the living and non-living components of ecosystem are so interwoven into the fabric of nature that their separation from each other becomes practically very much difficult. The mode of movement of materials and energy in an ecosystem is shown in simple model presented in Table 7.1. The producers, green plants, fix radiant energy and with the help of minerals like carbon, oxygen, zinc, iron, calcium etc. taken from their soil and aerial environment (nutrient pool) they build up complex organic matter (carbohydrates, fats, proteins, nucleic acids etc.). Some ecologists prefer to call the green plants as converters or transducers, since they feel that the term 'producer' from an energy viewpoint is somewhat misleading. Their viewpoint is that green plants produce carbohydrates and not energy and since they convert or transduce radiant energy into chemical form, they must be better called the converters or transducers. However, the term 'producer' is so widely used that it is preferred to retain it as such.

The two ecological processes of energy flow and mineral cycling, involving interaction between the physio-chemical environment and the biotic communities, may be thought as the 'heart' of the ecosystem dynamics.

According to the model shown in Table 7.1, energy flows in non-cyclic manner (unindirectional) from sun to the decomposers via producers an macroconsumers (herbivores and carnivores), whereas the minerals keep on moving in a cyclic manner. The cycling of the minerals is accomplished by different biogeochemical cycles super-imposed upon the undirectional energy flow through the biotic component of the ecosystem. It would become, however, clear later that energy not only flows unidirectionally but also lost from the system in several ways and that minerals too similarly show a net loss in several ways.

Productivity of Ecosystem. The productivity of an ecosystem refers to the rate of production i.e., the amount of organic matter accumulated in any unit time. Productivity is of the following types :

1. **Primary Productivity.** It is associated with the producers which are autotrophic, most of which are photosynthetic, and to a much lesser extent the chemosynthetic microorganisms. These are the green plants, higher macrophytes as well as lower forms, the phytoplanktons and some photosynthetic bacteria. Primary productivity is defined as "the rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of producers." Primary productivity is further distinguished as follows :

(i) **Gross Primary Productivity.** It is the total rate of photosynthesis including the organic matter used up in respiration during the measurement period. This is also sometimes referred to as total (gross) photosynthesis or total assimilation. It depends on the chlorophyll content. The rate of primary productivity are estimated in terms of either chlorophyll content per unit area, or photosynthetic number i.e., amount of carbon dioxide per hour.

(ii) **Net Primary Productivity.** It is the rate of storage of organic matter in plant tissues in excess of the respiratory utilisation by plants during the measurement period. This is thus the rate of increase of biomass and is also known as apparent photosynthesis or net assimilation. Thus, net primary productivity refers to balance between gross photosynthesis and respiration and other plant losses as death etc.

2. **Secondary Productivity.** It refers to the consumers or heterotrophs. These are the rates of energy storage at consumers level. Since consumers only utilise food materials (already produced) in their respiration, simply converting the food matter to different tissues by an overall process, secondary productivity is not divided into "gross" and "net" amounts. Thus, some ecologists prefer to use the term assimilation rather than "production" at this level—the consumers level. Secondary productivity actually remains mobile (i.e., keeps on moving from one organism to another) and does not lie in situ like the primary productivity.

3. **Net Productivity.** It refers to the rate of storage of organic matter not used by the heterotrophs (consumers) i.e., equivalent to net primary production minus consumption by the heterotrophs during the unit period,

as a season or year etc. It is thus the rate of increase of biomass of the primary producers which has been left over by the consumers.

Food Chains in Ecosystems

The transfer of food energy from the producers, through a series of organisms (herbivores to carnivores to decomposers) with repeated eating and being eaten, is known as a food chain. Producers utilise the radiant energy of sun which is transformed to chemical form, ATP during photosynthesis. Thus green plants occupy, in any food chain, the first trophic (nutritional) level—the producers level, and are called the primary producers. The energy, as stored in food matter manufactured by green plants, is then utilised by the plant eaters—the herbivores, which constitute the second trophic level—the primary consumers level, and are called the primary consumers (herbivores). Herbivores in turn are eaten by the carnivores, which constitute the third trophic level—the secondary consumers level, and are called the secondary consumers (carnivores). These in turn may be eaten still by other carnivores at tertiary consumers level i.e., by the tertiary consumers (carnivores).

Some organisms are omnivores eating the producers as well as the carnivores at their lower level in the food chain. Such organisms thus may occupy more than one trophic levels in the food chain. This classification of all the living organisms of any ecosystem is one of their functions and not of species. Species that are taxonomically widely different from each other may occupy the same trophic level as they all have the similar function in the food chain. Typha, Nymphaea, Chara, Volvox, Nostoc, photosynthetic bacteria, although taxonomically much different but all belong to the same trophic level—the producers level, as all have a common function i.e., the fixation of radiant energy into chemical form.

In any food chain, energy flows from primary producers to primary consumers (herbivores), from primary consumers to secondary consumers (carnivores), and from secondary consumers to tertiary consumers (carnivores/omnivores) and so on. This simple chain of eating and being eaten away is known as food chain. A food chain in grassland ecosystem starts with grasses and forbs and goes through grasshoppers, the frogs, the snake, the hawk in an orderly sequential arrangement based on the food habits, whereas in a pond the order would start with phytoplanktons, going through water fleas, smaller fish, bigger fish, birds, larger animal and so on.

In nature, we generally distinguish the following two general types of food chains :

Grazing Food Chain. This type of food chain starts from the living green plants, goes to grazing herbivores (that feed on living plant materials with their predators), and on to carnivores (animal eaters). Ecosystems

with such type of food chain are directly dependent on an influx of solar radiation. This type of chain thus depends on autotrophic energy capture and the movement of this captured energy to herbivores. Most of the ecosystems in nature follow this type of food chain. From energy standpoint, these chains are very important. The phytoplanktons-zooplanktons—fish sequence or the grasses-rabbit-fox sequence are the examples of grazing food chain. A grazing food chain in a pond ecosystem is shown below :

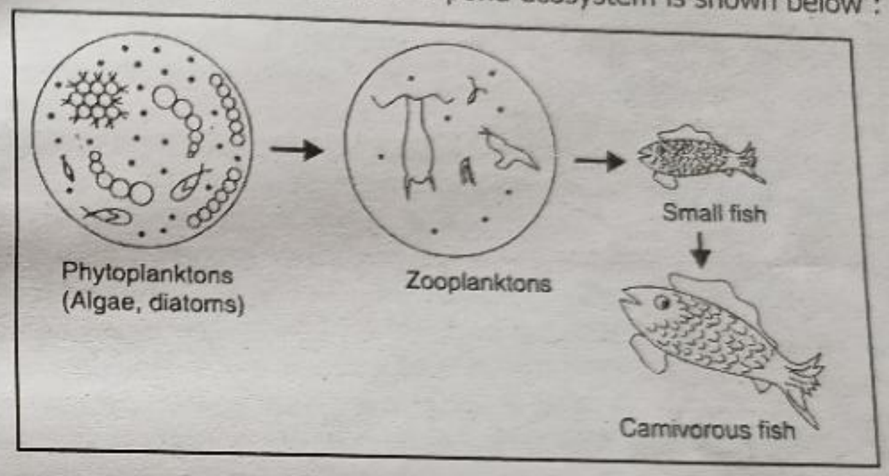


Fig. 7.1

Detritus Food Chain. This type of food chain goes from dead organic matter into microorganisms and then to organisms feeding on detritus (detriti-vores) and their predators. Such ecosystems are thus less dependent on direct solar energy. These depend chiefy on the influx of organic matter produced in another system. For example, such type of food chain operates in the decomposing accumulated litter in a temperate forest. A good example of a detritus food chain is based on mangrove leaves described by Heald (1969) and W.E. Odum (1970). In the brackish zone of Southern Florida, leaves of the red mangrove—Rhizophore mangle fall into the warm, shallow waters. Only 5 per cent of the leaf material was removed by grazing insects before leaf fall.

As shown in Figure 7.2 the fallen leaf fragments (acted on by such saprotrophs as fungi, bacteria, protozoa etc., and colonized mainly by phytoplanktonic and benthic algae) are eaten and re-eaten (coprophagy) by a key group of small animals. These animals include crabs, copepods, insect larvae, grass shrimps, mysids, nematodes, amphipods, bivalve molluscs etc. All these animals are detritus consumers. These detritivores are the key group of small animals, comprising only a few species but very large number of individuals. They ingest large amounts of the vascular plant detritus. These animals are in turn eaten by some minnows and small game fish etc., i.e., the small carnivores, which in turn serve as the main food for larger game fish and fish eating birds which are the large (top)

cornivores. The mangroves considered generally as of less economic value make a substantial contribution to the food chain that supports the fisheries, an important economy in that region. Similarly, detritus from seagrasses, saltmarsh grasses and seaweds support fisheries in many estuarine areas.

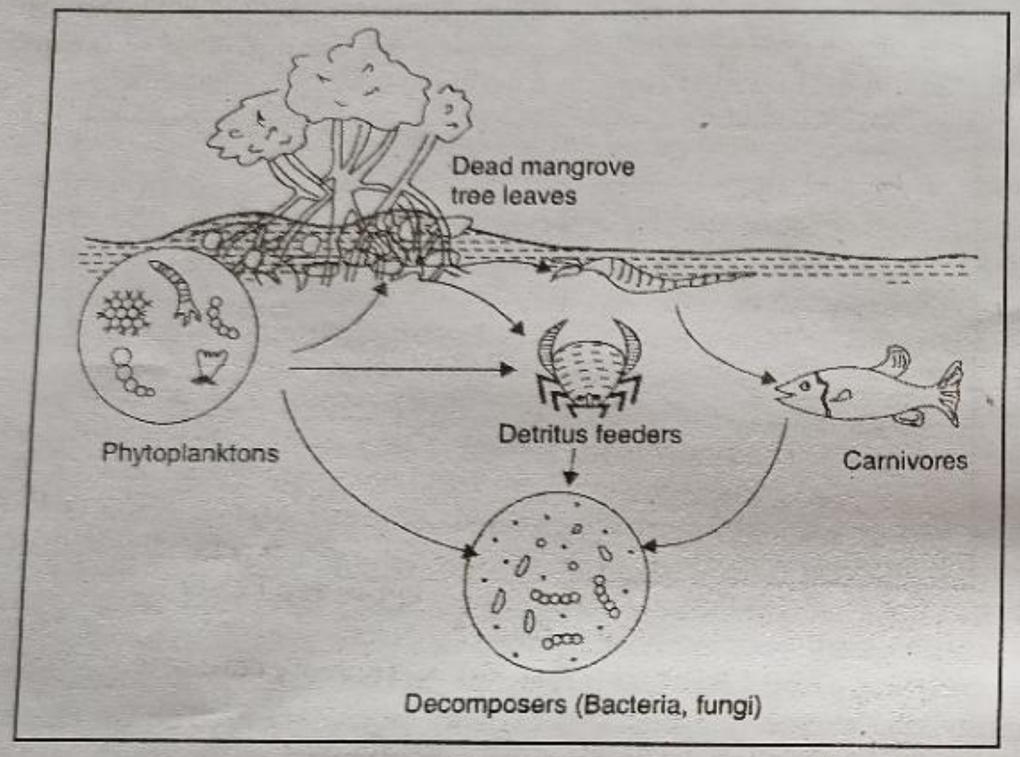


Fig. 7.2

Thus, we see that the detritus food chain ends up in a manner similar to the grazing food chain (big fish eat little fish), but the way in which the two chains begin is quite different. In detritus chain, the detritus consumers, in contrast to grazing herbivores are a mixed group in terms of trophic levels. These include herbivores, omnivorous and primary carnivores. As a group, the detritus feeders obtain some of their energy directly from plant material, most of it secondarily from microorganisms, and some tertiarily through carnivores (for example by eating protozoa or other small invertebrates that have fed on bacteria that have digested plant material).

But under natural situations, a system must always be self-sufficient. In fact this type of food chain (detritus type) is simply a sub-component of another ecosystem. In fact, the two types of food chain in nature are indeed linked together belonging to the same ecosystem.

Food Webs

Food chains in natural conditions never operate as isolated sequences, but are interconnected with each other forming some sort of interlocking with each other forming some sort of interlocking pattern, which is referred

to as a food web. Under natural conditions, the linear arrangement of food chains, hardly occurs and these remain indeed interconnected with each other through different types of organisms at different trophic levels. For example, in grazing food chain of a grassland, in the absence of rabbit, grass may also be eaten by mouse. The mouse in turn may be eaten directly by hawk or by snake first which is then eaten by hawk. Thus, in nature there are found alternatives which all together constitute some sort of interlocking pattern—the food web.

In such a food web in grassland, there may be as many as five linear food chains, which in sequence are :

(1) Grass → Grasshopper → Hawk
(2) Grass → Grasshopper → Lizard → Hawk
(3) Grass → Rabbit-Hawk (or vulture or fox or even man, if present)
(4) Grass → Mouse → Hawk
(5) Grass → Mouse → Snake-Hawk.

Besides those shown in Figure 10.8, there may also be present some other consumers as vultures, fox and man in grasslands, and if so, the food web may be even more complex than shown here. However, these all five chains are interlinked with each other at different points, forming food web. Similarly the population in an African grassland may be characterised by their feeding relationships in the following two food chains :

(1) Live grass (producer) → Wildebeest (herbivore) → Lion (primary carnivore in chain 1)
↓ ↓
(2) Dead grass (dead organic metter) → Termite (decomposer) → Aardvark (primary carnivore)

The broken arrows show how the two chains are linked into a food web. Real food webs usually have hundreds of species interlinked by their feeding habits. Food webs are basic units of ecosystem ecology.

A similar food web in a pond, with different interlinked food chains is shown in Figure 7.3. The food webs are very important in maintaining the stability of an ecosystem in nature. For example, decrease in the population of rabbit would naturally cause an increase in the population of alternative herbivore, the mouse. This may decrease the population of the consumer (carnivore) that prefers to eat rabbit. Thus alternatives (substitutes) serve for maintenance of stability the survival of all living organisms of the system. For instance, had primary consumers (herbivores) not been in nature, the producers would have perished due to overcrowding and competition. Similarly, the survival of primary consumers is linked with the secondary consumers (carnivores) and so on. Thus, each species of any ecosystem is indeed kept under some sort of a natural check so that the system may remain balanced.

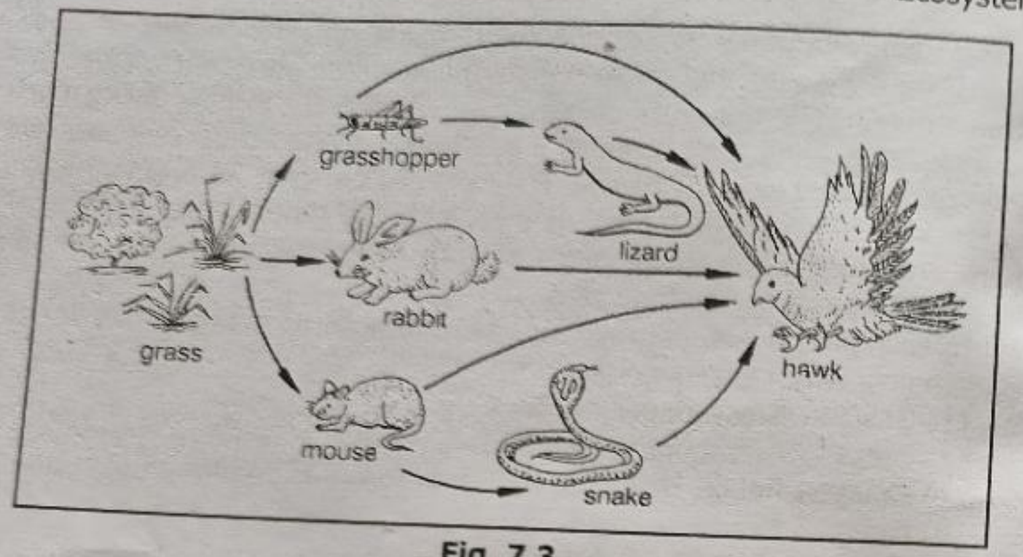


Fig. 7.3

The complexity of any food web depends upon the diversity of organisms in the system. It would accordingly depend upon two main points :

- Length of the food chain. Diversity in the organisms based upon their food habits would determine the length of food chain. More diverse the organisms in food habits, more longer would be food chain,
- Alternatives at different points of consumers in the chain. More the alternatives, more would be the interlocking pattern. In deep oceans, seas etc., where we find a variety of organisms, the food webs are much complex.

Ecological Pyramids

Trophic structure, i.e., the interaction of food chain and the size metabolism relationship between the linearly arranged various biotic components of an ecosystem is characteristic of each type of ecosystem. The trophic structure and function at successive trophic levels, i.e., producers → herbivores → carnivores, may be shown graphically by means of ecological pyramids where the first or producer level constitutes the base of the pyramid and the successive levels, the tiers making the apex. Ecological pyramids are of three general types :

(1) **Pyramid of Numbers.** It shows the relationship between producers, herbivores and carnivores at successive trophic levels in terms of their number. The pyramids of numbers in three different kinds of ecosystems are shown in Figure 7.4 (A-C). In a grassland (Fig. 7.4A) the producers, which are mainly grasses, are always maximum in number. This number then shows a decrease towards apex, as the primary consumers (herbivores) like rabbits mice etc., are lesser in number than the grasses; the secondary consumers, snakes and lizards are lesser in number than the rabbits and

mice. Finally, the top (tertiary) consumers hawks or other birds, are least in number. Thus, the pyramid becomes upright.

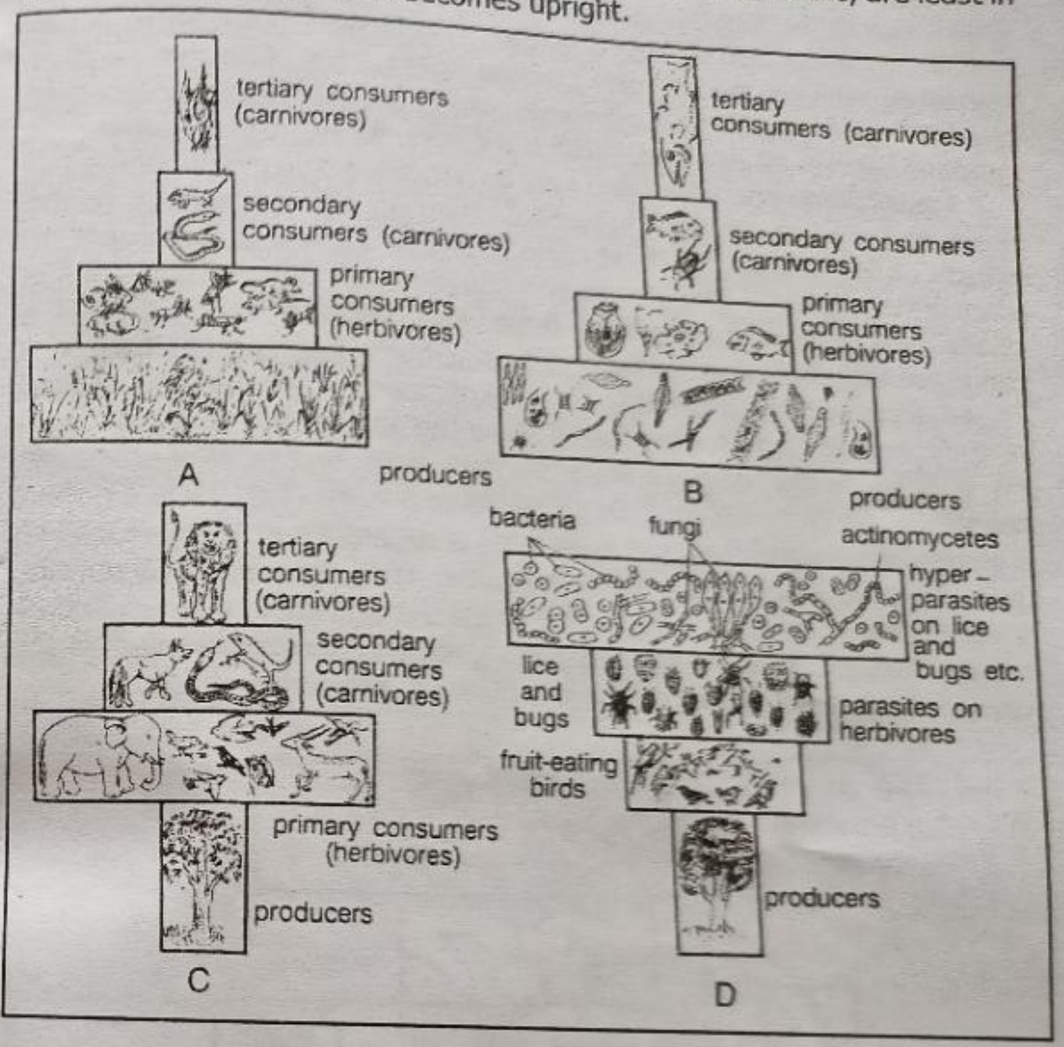


Fig. 7.4

Similarly, in a pond ecosystem (Fig. 7.4B) the pyramid is upright. Here the producers, which are mainly the phytoplanktons as algae, bacteria etc., are maximum in number; the herbivores, which are smaller fish; rotifers etc., are lesser in number than the producers; and the secondary consumers (carnivores), such as small fish eating each other, water beetles etc., are lesser in number than the herbivores. Finally, the top (tertiary) consumers, the bigger fish are least in number.

In a forest ecosystem (Fig. 7.4C) the pyramid of numbers is somewhat different in shape. The producers, which are mainly large-sized trees, are lesser in number, and form the base of the pyramid. The herbivores, which are the fruit-eating birds, elephants, deers etc., are more in number than the producers. Then there is a gradual decrease in the number of successive carnivores, thus making the pyramid again upright.

But, in a parasitic food chain (Fig. 7.4D) the pyramids are always inverted. This is due to the fact that a single plant may support the growth of many herbivores and each herbivore in turn may provide nutrition to several parasites, which support many hyperparasites. Thus, from the producer towards consumers, there is a reverse position, i.e., the number of organisms gradually shows an increase, making the pyramid inverted in shape.

Actually the pyramids of numbers do not give a true picture of the food chain as they are not very functional. They do not indicate the relative effects of the 'geometric', 'food chain' and 'size' factors of the organisms. They generally vary with different communities with different types of food chains in the same environment. It becomes sometimes very difficult to represent the whole community on the same numerical scale (as in forests).

(2) **Pyramids of Biomass.** They are comparatively more fundamental, as they, instead of geometric factor, show the quantitative relationships of the standing crops. The pyramids of biomass in different types of ecosystem are shown in Figure 7.5(A-C). In grassland and forest (Fig. 7.5 A, B), there is generally a gradual decrease in biomass of organisms at successive levels from the producers to the top carnivores. Thus pyramids are upright. However, in a pond (Fig. 7.5C) as the producers are small organisms, their biomass is least, and this value gradually shows as increase towards the apex of the pyramid, thus making the pyramid inverted in shape.

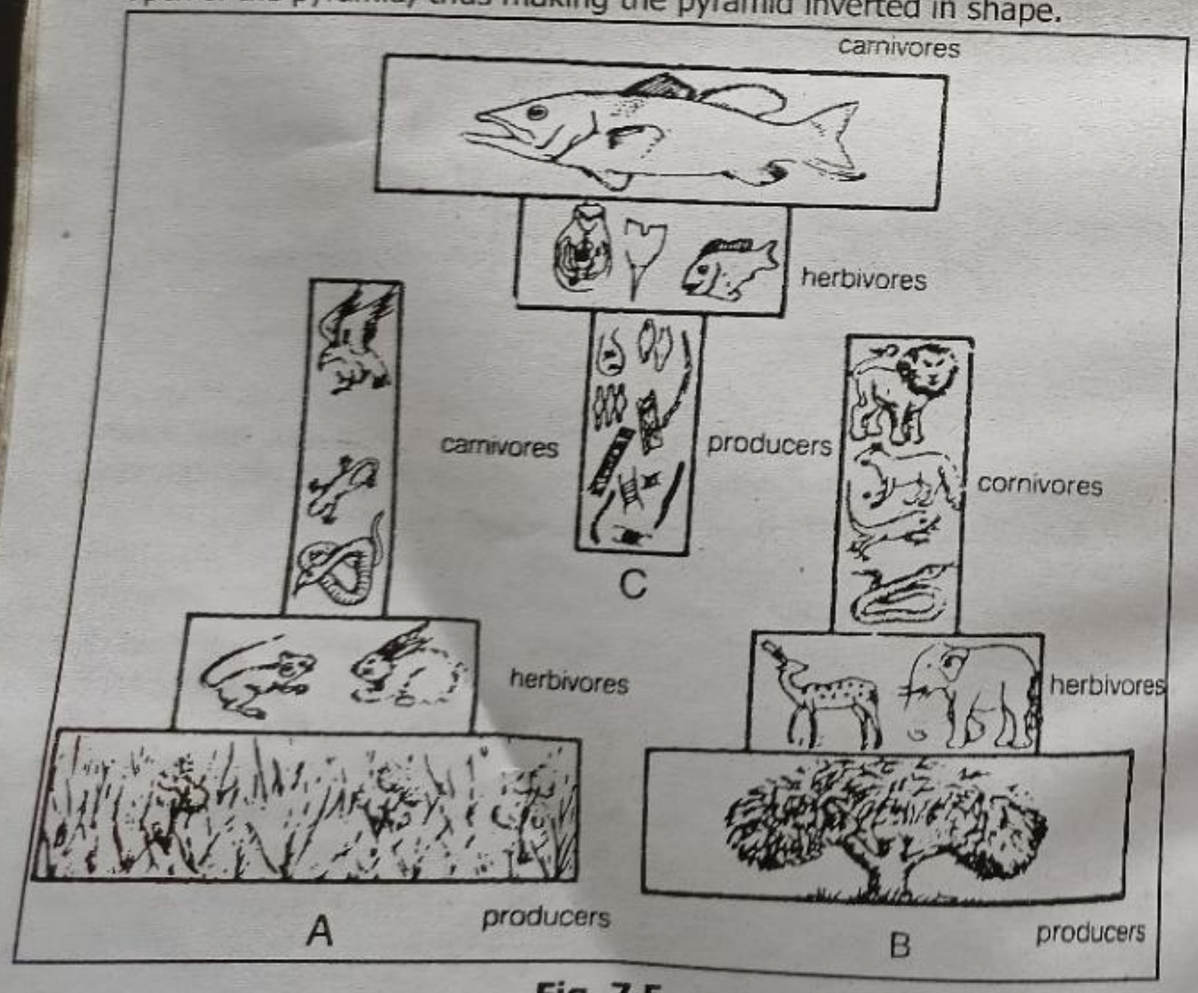


Fig. 7.5

(3) **Pyramid of Energy.** Of the three types of ecological pyramids, the energy pyramids give the best picture of overall nature of the ecosystem. Here, number and weight of organisms at any level depends not on the amount of fixed energy present at any one time in the level just below but rather on the rate at which food is being produced. In contrast with the pyramids of numbers and biomass, which are pictures of the standing situations (organisms present at any moment), the pyramid of energy is a picture of the rates of passage of food mass through the food chain. In shape it is always upright, as in most of the cases there is always a gradual decrease in the energy content at successive trophic levels from the producers to various consumers.

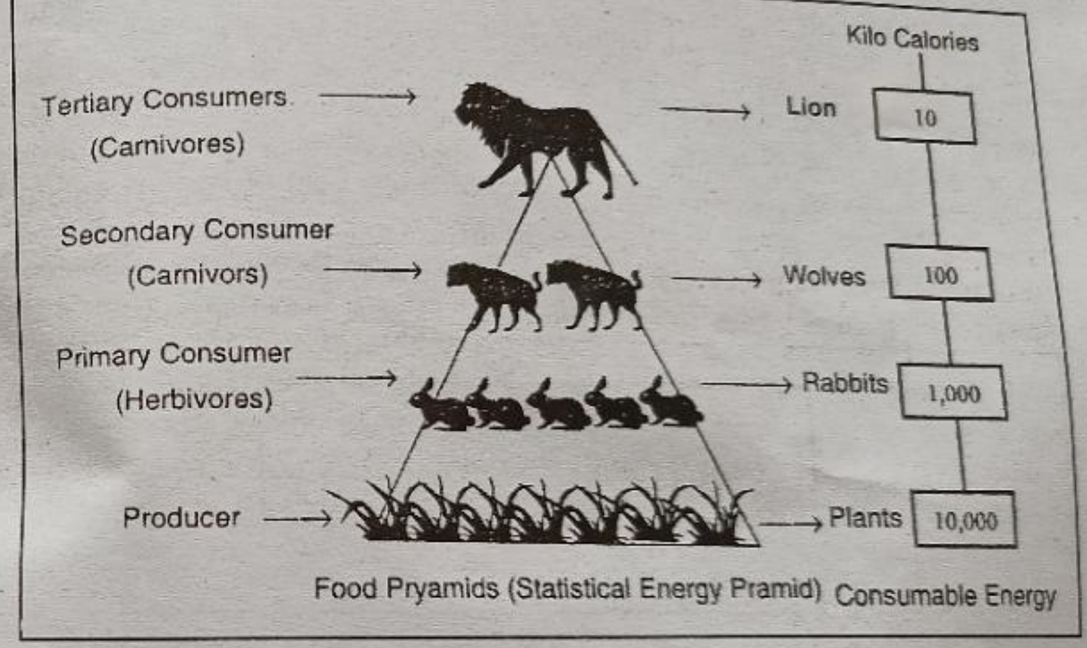


Fig. 7.6

The species structure includes not only the number and kinds of species but also the diversity of species i.e., the relationship between species and number of individuals on biomass; and the dispersion (spatial arrangement) of individuals of each species present in the community.

Energy Flow in Ecosystem

The behaviour of energy in ecosystem can be termed energy flow due to unidirectional flow of energy. From energetics point of view it is essential to understand for an ecosystem (i) the efficiency of the producers in absorption and conversion of solar energy, (ii) the use of this converted chemical form of energy by the consumers, (iii) the total input of energy inform of food and its efficiency of assimilation, (iv) the loss through respiration, heat, excretion etc., and (v) the gross net production.

Unlike the nutrients (like carbon, nitrogen, phosphorus etc.) which move in a cyclic manner and are reused by the producers after flowing through the food chain, energy is not reused in the food chain. Also, the flow of energy follows the two laws of thermodynamics :

The Ist Law of Thermodynamics states that energy can neither be created nor be destroyed but it can be transformed from one form to another. The solar energy captured by the green plants (producers) gets converted into biochemical energy of plants and later into that of consumers.

The IInd Law of Thermodynamics reveals that energy dissipates as it is used or in other words, in gets converted from a more concentrated to dispersed form. As energy flows through the food chain, there occurs dissipation of energy at every trophic level. The loss of energy takes place through respiration, loss of energy in locomotion, running, hunting and other activities. At every level there is about 90% loss of energy and the energy transferred from one trophic level to the other is only about 10%.

Energy Flow Models. The flow of energy through various trophic levels in an ecosystem can be explained with the help of various energy flow models.

(a) **Universal Energy Flow Model.** Energy flow through an ecosystem was explained by E.P. Odum as the universal energy flow model (Fig. 7.7). As the flow of energy takes place, there is a gradual loss of energy at every level, thereby resulting in less energy available at next trophic level as indicated by narrower pipes (energy flow) and smaller boxes (stored energy in biomass). The loss of energy lost in locomotion, exertion etc., or it is the energy lost in respiration (R) which is for maintenance. The rest of the energy is used for production (P).

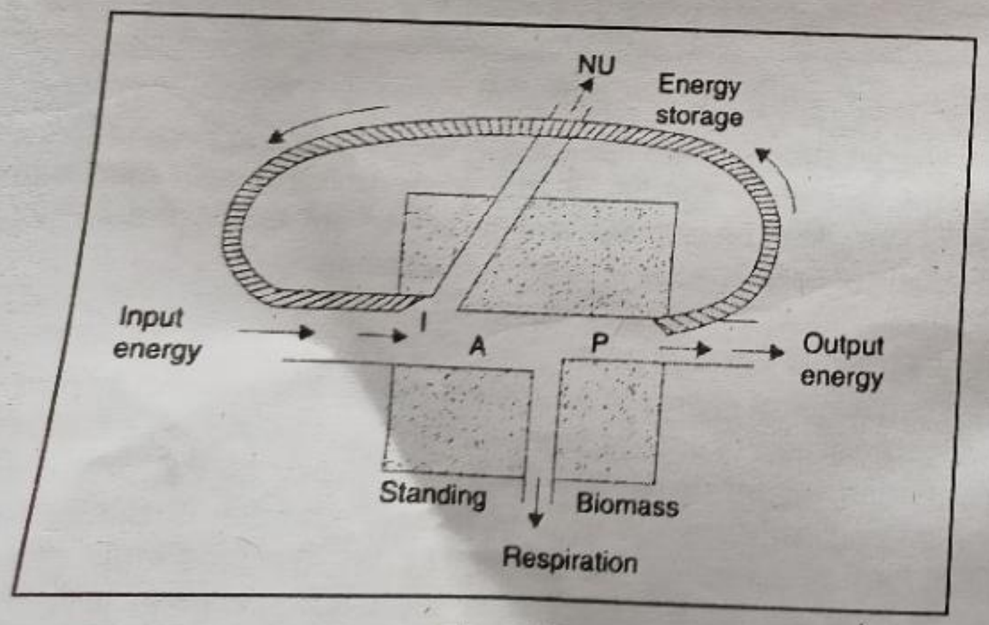


Fig. 7.7

(b) **Single Channel Energy Flow Model.** The flow of energy takes place in a undirectional manner through a single channel of green plants or producers to herbivores and carnivores. Fig. 7.8., depicts such a model and illustrated the gradual decline in energy level due to loss of energy at each successive trophic level in a grazing food chain.

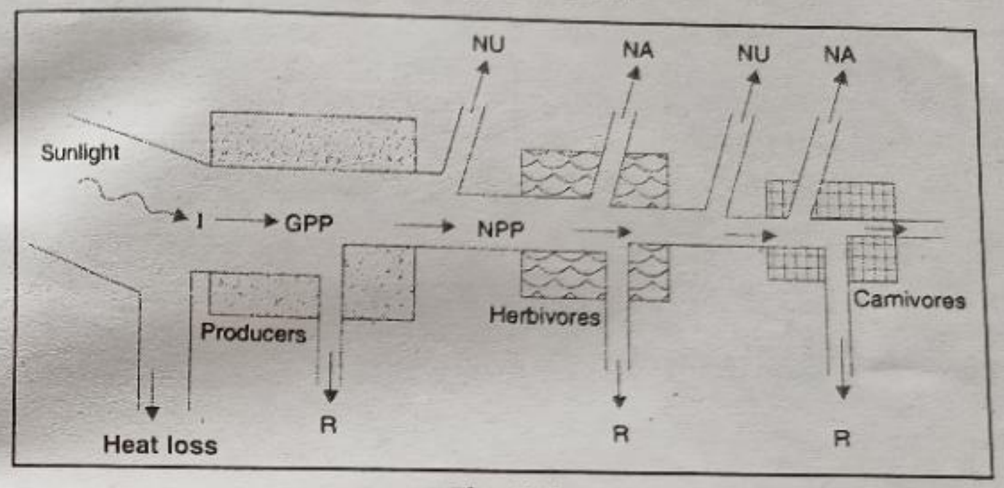


Fig. 7.8

(c) **Double Channel or Y-shaped Energy Flow Model.** In nature, both grazing food chain and detritus food chain operate in the same ecosystem. However, sometimes it is the grazing food chain which predominates. It happens in marine ecosystem where primary production in the open sea is limited and a major portion of it is eaten by herbivorous marine animals. Therefore, very little primary production is left to be passed on to the dead or detritus compartment. On the other hand, in a forest ecosystem the huge quantity of biomass produced cannot be all consumed by herbivores. Rather, a large proportion of the live biomass enters into detritus (dead) compartment in the form of litter. Hence the detritus food chain is more important there.

The two channel or Y-shaped model of energy flow shows the passage of energy through these two chains, which are separated in time and space (Fig. 7.9).

It must, however, be remembered that these models depict the basic pattern of energy flow in ecosystem. In practice, under natural conditions, the organisms are interrelated in a way that several food chains become interlocked and this results into a complex food web. We have already referred to food webs in a grassland and in pond ecosystems. The complexity of food web depends on the length of the food chains. Thus in nature there operate multichannel energy flows, but in these the channels belong to either of the two basic food chains i.e., will be either a grazing or a detritus food chain. Interlocking pattern of such several chains in food web of an ecosystem would lead to a multi-channel flow of energy. Thus in practice,

under field conditions, we might face difficulties in measuring the energetics of ecosystem.

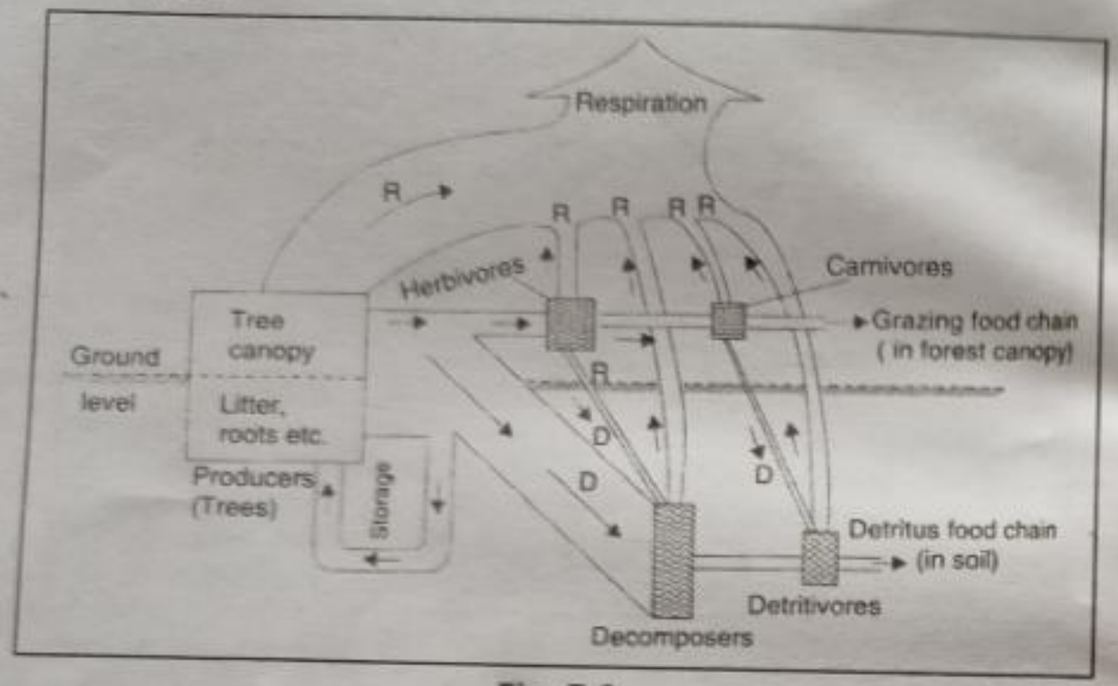


Fig. 7.9

Nutrient Cycles in Ecosystems

So far we have discussed the gross structure and function of an ecosystem where it may be seen that minerals and energy move through biotic and abiotic component of this ecological, self-sufficient system. Nutrient cycles closely parallel the routes of energy flow within the biotic components of ecosystems, but an important distinction between the two processes is the relationship with the abiotic component. While energy flow is profligate in the sense of being driven by an endless solar power supply, nutrient cycling is conservative, with chemical elements being drawn from finite pools and being largely retained within ecosystems. This is true also, as for any system to continue there must always be a movement of materials in a cyclic manner. The mineral elements taken up from the environment (soil as well as atmosphere) by the green plants—the producers, are again returned to the environment. In this taking and returning processes of minerals, there are involved a number of organisms as well as some physico-chemical phenomena, that make together an orderly operating cycle. Thus the movement (imports and exports) of minerals is accomplished by the operation of different chemical cycles that keep on passing the materials back and forth between organisms and their environment.

To stress the biological, geological (in rocks, soils and sediments) and chemical nature of the processes, they are sometimes called biogeochemical cycles. There are macronutrients as Carbon (C), Hydrogen (H) and Oxygen

(O) which have cycles with an atmospheric store, and some as Phosphorus (P) and Potassium (K) obtained from the soils. There are micronutrients as Copper (Cu), Iron (Fe) and Carbon Dioxide (CO), which have soil-based, or edaphic cycles. Nitrogen, a macronutrient, has inorganic pools in both the atmosphere and soil. A variety of biogeochemical processes controls the links between available and unavailable forms of edaphic nutrients. The qualitative and quantitative nature of nutrient cycles in natural ecosystems is very diverse. It is not possible to describe 'typical' cycles. Indeed, very few cycles have been elaborated in detail.

Hydrological Cycle. Strictly speaking, this is not an elemental cycle because it follows the course of a compound, water. Nevertheless, the movement of water within and between ecosystems is fundamental to an understanding of nutrient cycles for several reasons :

(i) source of hydrogen for photosynthesis in plants,

(ii) plants use large amount of water to maintain their hydrostatic skeletons and to move chemicals about their bodies,

(iii) plants take elements in aqueous solution from soil.

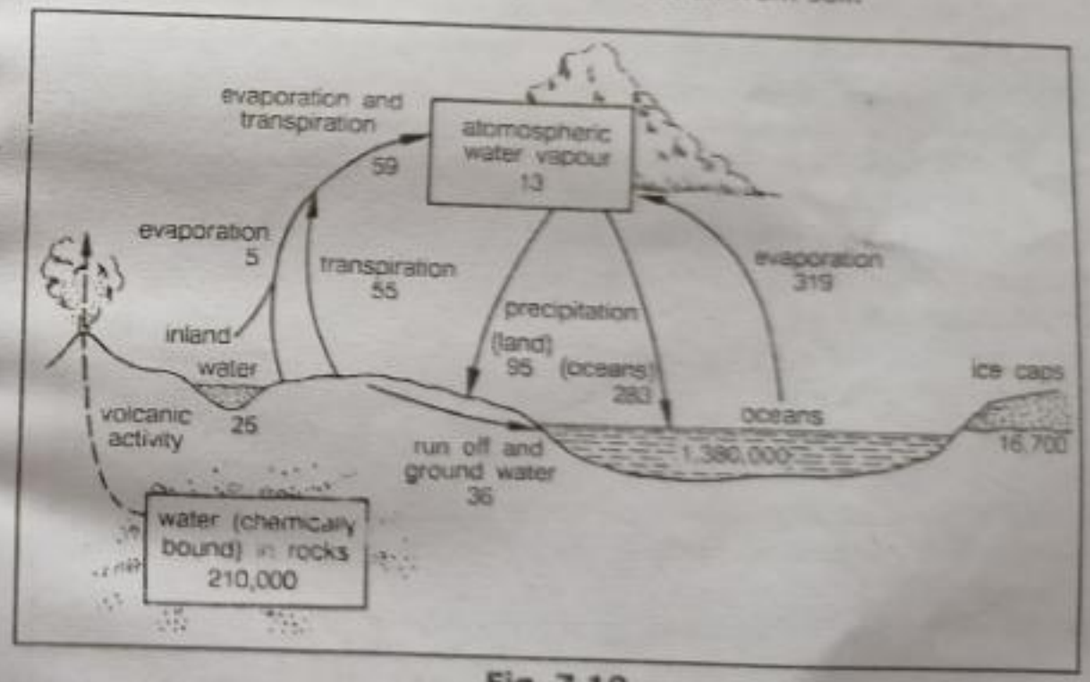


Fig. 7.10

Figure 7.10 shows the components of the global hydrological cycle and the fluxes between them. The major store is in the oceans, and the major flows are evaporation from them and precipitation upon them. However, there is a net flow of water vapour, driven by winds, from the oceans to land where it falls as rain, hail or snow. The balance of the cycle is maintained by water flowing from the land as surface run off or movement of groundwater into rivers and back to the oceans. A major part of water is locked up in earth's crust, but is only released in small quantities during

volcanic eruptions. Similarly, the large store in polar ice caps has little effect on the hydrological cycle in short-term due to negligible evaporation from them. The hydrological cycle is driven by the evaporative power of solar radiation and requires 8.2×10^{20}k Ja^{-1}, which is approximately 15 per cent of the total radiation reaching the outer atmosphere. This proportion compares with the 0.2 per cent used in gross primary production worldwide.

Carbon Cycle. The biospheric carbon cycle is primarily concerned with the atmospheric gas carbon dioxide, its incorporation into organic matter by photosynthesis, and its subsequent release by the respiration of all the biota (Fig. 7.11). Carbon also occurs in the earth's rock predominantly as calcium and magnesium carbonates. These compounds are largely organic in origin, being the mineralised remains of the skeletons of marine organisms. By subsequent geological shifting, carbonate rocks also occur on land and add to soil nutrients and plant nutrition by their subsequent weathering. Such transfers are small on a global scale compared with the exchanges between the biota and the atmosphere. When net primary production exceeds community respiration, carbon-rich organic matter accumulates in ecosystems. At times in the past, such accumulations have led to the deposition of fossil fuels, coal and oil. This occurs to minor extent today in peatlands.

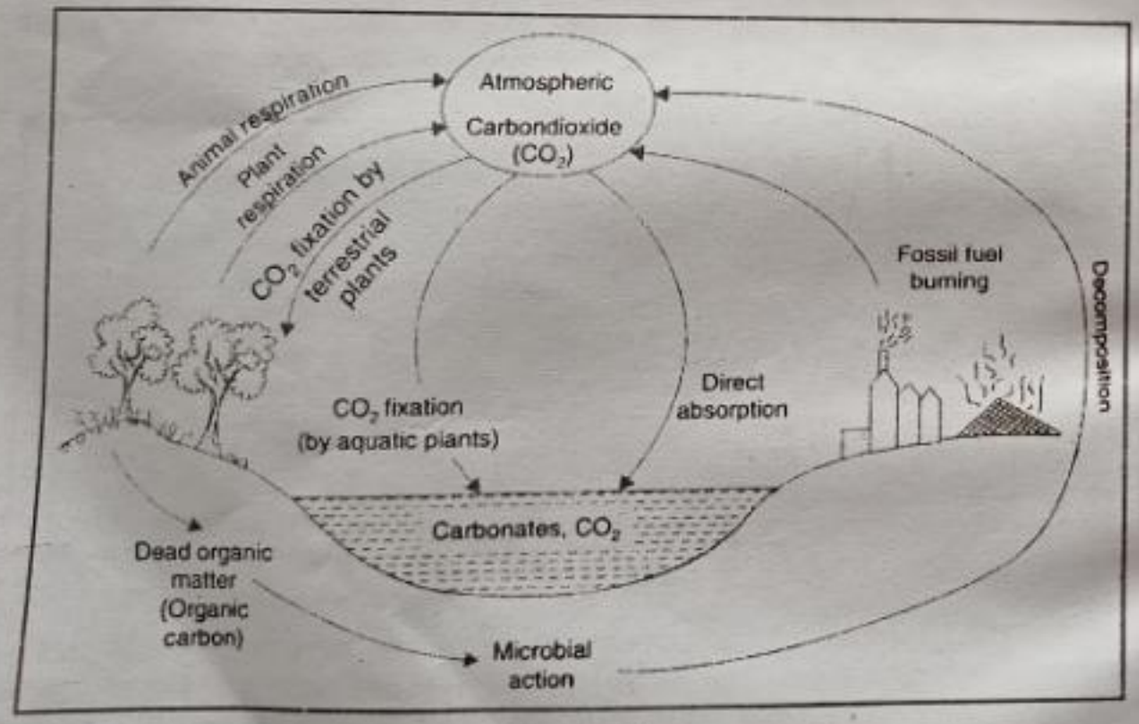


Fig. 7.11

Nitrogen Cycle. This is shown in Figure 7.12. It may be seen that these cycles are not entirely edaphic but most have an atmospheric component linked to the soil by nitrogen fixation, and dentrification.

Nevertheless plants obtain most of their nitrogen from soil as nitrate or ammonium ions, former being more important. Worldwide, atmospheric fixation accounts for around 10 kg ha^{-1} a^{-1} of the biospheric nitrogen flow. On land, more than 60 per cent fixation is due to agroecosystems, and most of the remainder is fixed in forests. Other ecosystems account for about 7 per cent of total nitrogen fixation. Overall, atmospheric fixation represents about 2 per cent of global nitrogen assimilation, the rest being cycled in non-gaseous forms. However, most of the nitrogen in soils and biota originated in the atmosphere and has accumulated over the millions of years in which nitrogen fixation has been taking place. Much of the terrestrial fixation is carried out by symbiotic bacteria in plant roots and to a lesser extent by free-living soil bacteria. Cyanobacteria (blue-green algae) also fix nitrogen and are of much significance in aquatic systems. Some termites have mutualistic gut microflora which fixes atmospheric nitrogen. Specialised, wide-spread soil bacteria play vital roles in nitrification (oxidation of the ammonium compounds produced by decomposition to nitrate). Some bacteria oxidise ammonium ions ($-NH_4$) to nitrite ($-NO_2$), and others complete the process by converting NO_2 to nitrate ($-NO_3$). These chemoautotrophs obtain energy from such transformations (276 kj and 73 kj, respectively, for each mole of precursor). Dentrifying bacteria reduce nitrate to gaseous nitrogen in anaerobic conditions, returning a small proportion of that circulating in the biosphere to atmosphere.

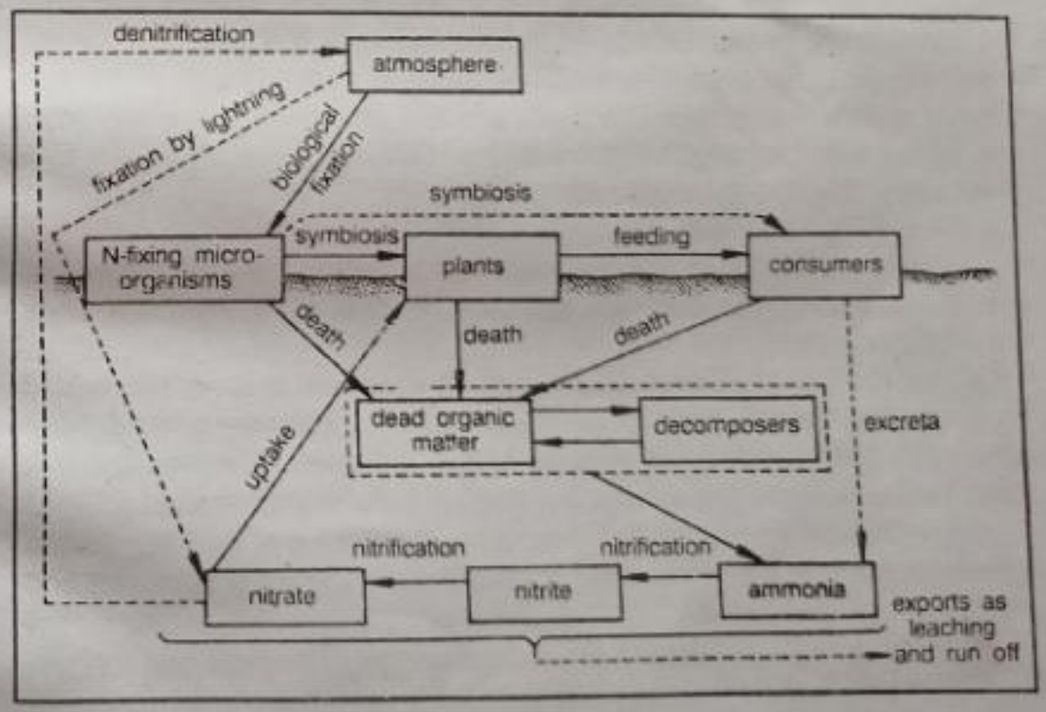


Fig. 7.12

8
Ecological Succession

Communities are never stable, but dynamic, changing more or less regularly over time and space. They are never found permanently in complete balance with their component species or with the physical environment. Environment is always changing over a period of time.

This process continues and successive communities develop one after another over the same area, until the terminal final community again becomes more or less stable for a period of time. This occurrence of relatively definite sequence of communities over a period of time in the same area is known as ecological succession.

Ecological succession is defined as an orderly process of changes in the community structure and function with time mediated through modifications in the physical environment and ultimately culminating in a stabilized ecosystem known as climax. The whole sequence of communities which are transitory are known as seral stages or seres whereas the community establishing first of all in the area is called a pioneer community.

Causes of Succession

Since succession is a process, more appropriately a series of complex processes, it is natural that there may not be a single cause for this. Generally, there are three types of causes :

Initial Causes. These are climatic as well as biotic. The former includes factors, such as erosion and deposits, wind, fire etc., caused by lightning or volcanic activity, and the latter includes the various activities of organisms. These causes produce the bare areas or destroy are existing populations in an area.

Continuing Causes. These are the processes as migration, ecesis, aggregation, competition, reaction etc., which cause successive waves of populations as a result of changes, chiefly in the edaphic features of the area.

Stabilishing Causes. These cause the stabilisation of the community. According to Clements, the climate of the area is the chief cause of stabilisation, other factors are of secondary value.

Trends of Succession

An ecological succession proceeds along the following four lines :

- A continuous change in the kinds of plants and animals.
- A tending increase in the diversity of species.
- An increase in the organic matter and biomass supported by the available energy flow (but in heterotrophic succession reverse is true).
- Decrease in net community production or annual yield.

Basic Types of Succession

The various types of succession have been grouped in different ways on the basis of different aspects. Some basic types of succession are, however, as follows :

Primary Succession. In any of the basic environments (terrestrial fresh water, marine), one type of succession is primary succession which starts from the primitive substratum, where there was no previously any sort of living matter. The first group of organisms establishing there are known as the pioneers, primary community or primary colonisers.

Secondary Succession. Another general type of succession is secondary succession which starts from previously built up substrata with already existing living matter. The action of any external force, as a sudden change in climatic factors, biotic intervention, fire etc., causes the existing community to disappear. Thus, area becomes devoid of living matter but its substratum, instead of primitive, is built up. Such successions are comparatively more rapid.

Autogenic Succession. After the succession has begun, in most of the cases, it is the community itself which, as a result of its reactions with the environment, modifies its own environment and thus causing its own replacement by new communities. This course of succession is known as autogenic succession.

Allogenic Succession. In some cases, however, the replacement of the existing community is caused largely by any other external condition and not by the existing organisms. Such a course is referred to as allogenic succession.

On the basis of successive changes in nutritional and energy contents, successions are sometimes classified as :

Autotrophic Succession. It is characterised by early and continued dominance of autotrophic organisms like green plants. It begins in a predominantly inorganic environment and the energy flow is maintained indefinitely. There is gradual increase in the organic matter content supported by energy flow.

Heterotrophic Succession. It is characterised by early dominance of heterotrophs, such as bacteria, actinomycetes, fungi and animals. It begins

in a predominantly organic environment, and there is a progressive decline in the energy content.

In ecological literature, there are mentioned still so many other kinds of succession, depending mainly upon the nature of the environment (primarily based upon moisture relations), where the process has begun, and thus it may be a hydrosere or hydrarch—starting in regions where water is in plenty, as ponds, lakes, streams, swamp, bog, etc.; a mesarch—where adequate moisture conditions are present; and a xerosere or xerarch—where moisture is present in minimal amounts, such as dry deserts, rocks etc. Sometimes, there are further distinguished, the lithosere—initiating on rocks, psammosere—on sand, and halosere—in saline water or soil.

General Process of Succession

The whole process of primary auto trophic succession is actually completed through a number of sequential steps, which follow one another. These steps in sequence are as follows :

Nudation. This is the development of a bare area without any form of life. The area may develop due to several causes such as landslide, erosion, deposition, or other catastrophic agency. The cause of nudation may be :

Topographic. Due to soil erosion by gravity, water or wind, the existing community may disappear. Other causes may be deposition of sand etc., landslide, volcanic activity and other factors.

Climatic. Glaciers, dry period, hails and storm, frost, fire etc., may also destroy the community.

Biotic. Man is most important, responsible for destruction of forests, grasslands for industry, agriculture, housing etc. Other factors are disease epidemics due to fungi, viruses etc., which destroy the whole population.

Invasion. This is the successful establishment of a species in a bare area. The species actually reaches this new site from any other area. This whole process is completed in following three successive stages.

Migration (Dispersal). The seeds, spores, or other propagules of the species reach the bare area. This process, known as migration, is generally brought about—by air, water, etc.

Ecesis (Establishment). After reaching to new area, the process of successful establishment of the species, as a result of adjustment with the conditions prevailing there, is known as ecesis. In plants, after migration, seeds or propagules germinate, seedlings grow, and adults start to reproduce. Only a few of them are capable of doing this under primitive harsh conditions, and thus most of them disappear. Thus as a result of ecesis, the individuals of species become established in the area.

Aggregation. After ecesis, as a result of reproduction, the individuals of the species increase in number, and they come close to each other. This process is known as aggregation.

Competition and Coaction. After aggregation of a large number of individuals of the species at the limited place, there develops competition (inter-as well as intraspecific) mainly for space and nutrition. Individuals of a species affect each other's life in various ways and this is called coaction. The species, if unable to compete with other species, if present, would be discarded. To withstand competition, reproductive capacity, wide ecological amplitude etc., are of much help to the species.

Reaction. This is the most important stage in succession. The mechanism of the modification of the environment through the influence of living organisms on it, is known as reaction. As a result of reactions, changes take place in soil, water, light conditions, temperature etc., of the environment. Due to all these the environment is modified, becoming unsuitable for the existing community which sooner or later is replaced by another community (seral community). The whole sequence of communities that replaces one another in the given area is called a sere, and various communities constituting the sere, as seral communities, seral stages or development stages. The pioneers are likely to have low-nutrient requirements, more dynamic and able to take minerals in comparatively more complex forms. They are small-sized and make less demand from environment.

Stabilisation (Climax). Finally, there occurs a stage in the process, when the final terminal community becomes more or less stabilised for a longer period of time and it can maintain itself in equilibrium with the climate of the area. This final community is not replaced, and is known as climax community and the stage as climax stage.

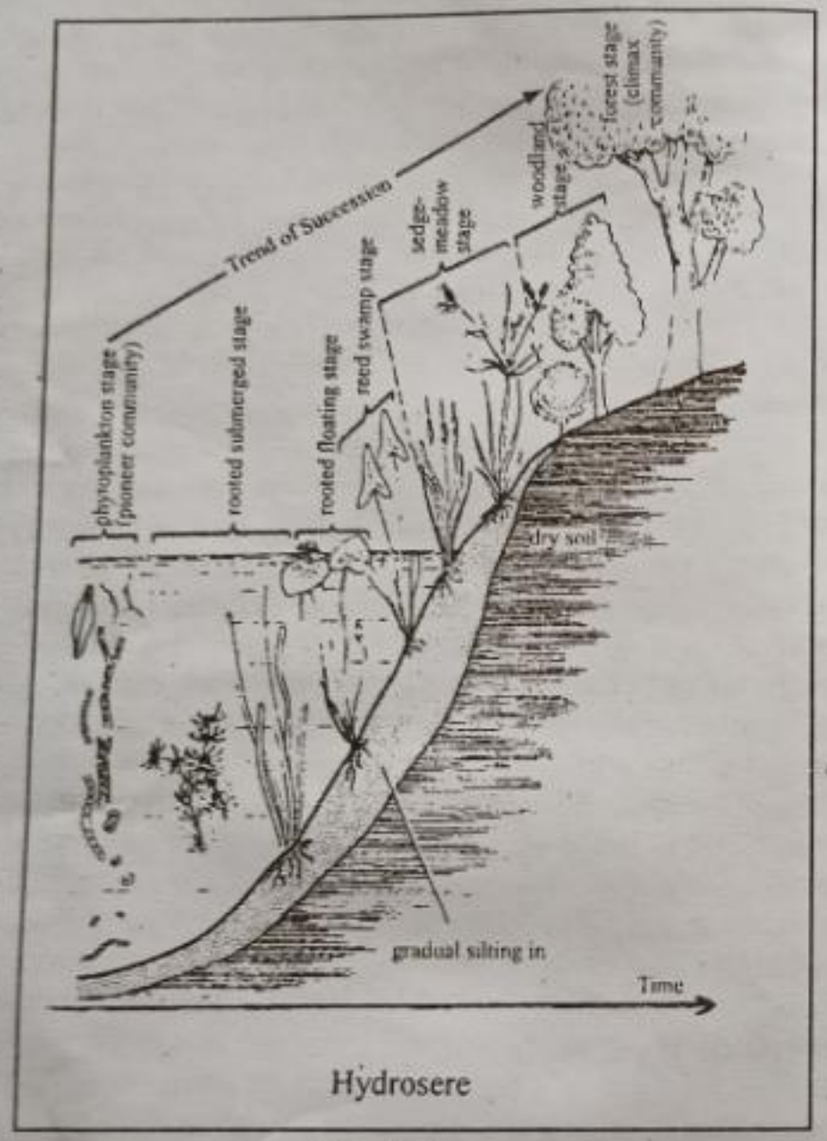
The above-mentioned general process of succession would become more clean by studying in detail the following different kinds of seres in different habitat conditions.

Hydrosere or Hydrarch

The various stages in a hydrosere are well studied in ponds, pools or lakes and we shall study for the present purpose this process of succession occurring in a pond. Hydrosere, originating in a pond, starts with the colonisation of some phytoplanktons which form the pioneer plant community, and finally terminates into a forest, which is a climax community together with their chief components of vegetation.

Just like other primary autotrophic successions, in a hydrosere too, successive changes take place in plants as well as animals' life. But as the changes are more obvious in plants than animals, it looks as it is a succession of plants only. But this is due to the fact, that changes in plants are so obvious, that we designate the different stages of succession, based upon the dominant forms of plants in that community, as photoplankton stage, rooted submerged stage, etc., and so on. These various stages together

with their chief components of plant species of a hydrosere as shown in Figure 8.1 are as follows :



Hydrosere

Fig. 8.1

1. **Phytoplankton Stage.** They constitute the pioneer community. Some blue-green algae, green algae, diatoms and bacteria etc., are the first organisms to colonise the primitive medium of the pond. The soils are very much reduced with a pH value of not more than 5.00. They multiply and grow for some time.

2. **Rooted Submerged Stage.** As a result of death and decomposition of phytoplanktons, and their mixing with the silt, brought from the surrounding land by rain waters and by wave action of pond water, there develops a soft mud at the bottom of pond. This new habitat which tends to be a bit shallower and where light penetration may now occur easily

like Myriophyllum, Eolodea, Hydrilla, Potamogeton, Vallisneria, Utricularia etc. These plants bring about further build up of the substratum as a result of their death and decay. The water level also decreases making the pond more shallower. This new habitat now replaces these plants giving way to another type of plants which are of floating leave type.

3. **Rooted Floating Stage.** By now the water depth is almost 2-5 feet. These plants colonise the habitat with their rhizomes. They all are rooted hydrophytes with their large leaves floating on the water surface. These are species of Nelumbo, Nymphaea, Limnanthemum, Aponogeton, Trapa, Monochoria etc. Some free-floating species as Azolla, Lemna, Wolffia, Pistia, Spirodella, Salvinia etc., also become associated with the rooted plants, due to availability of salts and other minerals in abundance. The water level by now becomes very much decreased, making the pond more shallower. The decomposing organic matter formed due to death of these plants brings about further build up of the substratum. Thus floating species sooner or later disappear from the area.

4. **Reed-Swamp Stage.** This stage is also known as amphibious stage as the plants of community are rooted but most parts of their shoots (assimilatory organs) remain exposed to air. Species of Scripus, Typha, Sugittaria and Phragmites etc., are the chief plants of this stage. They have well-developed rhizomes and form a very dense vegetation. The water level is by now very much reduced and finally becomes unsuitable for the growth of these amphibious species.

5. **Sedge-Meadow Stage.** Due to successive decrease in water level and further changes in the substratum, species of some Cyperaceae and Gramineae, such as Carex, Juncus. Cyperus and Eleocharis colonise the area. They form a mat-like vegetation towards the centre of the pond with the help of their much branched rhizomatous systems. As a result of high rate of transpiration, there is much rapid loss of water, and sooner or later the mud is exposed to air as a result of which nutrients like ammonia, sulphides etc., become oxidised to nitrates and sulphates. Thus mesic conditions approach the area and marshy vegetation disappears gradually and gradually.

6. **Woodland Stage.** By the time of disappearance of marshy vegetation, soil becomes drier for most time of the year. This area is now invaded by terrestrial plants, which are some shrubs (Salix, Cornus) and trees (Populus, Alnus). By this time there is much accumulation of humus with rich flora of microorganisms. Thus, mineralisation of the soil favours of arrival of new tree species in the area.

7. **Forest Stage.** This is the climax community. The woodland community is rapidly invaded by several trees. In tropical climates with heavy rainfall, there develop tropical rain forests, whereas in temperate regions, there develop mixed forests of Ulmus, Acer and Quercus. In regions of moderate rainfall, there develop tropical, deciduous forests or monsoon forests.

Thus in the hydrosere, described above, stage 1 is the pioneer community, stage 7 the climax community, and stages 2 to 6 as the seral communities (seral stages). The various stages of a hydrosere and the chief component plant species appearing at each stage are shown in Figure 8.1.

Successive Changes in Animal Life. With the ageing of a pond and the development of marshes, the animal life also undergoes changes. These are as follows :

The protozoans like Paramecium, Amoeba, Euglena etc., are the pioneers. But, if the planktonic growth forms are very rich, other animal life as blue gill fish, sun fish, large mouth bass etc., start appearing. Some caddisflies are also found. In the next, submerged stage the caddisflies are replaced by other animals that may creep over the submerged vegetation. Thus, dragon flies, mayflies and some crustaceans as Asellas, Grammarus, Daphnia, Cypris, Cyclops, etc., inhabit the pond at this stage.

At the floating stage, the animal life is chiefly represented by Hydra spp., gill breathing snails, frogs, salamanders, diving beetles, whirligig beetles and other insects. There also appear some turtles and snakes.

At the reed-swamp stage, the pond becomes shallower, and the bottom starts to be exposed. The floating animals are replaced by different species of mayflies and dragon flies, whose nymphs remain attached to submerged parts of the vegetation, and adults present on the surfaces of emergent parts. Gill breathing snails are replaced by lung breathers as Lymnea, Physa, and Gyraulus. Among insects, water scorpion, giant water bug, scavenger beetles etc., are present at this stage. The bottom of the pond is now inhabitat by some annelids, mud pickrel and bull heads. Red winged black birds, king fisher, great blue heron, swamp sparrow, ducks, musk rats, beavers etc., become common in the area.

At the sedge-meadow stage, the animals like avails as Anodonta, Psidium etc., become common. Finally, at the woodland stage, under terrestrial conditions most of the terrestrial forms of animal life appear in the area.

Functional Changes in Hydrosere. It can be concluded that during succession in a pond (hydrosere) the major changes from a structural standpoint i.e., changes in composition, are (i) a change in species composition, and (ii) a change in variety or diversity. Besides them there take place marked changes in number and kinds of both, autotrophs and heterotrophs i.e., functional changes. Two major functional changes include (i) a progressive increase in amouht of both, living (biomass), and dead organic matter, and (ii) a shift in community metabolism from young ponds. The increasing heterotrophy of these aquatic system applies to that phase of their succession in which they achieve a terrestrial condition. These four major structural and functional attributes of ecological succession (increase in species diversity, increase in structural complexity, increase in organic matter, and tendency towards metabolic stability) are, in a sense, both causes and effects of the very processes of change and the eventual stability that characterise ecosystems in general.

Lithosere—A Xerosere

This is a type of xerosere originating on bare rock surfaces. The original subtratum is deficient in water and lacks any organic matter, having only minerals in disintegrated unweathered state. The pioneers to colonise this primitive subtractum are crustose type of lichens, and through a series of successive seral stages the succession finally terminates into a forest which constitutes the climax community. As pointed out in hydrosere, in a lithosere also successive changes take place in both plants as well as animals. But here also, as in most of the primary autotrophic successions, changes in plants' life are more obvious than those in animals. The changes in plants are obvious to the extent that it looks as a succession of plants only and various stages are named on the basis of particular stage dominated by a particular plant species.

The various stages and their component plant species of a lithosere appearing on a rock are shown in Figure 8.2. These are as follows :

1. **Crutose Lichens Stage.** As mentioned earlier, the substratum colonised by these pioneers is very poor in moisture and organic matter, subjected with extremes of temperature. The lichens of this stage are species of Rhizocarpon, Rinodina and Lecanora. They produce some acids which bring about weathering of rocks. The dead

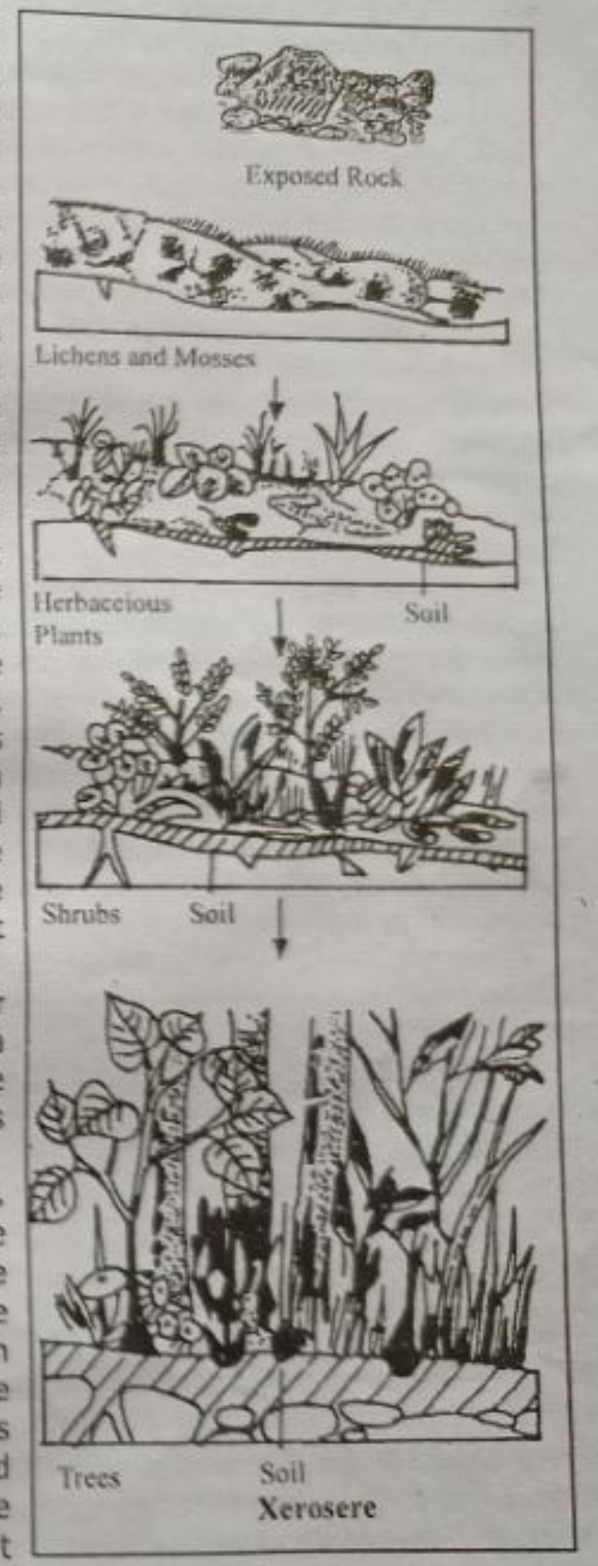


Fig. 8.2

organic matter of lichens becomes mixed with the small particles of rocks. However, this process is very slow. These lichens are then replaced by foliose type of lichens.

2. **Foliose Lichens Stage.** They appear on the substratum partially built up by the crustose lichens. This community includes species of Parmelia, Dermatocarpon etc., which have large leaf-life thalli. They can absorb and retain more water and are able to accumulate dust particles which help in the further build up of the substratum. Thus some humus becomes accimulated. The weathering of rocks and its mixing with humus results into the development of a refine thin soil layer on rock surface, and thus there is a change in the habitat.

3. **Moss Stage.** The development of thin soil layer on rock surface, especially in the crevices, favours the growth of some such xerophytic mosses as species of Polytrichum, Tortula and Grimmia. At their successful growth, they compete with the lichens. Due to their death and decay there is further additional of organic matter in the soil. The thickness of the soil layer now increases.

4. **Herbs Stage.** Due to more extensive growth of mosses there accumulates more soil and there are added more minerals to it due to leaching out from the overlying vegetation. This changed habitat favours the growth of some herbaceous weeds which are chiefly the annuals, in turn being followed by some biennials and perennials. Due to their growth and death there is much more accumulation of humus in soil together with further weathering of rock. Thus, habitat changes with decreasing xeric conditions. This stage is constituted by such shallow rooted grasses as Aristida, Festuca, Poa, Solidago, etc., which in turn are replaced by shrubs.

Table 8.1

Pioneer Community	Seral Communities				Climax Community
1 Crustose lichen stage	2 Foliose lichen stage	3 Moss stage	4 Herb stage	5 Shrub stage	6 Forest stage
Rhizocarpon Rinodina Lecanora	Parmelia Dermato-Carpon	Polytrichum Tortula Grimmia	Aristida Festuca Poa	Rhus Phyto-Carpus	Meso-phytic trees
General trend of succession →					

5. **Shrub Stage.** Due to much accumulation of soil, the habitat becomes suitable for shrubs which start migrating in the area. These are species of *Rhus, Phytocarpus* etc. They overshadow the herbaceous vegetation. The soil is further enriched by this dense shrubby growth. These in turn are finally replaced by trees which make up the climax community.

6. **Forest Stage.** Some xerophytic tree species invade the area. Further weathering of rocks and increasing humus content of the soil favour the arrival of more trees and vegetation finally becomes mesophytic. Thus, there develops finally a forest community.

Changes in Animal Life. As in a hydrosere, there occur successive changes in animal life during the lithosere also. Associated with the lichens, the pioneers, are a few mites. Fauna is sparse in terms of species composition. There are a few ants and few spiders present in the cracks and crevices of rock. These are the pioneer animal species which are exposed to harsh environment—the thermal extremes etc. The mites become more varied in terms of species and small spiders, springtails as well as tradigrades become associated with the secondary community of mosses. At later stage of succession and when grasses start developing, the fauna undergoes a quantitative and qualitative increase. Nematodes and larval insects, collembola, ants, spiders and mites appear in this new environment. With the development of forest climax community, there develop a rich fauna consisting of invertebrates as well as vertebrates. These include slugs, snails, wire worms, millipedes, centipedes, ants, sow bugs, springtails, mites, squirrels, shrews, mammals like fox, chipmunk mouse and mole, birds like grouse and flycatcher, reptiles like skins, turtles, snakes etc., and amphibians such as salamanders and frogs.

Table 8.2

Senescent Tissue		Dead Tissue	
Primary Colonisers			
Stage 1a Weak parasites	Stage 1 Primary saprophytic sugar fungi, living on sugars and carbon compounds (mucoraceous phycomycetes)	Stage 2 Cellulose decomposers and associated secondary saprophytic sugar fungi, sharing products of cellulose decomposition (ascomycetes and some mucorales)	Stage 3 Lignin decomposers and associated fungi (basidio-mycetes and others)
General of succession →			

Heterotrophic (Microbial) Succession

Succession of microorganisms like fungi, bacteria, actinomycetes etc., that occurs within a microhabitat (microenvironment or microclimate), has been variously called as microsuccession, serule or microsere. This type of

9
Types of Ecosystem

We find various types of ecosystem operating as self-sufficient interacting systems in the biosphere. For example, a pond, a lake, a river, a stream, a spring, an estuary, the sea, a desert, a grassland, a forest, a coral reef, a cropland (field of maize, wheat, sugarcane, paddy) etc., operate as individual ecosystems of nature. All these ecosystems have a more or less similar fundamental plan of their gross structure and function, however, they differ in respect of their species composition, and rates in production etc. Thus we shall now consider in brief individual organizational pattern of each of these ecosystems and then, to some extent, would assess the relative value of each in respect of the total primary production of biosphere. Ecosystems chosen for the purpose and described here.

Forest Ecosystem

Forests occupy roughly 40 per cent of the land. In India, the forests occupy roughly one-tenth of the total land area. The different components of a forest ecosystem, like others, are as follows :

Abiotic Component. These are the inorganic as well as organic substances present in the soil and atmosphere. In addition to the minerals present in forests we find the dead organic debris—the litter accumulation, chiefly in temperate climate. Moreover, the light conditions are different due to complex stratification in the plant communities.

Biotic Component. The living organisms present in the food chain occur in the following order :

(i) **Producers.** These are mainly trees that show much species diversity and greater degree of stratification especially in trophical moist deciduous forests. The trees are of different kinds depending upon the kind of the forest formation developing in that climate. Besides trees, there are also present shrubs and a ground vegetation. In these forests, dominant members of the flora, the producers, are such trees as Tectona grandis, Butea frondosa, Shorea rubusta and Lagerstroemia parvifiora. In temperate coniferous forests, shrubs and ground flora are insignificant. In temperate deciduous forests the dominant trees are species of Quercus, Acer, Betula, Thuja, Picea etc., whereas in a temperate coniferous forests, the producer trees are species of Abies, Picea, Pinus, Cedrus, Juniperus Rhododendron etc.

1955, this Authority was redesignated as the National River Conservation Directorate (NRCD). The NRCD has drawn up the National River Conservation Plan and coordinates the implementation of the schemes under GAP and the Action Plans for the other rivers.

More than Rs. 500 million has been spent on GAP, but pollution levels in the Ganga are as high as ever. Meanwhile, a new National Lake Conservation Plan has come into being.

Marine Pollution

Man, for the fulfilment of his requirements and selfishness has put so many effluents in the water that the quality of marine water has been spoilt. This is called as marine pollution.

In simple words, because of human and natural factors the changes in the nature and quality of water which is harmful for both human and other living beings, is called marine pollution.

Causes of Marine Pollution. There are various factors responsible for marine pollution. They are as follows :

(1) **Waste of Coastal Towns.** The sea coast touches vast areas of the world. Thousands and thousands of towns and settlements are situated on sea coasts. Thus release huge amounts of excreta and garbage into the sea. The ash, dirty water, dirt and dust produced while cleaning the machines and oil and grease, industrial effluents pollute the marine water. The picture taken from sky, shows that the water of the sea near any city is darker as compared to other areas.

(2) **Polluted Water of Rivers.** Thousands of the rivers fall in ocean. If their water is tested on their places of origin then it will be found clear and pure but if we test the water on their edges and further on then it can be called very dangerous and a healthy person cannot have it for more than three months. So it is clear that these rivers pour a great quantities of polluted water into the seas. On the single Ganga river, about 114 major cities are situated, with population about 50 thousand each. So this river pours all its effluents and sewage in the sea.

(3) **Oil Pollution.** 75% of the total world oil is drilled from the sea bed. During this process thousand litres of oil mixes in sea-water. Some of it mixes in sea water while filling or empting the tankers etc. The oil wells in the sea leak continuously. Oil in the sea water affects sensitive flora and fauna. Such kind of oil pollution is found almost every coastal area of the world.

(4) **Role of Water Transport.** Water transport is a traditional means of transport, but there have been technical changes over time. Ships and boats contribute iron, grease and oil etc. constantly to the waters. Sometimes due to accidents, the ship and its goods etc. down. Sea journeys are not short but prolonged over years. Sailors take with them so many things and

throw them into the sea after use.

(5) **Atomic and Nuclear Tests.** During the atomic and nuclear tests elements such as uranium and thorium etc. are used releasing elements like strontium, cobalt, cesium, etc. with high destructive energy. They are lethal and in lethal doses. Almost all the countries which have nuclear power, perform these tests in the sea, specially the countries which don't have open spaces, for instance, France generally conducts nuclear tests in Atlantic Ocean while America uses Pacific Ocean as also China. Sometimes there are explosions in the ships which carry these nuclear weapons. Thus the radioactive elements spread over the sea and dumped in deep sea. These nuclear effluents spread over the sea water.

(6) **Role of Navy.** All the countries on the sea have Navy wing. Navy use various kinds of artillery, equipments etc. Every kind of destructive arms is used in wars, Ships, water tankers break and so many things spread over the sea. As a result so many toxic substances get assimilated in the sea water and cause marine pollution on a large scale.

Effects of Marine Pollution. Marine Pollution is harmful for all humans, biosphere and ecosystem because it affects them in many ways. These have been described thus :

(1) **Effect on Man.** Marine pollution affects human life in many ways. As a large part of human population lives on Islands, their life and protection lies in the fact whether the sea is polluted or not. Marine pollution would endanger their life.

1. Because of polluted water, coastal people will suffer from many diseases and these diseases through communication will spread in every part of the world and will be a threat to human health.

2. It can be said about coastal people that the sea is the only source of their livelihood. If the sea water is not pure then there is no possibility of fish nearby and there will be a problem food and employment for these people. Likewise the air-waves over the sea if polluted will cause many diseases.

3. Due to marine pollution, there is a possibility of increase in temperature of water and atmosphere. If 1% of the frozen ice, melts, then more than 1.3 population of coastal people/cities will drown. At present the existence of so many coastal countries of the world is in danger.

(2) **Effect on Biosphere.** A major part of the biosphere is constituted by the sea. The sea creatures are safeyouly, as long as the water is pure. But today every small fish and even the blue whale, the largest creature in the sea, is in danger. Due to the accident on 18 November, 2002, in the sea near of Spain, one oil tanker broke up and dumped 77 thousand metric tonne oil, which spread over the sea. As a result, all the fishes and other marine life in 50 km area was destroyed. On the coast of Spain, such kind of incidents are quite common; that's why it is called 'Coast of Death'.

(ii) **Consumers.** Various types of consumers are as follows :

Primary consumers are the herbivores that include the animals feeding on tree leaves as ants, flies, beetles, leafhoppers, bugs and spiders etc., and larger animals grazing on shoots and/or fruits of the producers, the elephants, nilgai, deer, moles, squirrels, shrews, flying foxes, fruit bats, mongooses etc.

Secondary Consumers are the carnivores like snakes, birds, lizards, fox etc., feeding on the herbivores.

Tertiary Consumers are the top carnivores like lion, tiger etc., that eat carnivores of secondary consumers level.

(iii) **Decomposers.** These are wide variety of microorganisms including fungi (species of Aspergilus, Coprinus, Polyporus, Ganoderma, Fusarium, Alternaria, Trichoderma etc.), bacteria (species of Bacillus, Clostridium, Pseudomonas, Angiococcus etc.), and actinomycetes, like species of streptomyces etc. Rate of decomposition in tropical and subtropical forests in more rapid than that in the temperate ones.

Various Types. Depending upon the prevailing climatic conditions forests can be of various types :

(a) **Tropical Rain Forests.** They are evergreen broadlef forests found near the equator. These regions have abundant rainfall (2000-4500 mm per year) that occurs almost daily, and the temperature varies little over the year. They are found in South and Central America, Western and Central Africa, South East Asia, and in some islands of the Indian and Pacific Oceans.

Though they occupy just 2 per cent of the earth, tropical rainforests contain 50-80 per cent of all terrestrial plant species. The enormous biodiversity in plant life is supplemented by an abundance of amphibians, reptiles, birds, monkeys, and small mammals, as well as predators like tigers and jaguars.

These rainforests are marked by a variety of tall trees and a dense canopy. There are at least three distinct stories or layers of vegetation. The soils are thin, acidic, and nutrient-poor. Little organic matter accumulates since the litter that falls on the floor is very quickly decomposed and the minerals quickly absorbed by the roots.

Importance of Tropical Forests. Apart from preserving immense biodiversity, tropical forests play a major role in recycling water. In a landmark research study conducted in the early 1980s in the Amazon, a team of Brazilian scientists led by Eneas Salati of the University of Sao Paulo found that a forest could return as much as 75 per cent of the moisture it received back into the atmosphere.

We have always been told that more trees meant more rain, but this Brazilian study gave a scientific basis to this connection. The research showed that the forests could return sufficient amounts of water to cause the formation of rain clouds. Land that is covered by trees collects and returns

to the atmosphere at least 10 times more moisture than deforested land does.

(b) **Temperate Forests.** Temperate forests have seasonal variations in climate; they are very cold in winter and warm and humid in summer. The annual rainfall is about 750-2000 mm and the soil is rich.

Temperate forests are found in western and Central Europe, Eastern Asia and Eastern North American. They have deciduous (leaf-shedding) trees like oaks, maples, ash and beech and some coniferous trees like pines. Shrubby undergrowth, ferns, lichens, and mosses are also found.

These forests contain abundant micro-organisms, and mammals like squirrels, porcupines, chipmunks, raccoons, hares, deer, foxes, coyotes and black bear. Birds like warblers, wood-peckers, owls, and hawks, besides snakes, frogs, and salamanders, are common.

(c) **Coniferous Forests.** These forests derive their name from the abundance of coniferous trees like spruce, fir, pine, and hemlock. A coniferous tree produces hard dry fruit called cones. Coniferous forests also contain smaller amounts of deciduous trees like birch and maple. They occur in the northern parts of North America, Europe, and Asia.

In coniferous forests, winters are usually long and cold. The precipitation is often light in winter and heavier in summer. The soil in these forests is acidic and humus-rich and there is much leaf litter.

The main animals found in these forests are large herbivores like the mule deer, moose, elk, and caribou. There are also smaller herbivores like mice, hares, and red squirrels; and predators like lynx, foxes, and bears. They are often important nesting areas for many migratory birds like warblers and thrushes.

(d) **Tundra.** The forests in the Arctic are called tundra. They occur in the extreme northern latitudes, where the snow melts seasonally. There is no equivalent in the southern hemisphere, since there is no land in the corresponding latitude.

The region has long and harsh winters and very short summers. Precipitation occurs mostly in summer and the annual average is just 10-25 cm.

The species diversity is low, but the few species that do exist here do so in large numbers. Mosses, lichens, grasses, and some dwarf trees are the main plants. The animal species include lemmings, weasels, arctic foxes, hares, snowy owls, and musk oxen. Many bird species migrate here in summer and feast on the abundance of insects—mosquitoes, black flies, deerflies, etc.

The tundra is a fragile ecosystem. Even a casual hike by humans across the land causes enormous damage, and regeneration is very slow. Large parts of the Arctic tundra have been affected by oil explanation and military use.

Forests in India. The State of Forest Report 2001, prepared by the Forest Survey of India (FSI), Dehradun, estimates the country's forest cover at 676,000 sq km, constituting 20.55 per cent of the geographic area of the country. Of this cover, 417,000 sq km is dense forest, 259,000 sq km open forest, and 4490 sq km mangroves. The report claims that, between 1999 and 2001, the total forest cover increased by 6 per cent. Madhya Pradesh accounts for the largest forest cover of the country with 77,265 sq km followed by Arunachal Pradesh (68,045 sq km) and Chhattisgarh (56,448 sq km).

Environmentalists and voluntary organizations have raised questions about these statistics. Grassroots organizations are witness to the unending deforestation in many parts of the country and they say that an increase of 6 per cent in two years does not appear possible. The apparent increase could be due to the new assessment methodology used by the FSI.

Table 9.1 : Distribution of Indian Forests by Type

Type	Percentage	Locations
Tropical moist deciduous	37	Andamans, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Karnataka, Kerala
Tropical dry deciduous	28	North-South strip from Himalayas to Kanyakumari
Tropical dry evergreen	8	Western Ghats, Assam, Andamans
Subtropical pine	7	Himalayas
Others	20	—
Total	100	

Grassland Ecosystem

This is a type of terrestrial ecosystem. Grasslands occupy a comparatively fewer area, roughly 19 per cent of the earth's surface. The various components of a grassland ecosystem are as follows :

Abiotic Component. These are the nutrients present in soil and the aerial environment. Thus the elements like C, H, O, N, P, S etc., are supplied by carbon dioxide, water, nitrates, phosphates and sulphates etc., present in air and soil of the area. Moreover, in addition to the above, some trace elements are also present in soil.

Biotic Component. These may be categorised as :

(i) **Producers.** They are mainly grasses, as species of Dichanthium, Cynodon, Desmodium, Digitaria, Dactyloctenium, Brachiaria, Setaria,

Sporobolus etc. Besides them a few forbs and shrubs also contribute to primary production.

(ii) **Consumers.** These occur in the following sequence :

Primary consumers are the herbivores feeding on grasses are mainly such grazing animals as cows, buffaloes, deers, sheep, rabbit, mouse etc. Besides them, there are also present some insects as Leptocorisa, Dysdercus, Oxyrhachis, Cicincella, Coccinella, some termites and millipedes etc., that feed on the leaves of grasses.

Secondary consumers are the carnivores feeding on herbivores. These include the animals like fox, jackals, snakes, frogs, lizards, birds etc. Sometimes the hawks feed on the secondary consumers thus occupying tertiary consumers level in the food chain.

(iii) **Decomposers.** The microbes active in the decay of dead organic matter of different forms of higher life are fungi, as species of Mucor, Aspergillus, Penicillium, Cladosporium, Rhizopus, Fusarium etc., and some bacteria and actinomycetes. They bring about the minerals back to the soil, thus making them available to the producers.

Various Types. Three types of grasslands are found to occur in different climatic regions :

(a) **Tropical Grasslands.** They occur near the borders of tropical rain forests in regions of high average temperature and low to moderate rainfall. In Africa, these are typically known as Savanas, which have tall grasses with scattered shrubs and stunted trees. The Savannas have a wide diversity of animals including zebras, giraffes, gazelle, antelopes etc. During dry season, fires are quite common. Termite mounds are very common here. The termites gather the detritus (dead organic matter) containing a lot of cellulose and build up a mound. On the top of the mound fungi are found to grow which feed upon this dead matter including cellulose and in turn release methane, a greenhouse gas.

Tropical savannas have a highly efficient system of photosynthesis. Most of the carbon assimilated by them in the form of carbohydrates is in the perennating bulbs, rhizomes, runners etc., which are present underground. Deliberate burning of these grasslands can release huge quantities of carbon dioxide, another green house gas, responsible for global warming.

(b) **Temperate Grasslands.** They are usually found on flat, gentle sloped hills, winters are very cold but summers are hot and dry. Intense grazing and summer fires do not allow shrubs or trees to grow.

In United States and Canada these grasslands are known as Prairies, in South America as Pampas, in Africa as Velds and in Central Europe and Asia they are known as steppes.

Winds keep blowing and evaporation rate is very high. It also favours rapid fires in summer. The soils are quite fertile and therefore, very often these grasslands are cleared for agriculture.

(c) **Polar Grasslands (Arctic Tundra).** They are found in Arctic polar region where severe cold and strong, frigid winds along with ice and snow create too harsh a climate for trees to grow. In summers the sunshines almost round the clock and hence several small annual plants grow in the summer. The animals include arctic wolf, weasel, arctic fox, reindeer etc. A thick layer of ice remains frozen under the soil surface throughout the year and is known as permafrost. In summer, the Tundra shows the appearance of shallow lakes, bogs etc., where mosquitoes, different types of insects and migratory birds appear.

Desert Ecosystem

Deserts occupy about 17 per cent of land, occurring in the regions with an annual rainfall of less than 25 centimetres. The species composition of such ecosystem is much more varied and typical due to extremes of both, temperature and water factors. The various biotic components are as follows :

(i) **Producers.** These are shrubs, especially bushes, some grasses and a few trees. The shrubs have widespread, branched root system with their stems and branches variously modified. Sometimes a few succulents like cacti are also present. Some lower plants like lichens and xerophytic mosses may also be present.

(ii) **Consumers.** The most common animals are reptiles and insects, able to live under xeric conditions. In additions to them, there are also found some nocturnal rodents and birds. The 'ship of desert', camels feed on tender shoots of the plants.

(iii) **Decomposers.** These are very few, a due to poor vegetation and amount of dead organic matter is correspondingly less. They are some fungi and bacteria, most of which are thermophilic.

Types of Grassland. Deserts are of three major types, based on climatic conditions :

(a) Tropical deserts like Sahara and Namibia in Africa and Thar desert, Rajasthan, India are the driest of all with only a few species. Wind blown sand dunes are very common.

(b) Temperate deserts like Mojave in Southern California where day time temperatures are very hot in summer but cool in winters.

(c) Cold deserts like the Gobi desert in China has cold winters and warm summers.

Desert plants and animals are having most typical adaptations for conservation of water. Many desert plants are found to have reduced, scaly leaves so as to cut down loss of water due to transpiration or have succulent leaves to store water. Many a times their stems get flattened and develop chlorophyll so that they can take up the function of photosynthesis. Some plants show very deep roots to tap the groundwater. Many plants have a

waxy, thick critical over the leaf to reduce loss of water through transpiration. Desert animals like insects and reptiles have thick outer coverings to minimize loss of water. They usually live inside burrows where humidity is better and heat is less. Desert oil is rich in nutrients but deficient in water.

Plants and Animals. The desert soil has very little organic matter, but it is rich in minerals. The desert plants have adapted to the dry conditions and conserve water by having few or no leaves. The giant saguaro cactus, for example, has a stem that can expand to store water. Many have thorns or toxins to protect themselves from being grazed by animals.

Some plants have wax-coated leaves that minimize the loss of moisture. Others have deep roots that reach the groundwater. Alternatively, some have widely spread, shallow roots that collect water after any rain and store it in spongy tissues.

Desert animals are usually small in size and they remain under cover during the day and come out to feed at night. Many have a thick external shell that minimizes moisture loss due to evaporation, and they can lie dormant during the driest periods. Some of the animals found in the desert are frogs, reptiles, rodents, jack rabbits, foxes and owls.

In deserts, during the day the sun heats up the ground and the temperature is high. The night can be quite cold, since the lack of vegetation allows the heat from the ground to radiate away into the atmosphere very quickly.

Human Impact on Deserts. A dry and hot desert cannot be damaged much by human activity. In fact, the desert ecosystem is quite sensitive and delicate. A heavy vehicle driven across the desert can do enormous damage to the think topsoil and the sparse vegetation. The disturbed area will take a long time to recover because of the extremely slow rate of growth of vegetation and low species diversity.

Apart from soil destruction, there are other human disturbances to desert ecosystems. The creation of desert cities, depletion of ground water supplies, land disturbance, the pollution from mining, and the storage of toxic and nuclear wastes are some of the human activities that cause damage.

Aquatic Ecosystems

Aquatic ecosystems dealing with water bodies and the biotic communities present in them are either freshwater or marine. Freshwater ecosystems are further of standing type (lentic) like ponds and lakes or free-flowing type (lotic), like rivers.

Aquatic life zones, which include the ocean, rivers, lakes and wetlands, differ in many respects from terrestrial biomes. Unlike the situation in terrestrial biomes, temperature and precipitation are not the factors that

determine the types of organisms that thrive in an aquatic life zone. First, water itself tends to moderate temperature and second, any precipitation falling on water cannot obviously be a major influence. In aquatic life zones, the characteristics of water—salinity, light penetration, nutrient levels, waves and currents—are the crucial factors. The two main categories of aquatic life zones are saltwater systems and freshwater systems.

Types of organisms in Aquatic Life Zones. There are three main types of organisms in aquatic life zones : plankton, nekton, and benthos. The free-floating plankton are micro-organisms that cannot swim easily and are buffeted about by the waves and currents. Plankton again are of two types : phytoplankton and zooplankton.

Phytoplankton are the photosynthetic producers of the ocean and they form the basis of the ocean's food web. The tiny zooplankton are the primary consumers that feed on phytoplankton. They in turn become food for newly-hatched fish and small organisms, and the food chain continues up the trophic levels.

The nekton are strong swimmers, and they include all the larger organisms like fish, turtles and whales. The benthos are bottom-dwellers adapted to living on the floor of the water body. Some fix themselves to one spot like sponges, oysters, and barnacles. Others burrow into the sand like worms and clams. Some others move about on the floor, like crawfish and brittle stars.

Pond Ecosystem

A pond as a whole serves a good example of a fresh water ecosystem. A pond indeed exhibits a self-sufficient, self-regulating system. Not only is the pond a place where plans and animals (living organisms) live, but plants and animals make the pond what it is (physico-chemical environment). This would become clear if you examine a bottle full of pond water or a scoop full of bottom mud, which shall show the living organisms (plants as well as animals) and a mixture of inorganic and organic compounds. Some larger forms of life are also present in pond. Thus, whole system becomes much complex indeed.

Lake Ecosystem

Lakes are natural bodies of standing freshwater. They are formed when precipitation, run-off or groundwater seepage fills up depressions in the land formed by geological changes. A large lake has four zones : the littoral, limnetic, profundal, and benthic.

The littoral zone is the area of sunlit shallow water near the shore of the lake. It extends to the depth at which rooted plants stop growing. Due to the edge effect, this is a zone of high biodiversity and photosynthesis,

with the nutrient supply coming from the surrounding land. Some of the organisms found in this zone are frogs, turtles, worms, fish and insect larvae.

The limnetic zone is the open water away from the shore of the lake. It extends down till the depth to which sunlight penetrates and permits photosynthesis. The vegetation in this zone is less than that in the littoral zone, but there are plenty of producers making food for most of the consumers, phytoplankton, zooplankton, and larger fish are all found here.

The profundal zone, found in large lakes, is the deep water, which is too dark to permit photosynthesis. There are no plants or algae found here, but food drifts down from the other zones. Bacteria decompose the dead organisms that reach this zone, using up oxygen and releasing minerals in the process. The benthic zone is the bottom of the lake. The organisms that live here can withstand the low temperatures and low oxygen levels found here.

Stratification. The lakes show stratification or zonation based on temperature differences. During summer, the top waters become warmer than the bottom waters. Therefore, only the warm top layer circulates without mixing with the colder layer, thus forming a distinct zonation :

Epilimnion. Warm, lighter, circulating surface layer.

Hypolimnion. Cold, viscous, non-circulating bottom layer.

In between the two layers is thermocline, he region of sharp drop in temperature.

Types of Lakes. Some important types of lakes are :

(a) Oligotrophic lakes which have low nutrient concentrations.

(b) Eutrophic lakes which are over nourished by nutrients like nitrogen and phosphorus, usually as a result of agricultural run-off or municipal sewage discharge. They are covered with "algal blooms" e.g., Dal Lake.

(c) Dystrophic lakes that have low pH, high humic acid content and brown waters e.g., bog lakes.

(d) Endemic lakes that are very ancient, deep and have endemic fauna which are restricted only to that lake e.g., the Lake Baikal in Russia; the deepest lake, which is now suffering a threat due to industrial pollution.

(e) Desert salt lakes that occur in arid regions and have developed high salt concentrations as a result of high evaporation. E.g., Great salt lake, Utah; Sambhar lake in Rajasthan.

(f) Volcanic lakes that receive water from magma after volcanic eruptions e.g., many lakes in Japan. They have highly restricted biota.

(g) Meromictic lakes that are rich in salts and are permanently stratified e.g., lake Nevada.

(h) Artificial lakes or impoundments that are created due to construction of dams e.g., Govindsagar lake at Bhakra-Nangal.

Streams

These are freshwater aquatic ecosystems where water current is a major controlling factor, oxygen and nutrient in the water is more uniform and land—water exchange is more extensive. Although stream organisms have to face more extremes of temperature and action of currents as compared to pond or lake organisms, but they do not have to face oxygen deficiency under natural conditions. This is because the streams are shallow, have a large surface exposed to air and constant motion which churns the water and provides abundant oxygen. Their dissolved oxygen level is higher than that of ponds even though the green plants are much less in number. The stream animals usually have a narrow range of tolerance to oxygen. That is the reason why they are very susceptible to any organic pollution which depletes dissolved oxygen in the water. Thus, streams are the worst victims of industrial development.

River Ecosystem

Rivers are large streams that flow downward from mountain highlands and flowing through the plains fall into the sea. So the river ecosystems show a series of different conditions.

The mountain highland part has cold, clear waters rushing down as water falls with large amounts of dissolved oxygen. The plants are attached to rocks (periphytons) and fishes are cold-water, high oxygen requiring fish like trouts.

In the second phase on the gentle slopes, the waters are warmer and support a luxuriant growth of plants and less oxygen requiring fishes.

In the third phase, the river waters are very rich in biotic diversity. Moving down the hills, rivers shape the land. They bring with them lots of silt rich in nutrients which is deposited in the plains and in the delta before reaching the ocean.

What is the status of India's rivers? More than 70 per cent of India's territory drains into the Bay of Bengal via the Ganga-Brahmaputra river system and a number of large and small peninsular rivers.

The Ganga and the Brahmaputra, together with their tributaries, drain about one-third of India. The Ganga, considered a sacred river, is 2500 km long from its origin to its mouth. Although its deltaic portion lies mostly in Bangaldesh, the course of the Ganga which in India is longer than that of any of the country's other rivers.

Since the Ganga is fed by the melting of snow in the Himalayas, the variability of its flow is considerably less than that of the exclusively rain-fed peninsular rivers. This consistency of flow enhances its suitability for irrigation and navigation.

Although the total length of the Brahmaputra (about 3000 km) exceeds that of the Ganga, only 750 km of its course lies within India. The

Brahamputra, like the Indus, has its source in a trans-Himalayan area about 60 miles southeast of Lake Manasarovar in the Tibet Autonomous Region of China. The narrow Brahmaputra basin in Assam is prone to flooding because of its large catchment area, parts of which experience exceedingly heavy rainfall.

The Indus basin (in northwestern India) and a completely separate set of basin to the south (in Gujarat, Madhya Pradesh, and Maharashtra) drain into the Arabian sea. India shares the Indus drainage basin with China, Afghanistan and Pakistan. The Indus and its tributaries the Sutlej, Jhelum, Chenab, Ravi and Beas are the major rivers in the north-western basin. Despite low rainfall in the Punjab plains, the moderately high runoff from the Himalayas ensures a year-round flow in the Indus and its tributaries, which are extensively utilized for canal irrigation.

The two most important west-flowing rivers of peninsular India are the Narmada and Tapti. The Narmada and its basin are undergoing large-scale, multipurpose development.

The major rivers that drain into the Bay of Bengal are the Mahanadi, Godavari, Krishna and Kaveri. Except for the Mahanadi, the headwaters of these rivers are in the high-rainfall zones of the Western Ghats, and they flow along the entire width of the plateau before reaching the Bay of Bengal. The Mahanadi's source is at the southern edge of the Chhattisgarh plain.

The peninsular rivers experience considerable variations in flow between the dry and wet seasons. However, thanks to relatively steep gradients, they rarely give rise to floods of the type that occur in the plains of northern India.

Coastal Zone

The coastal zone is the area of interaction between land and ocean. There is no clear definition of this zone. On the seaward side, it is commonly taken to extend up to the gently sloping, shallow edge of the continental shelf. On the landward side, we could define the limit of the zone as the high tide line or even up to the watershed. Thanks to the edge effect, this zone shows very high levels of biodiversity. Ninety per cent of all marine species are found in this zone.

The coastal zone is easily affected by human activities. A general trend in the world is for the population to move towards the coastal zone. One estimate is that 60 per cent of the world's population new lives within 60 km of the coast. This proportion is expected to increase to 75 per cent by 2025. Even conservative estimates suggest that at least 40 per cent of the population lives within 100 km of the coast. One incontrovertible fact is that the rate of increase of coastal population is higher than that of the general population.

Most of the large cities of the world are to be found on the coast. Twelve of the 20 highly populated urban areas in the world are within 150

km of the coast and these include Mumbai and Kolkata. Coastal megacities have very large ecological footprints. In most cases, they dump enormous amounts of untreated sewage and industrial pollutants into the ocean.

Intertidal Zone. Within the coastal zone, the intertidal zone is the area of shoreline between the low and high tide marks. It is the transition between the land and the ocean and is marked by high levels of sunlight, nutrients and oxygen. As a result, it is biologically very productive with a variety of ecological niches, but it is also a zone of high stress for the organisms that live there.

If the zone is sandy, the organisms must adapt themselves to a constantly shifting environment. Since there is no protection against wave organisms are exposed to wave action during high tide and the process of drying and warming up during the low tide. They usually have a means of attaching themselves to rocks, such as thread-like anchors or glue-like secretions.

Estuaries Coastal Wetlands. Estuaries and coastal wetlands include river mouths, bays, mangrove forests, and salt marshes. Here the seawater mixes with freshwater and nutients from rivers, streams, and the run-off. These ecosystems experience wide daily and seasonal fluctuations in temperature and salinity levels because of tidal rhythms, variations in freshwater inflow from the land and from rivers, and the impact of storms.

The organisms in these ecosystems have to adapt to the changing conditions. Yet, these ecotones are among the most fertile ecosystems, often more productive than the adjacent ocean or river. The main reasons for this are the flow of nutrients from the land, the removal of waste products by tidal action, and the availability of sunlight.

Coastal saltwater wetlands are the ocean's nurseries, where many fish species spend the first part of their lives. These wetlands also protect coastlines from erosion and reduce damage from storms and cyclones. The flow of groundwater through coastal marshes prevents saltwater intrusion that would otherwise contaminate the wells in these areas. Coastal wetlands are, however, in steep decline all over the world.

Freshwater Wetlands. Wetlands are land surfaces covered or saturated with water for the whole or a part of the year. They are shallow ecosystems with black and rich sediments and abundant nutrients. They have vegetation adapted to thrive in saturated conditions.

There are three types of wetlands : swamps, marshes and bogs. Marshes have no trees, but they contain grasslike plants (cattails, sedges and reeds). Swamps have water-tolerant trees like the red maple and cedar. Bogs are waterlogged areas saturated with groundwater or rainwater and may contain sphagnum moss and low shrubs.

Marshes and swamps are marked by the full penetration of light and consequently high photosynthetic activity. Biomass production and species

diversity are much higher than in the surrounding uplands. They provide a habit for migrating waterfowl and other birds, beavers, otters, muskrats and game fish.

Traditionally, wetlands were considered wastelands, which bred mosquitoes. They were drained and developed for agriculture, fish farming, or human habitation. Their value as providers of ecosystem services is only now being realized.

Wetlands control flooding by holding excess water and releasing it slowly. They help in recharging groundwater and in purifying water by trapping and holding pollutants in the soil. They are the major breeding, nesting and migration staging areas for the waterfowl and shorebirds.

They add moisture to the atmosphere, which could fall back as rain. They can even be used as sewage treatment plants that require little technology or maintenance. If they are managed well, they do not breed mosquitoes because of the present of fish, insects and birds.

Even as we realize their importance, however, they are shrinking rapidly all over the world. Almost half of them have disappeared over the past century and those that remain have been fragmented by 'development'. What is worse, some wetlands have been used as toxic waste dumps and landfills.

Ocean (Marine) Ecosystem

Major oceans of the world, Atlantic, Pacific, Indian, Arctic and Antarctic cover approximately 70 per cent of the earth's surface. Each ocean indeed represents a very large and stable ecosystem. Marine environments, as compared with fresh water, appear to be more stable in their chemical composition due to being saline, and moreover other such physico-chemical as dissolved oxygen content, light and temperature are also different. These aspects would be considered in some detail later under 'Habitat Ecology'.

The biotic components of an ocean ecosystem are of the following orders :

Producers. These are autotrophs and also designated as primary producers, since they are responsible for trapping the radiant energy of sun with the help of their pigments. Producers are mainly the phytoplankton, such as diatoms, dinoflagellates and some microscopic algae. Besides them, a number of macroscopic seaweeds, as brown and red algae (members of phaephyceae and Rhodophyceae), also contribute significantly to primary production. These organisms show a distinct zonation at different depths of water in the sea.

Consumers. These all are heterotrophic macroconsumers, being dependent for their nutrition on the primary producers. These are :

Primary consumers, the herbivores, that feed directly on producers, are chiefly crustaceans, molluscs, fish etc.

Secondary consumers, which are carnivorous fish, as Herring, Shad, Mackerel etc., feeding on the herbivores.

Tertiary consumers, are other carnivorous fishes like Cod, Haddock, Halibut etc., that feed on other carnivores of the secondary consumers level. Thus these are the top carnivores in the food chain.

Decomposers. The microbes active in the decay of dead organic matter of producers and macroconsumers are chiefly bacteria and some fungi.

Meaningful Zones. The large marine ecosystem is divided into two major zones : the coastal zone and the open ocean (see Figure 4.1). The coastal zone extends from the high tide mark on land to the edge of the continental shelf, which is the submerged part of the continent. At this point, there is a sharp increase in the depth of water and from here onwards it is open ocean. The coastal zone is discussed in a later section of this chapter. The open ocean is divided into three zones by depth. The euphotic zone is the upper part where there is enough light for the phytoplankton to carry out photosynthesis. Large fish like sharks and swordfish are found here. The bathyal zone lacks sunlight and hence contains no producers. Zooplankton and smaller fish that populate this zone have to move to the upper levels at night to feed. The abyssal zone is the cold and dark zone at the bottom, reaching in places to a depth of 4000-6000 m. It is too dark for photosynthesis and yet there are producer organisms at this depth near hydrothermal vents. They are bacteria that can withstand temperatures of 200°C, and they produce food through a chemical reaction.

Coral Reefs. Coral reefs are one of the natural wonders of the ocean. On many beaches these beautiful and colourful creations are on sale. Where do they come from and who makes them? Coral reefs are found in the shallow coastal zones of tropical and subtropical oceans, where light can penetrate. Apart from being aesthetically appealing, they are also among the world's oldest, most diverse, and most productive ecosystems.

Corals are formed by huge colonies of tiny organisms called polyps. They secrete calcium carbonate (limestone) to form a protective crust around their soft bodies. When they die, their outer skeletons remain as a platform for others to continue building the coral. The intricate crevices and holes in the coral catacombs become the home for 25 per cent of all marine species.

The colour of the coral comes from zooxanthellae, the tiny single-celled algae that live inside the tissues of the polyps. In return for the home provided by the polyps, zooxanthellae produce food and oxygen through photosynthesis.

Importance of Coral Reefs. Coral reefs are complex ecosystems that perform many ecological services. When polyps form their shells, they absorb some carbon dioxide as part of the carbon cycle. These reefs help protect the coastal zone from the impact of the waves and from storms. They act as nurseries for hundreds of marine organisms. In their biodiversity and intricacy of relationships, they can be called the rainforests of the ocean.

On the economic side, they provide fish, shellfish, building materials, medicines, and employment to people. Through tourism, they bring in valuable foreign exchange and give us the pleasure of enjoying the world under the sea.

Coral reefs are of course in trouble. They are very vulnerable to damage because they grow very slowly, get disrupted easily, and are very sensitive to variations in temperature and salinity.

Coral bleaching is the biggest threat faced by all colonies. When a reef becomes stressed, it expels the zooxanthellae, loses its colour and food, and ultimately dies. An increase of even one degree in the water temperature can trigger bleaching. Sediment run-off from land that smothers the reef and prevents photosynthesis is further stress. Any pollution and disease could also lead to bleaching. Direct physical damage can also occur.

Of the world's reefs, 60 per cent are threatened by coastal development, pollution, overfishing, and warmer temperatures. Of more than 100 countries with large coral formations, 90 per cent are experiencing the decline of the reefs. South East Asia, with the most species of all coral reefs, is the most threatened region. Three hundred reefs in 65 countries are protected as reserves and 600 more are under consideration. Protected reefs do recover, but the process is both difficult and expensive.

Importance of Mangroves. Mangroves are unique half-tolerant trees with interlacking roots that grow in shallow marine sediments. Often they are found just inland off coral reefs. Mangroves provide valuable ecosystem services. Their roots are the breeding grounds and nurseries for many fish species like shrimp and sea trout. The branches are nesting sites for birds like pelicans, spoonbills, and egrets. They stabilize the soil, preventing erosion, and provide protection to the coast during cyclones. They are more effective than concrete barriers in absorbing wave action.

Mangroves occur all along the Indian coast covering 6700 sq km, which is about 7 per cent of the world's total mangrove area. Some of the important mangrove forests are found in the Andaman and Nicobar Islands, the Sunderbans (West Bengal), Bhitarkanika (Orissa), Pitchavaram (Tamil Nadu) and Goa.

In India and elsewhere, mangroves are fast disappearing due to coastal development, logging, and shrimp aquaculture. Between 1985 and 2000, the world lost half its mangroves.

Before we move to the coastal zone and the fresh water lifezones, let us look at a unique part of the ocean, that is, the Southern Ocean.

Antarctica and the Southern Ocean. Antarctica is an icy continent, surrounded by the Southern Ocean. It is a fragile ecosystem and is relatively unexploited. The Antarctic ice cap contains 70 per cent of the world's freshwater. A thin layer on the ocean supports krill (very small shellfish), which is consumed by other fish, seals, penguins, and whales.

Antarctica is a sensitive indicator of environmental charges. Between 1947 and 2000, the mean temperature of the Antarctic Peninsula went up by 2.5°C in summer and 5.6°C in winter. The reason for this may be global warming from the burning of fossil fuels. With increasing temperature, huge pieces of the ice shelf have been breaking off. Over a period of time, this melting of ice could raise global sea levels.

Seals and whales were first hunted in Antarctica, leading to the near-extinction of the southern fur seal, the elephant seal, and the blue whale. The pollution from the rest of the world has now reached Antarctica. Radioactive particles from atomic testing as well as pesticides like DDT and other chemical residues have been found in these waters. Tourism that is being promoted now will also have ecological consequences.

No country owns Antarctica, though several countries have made claims on parts of it. In 1991, 41 countries (including India) signed the Antarctic Treaty. They agreed to ensure that Antarctica is used for peaceful purposes, for international cooperation in scientific research, and does not become the scene or object of international discord.

The treaty, which seeks to establish Antactica as a zone free of nuclear testing and radioactive waste, includes agreed measures for the conservation of Antarctic fauna and flora.

Several countries including India have been conducting scientific research and exploration for oil and minerals in Antarctica. The first Indian expedition to Antarctica was sent in 1981 and since then Indian scientists have established two research stations, Dakshin Gangotri and Maitri, on the continent. Joint teams representing a number of scientific organization in the country have participated in more than 20 expeditions to the continent.

Environmental Concerns. The ocean is a finite resource and that human activities are already having an extremely adverse impact on the ocean. The world over, fish-catches have been steadily declining because of pollution and overfishing, with large trawlers and factory ships. Many fish species have disappeared forever.

The deep seabed has mineral as well as biological resources and many countries are now developing techniques to tap this wealth. The insatiable demand for petroleum has led to large-scale extraction of oil from the ocean with many negative consequences. The main shipping lanes of the ocean now carry very heavy traffic with consequent problems like large oil spills from giant tankers.

The dumping of hazardous waste, including nuclear material, into the ocean is raising pollution levels to great heights. Near the shore, heavy discharges from industry and sewage systems are also adding to the pollution. In fact, it is estimated that 77 per cent of marine pollution originates from the land.

Who controls the ocean activities? For a long time the ocean area beyond the territorial limits of countries was governed by the concept of the 'Freedom

10
Environmental Pollution-I

Pollution is an undesirable change in the physical, chemical or biological characteristics of air, water and soil that may harmful affect the life or create a potential health hazard of any living organism. Pollution is thus direct or indirect change in any component of the biosphere that is harmful to the living components (S), and in particular undesirable for man, affecting adversely the industrial progress, cultural and natural assets or general environment.

What are pollutants? Any substance which causes pollution is called a pollutant. A pollutant may thus include any chemical or geochemical (dust, sediment, grit etc.) Substance, biotic component or its product or physical factor (heat) that is released intentionally by man into the environment in such a concentration that may have adverse harmful or unpleasant effects. A pollutant has also been defined as "any solid, liquid or gaseous substance present in such concentration as may be or tend to be injurious to the environment. Pollutants are the residues of things we make, use and throw away. There are many sources of such pollutants. The lakes and rivers are polluted by wastes from chemical and other factories, and the air by gases of automobile exhausts; industries, thermal power plants etc.

Some experts and institutions have defined pollution as follows :

- According to **Lord Carnait,** "The presence of those elements and energy which are produced by man intentionally or unintentionally and which affects human health adversely, is termed as Pollution."
- According to **G.M. Dicksan,** "Pollution includes all the voluntary and involuntary activities of man and his pet animals and their effects and results which reduce the capacity of a man to get prefect pleasure and profit by his environment.
- According to **Central Pollution Control Board,** Environment Pollution means, "Any undesirable change in the physical, chemical or biological state of our environment which cause harmful effects to human beings, animals, vegetables or other natural elements. This loss can be of direct or indirect nature. Any kind of disequilibrium in the solid, liquid or gaseous form of environment, is also termed as pollution."

- The trust **'Massachusetts Institute of Technology'** which is working for Environment, has described the Environment Pollution as follows :
  "In every step of the production and consumption of things, waste materials are produced. These waste materials are termed as pollution when they adversely affect atmospheric or hydrospheric environment."

So in a way, it is obvious that the lack of beneficial elements and presence of harmful elements in land, water and air is called pollution.

There has grown up a serious concern all over the world about the rivers turning murky, fish rotting on sea shores, trees withering, cities choking with foul air, toxic chemicals being cycled into food stuffs and disease epidemics appearing so frequently. At UN conference on environment on June 14, 1972 at Stockholm (Sweden), the late Prime Minister of the country, Smt. Indira Gandhi had said "Modern man must re-establish an unbroken link with nature and with life. He must again learn to invoke the energy for growing things and to recognise, as did the ancients in India centuries ago, that one can take from the earth and the atmosphere only so much as one put back into them."

The various principal pollutants which pollute our air, water, land are as follows :

- Deposited matter—Soot, smoke, tar, dust, grit etc.
- Gases—Oxides of nitrogen (NO, NO_2), Sulphur (SO_2), Carbonmonoxide, halogens, (chlorine, bromine, iodine),
- Acids droplets—Sulphuric acid, nitric acid etc.
- Aluorides.
- Metals—Mercury, lead, iron, zinc, nickel, tin, cadmium, chromium etc.
- Agrochemicals—Biocides (pesticides, herbicides, fungicides, nematicides bactericides, weedicides etc.), and fertilisers.
- Complex organic substances—Benzene, ether, acetic acid, benzpyrenes etc.
- Photochemical oxidants—Photochemical smog, ozone, peroxyacetyl nitrate (PAN), peroxybenzoil nitrate (PB_2N), nitrogen oxides, aldehydes, ethylene etc.
- Solid wastes.
- Radioactive waste.
- Noise.

Kinds of Pollution. Various types of pollutions are classified in different ways. On the basis of the type of environment being polluted, we may recognise air pollution, water pollution, land (soil) pollution, marine pollution etc. On the basis of kind of pollutant involved, we may have sulphur dioxide pollution, fluoride pollution, carbon monoxide pollution, smoke pollution,

lead pollution, mercury pollution, solid waste pollution, radioactive pollution, noise pollution etc. Of the variety of pollutants, we recognise the following two basic types of pollutants : nondegradable and biodegradable. Nondegradable pollutants are the materials and poisonous substances like aluminium cans, mercuric salts, long-chain phenolics, DDT etc., that either do not degrade or degrade only very slowly in nature. They are not cycled in ecosystem naturally. They not only accumulate but are often biologically magnified with their subsequent movement in food chains and biogeochemical cycles. Biodegradable pollutants are the domestic wastes that can be rapidly decomposed under natural conditions. They may create problems when they accumulate.

Air Pollution

Air pollution is said to exist if the levels of harmful gases, solids, or liquids present in the atmosphere are high enough to affect humans, other organisms, buildings, monuments, etc.

In simple words, air pollution means the presence of pollutants such as dust, smoke, fog and foul smell which are unimportant and even harmful for plants and other living being. Air pollution is of two types : First particulate matter, solid and gaseous elements in the form of very tiny in the air. These elements flow to far off regions by the pressure of wind. This problem generally occurs in industrial areas. The tiny particles like smoke, dust, ash, cotton, lead, nickel etc. pollute the air by mixing in it.

The second type of pollution is called chemical pollutants. In this the carbonic as well as non-carbonic elements of various gases are mixed with air. The main carbonic elements are monoxide, methane, benzene, ethylene and main non-carbonic elements are—nitrogen, carbon and sulphur dioxide, ammonia and chlorine, etc.

Causes of Air Pollution. The following are the causes of air pollution :

1. **Urbanisation.** Urbanisation has unveiled before us an alarming situation. Expanding urbanisation has influenced the atmosphere in different ways, such as growth of vehicle population, sanitation, multiplying industrialization, power consumption etc. Urbanisation leads to development of industrial centres without a corresponding development in civic amenities and pollution control machinery.

The vehicular pollution accounts for nearly 70 per cent of the total air pollution in India. According to the World Health Organisation, Delhi is one among the top ten most polluted cities in the world and almost all-major Indian cities are above the prescribed standard limit of the SPM.

Urbanisation has spelt out greater comforts in luxurious living with dramatic improvements in the technology used. However, this development in technology accentuates the problem of indoor air pollution scientific evidence has indicated that air within homes and other buildings can be more polluted than the outdoor air, particularly in he largest and

the most polluted cities. Similarly, research indicates that women spend nearly 90 per cent time indoors. Thus, for many people, risks to health may be greater due to exposure to indoor air rather than air outdoors.

2. **Industrialisation and Other Development Activities.** The rapid rate of industrialisation has resulted in more and more air pollution. Various industrial processes release almost all types of pollutants into the air. Some industries like cement, iron and steel, fertilizer, petrochemical, etc., are of great concern because of the difficulty in controlling the emission of pollutants from them. Acid rain has become a great threat to the environment. The use of solvents is increasing with the growing use of paints, spray, polish, etc. Due to presence of hydrocarbons in these materials, air pollution is caused which is dangerous for health. Similarly, spray of pesticides in agriculture is also responsible for air pollution even in rural areas.

India's reliance on low-grade coal with high carbon content is the prime cause for large-scale carbon emission. Carbon emission has been exacerbated by the low energy efficiency of coal-based plants. Chemical industries including manufactures of cement, fertilisers, textiles, iron and steel, non-metal products, paper, food production, printing and publishing, and leather industry pesticides etc., release a host of harmful gases and compounds into the atmosphere.

3. **Deforestation.** The burning of fuel wood is one of the major sources of air pollution in India. Intense use of fuel wood mainly for domestic chores contributes to high level of air particulate matter and has caused the depletion of forest resources. Besides, deforestation is aided by over increasing urban infrastructural demand, such as metalled highway, better places of dwelling etc. As a result, large-scale utilisation of forest resources caused serious economical, environmental and social hazard. It is now a serious national problem and has invited attention of national planners and environmental advisers. The statistics of forest coverage in India give a clear picture how far India lags behind the minimum standard of forestation. The destruction of forest resources, the percentage of harmful gases like sulphur dioxide and monoxide and dioxides of carbon, etc., increase steadily resulting in acid rain, global warming and other such dreaded phenomena.

4. **Vehicular Exhaust.** The automobile is man's greatest achievement in minimizing distances. The number of automobiles is increasing day by day and has become a cause of air pollution and degradation of the environment. The automobile, with its internal combustion engine, emits poisonous gases that are harmful to human health and is the most serious pollution of the technological age.

5. **Poverty.** Nearly more than two third of the total population in India still live below the poverty line, striving hard to make both ends meal. Since their number is considerably large, their contribution to air pollution cannot be ignored. These people mostly use cowdung cakes : leaves, twigs and wood as fuel which being solid fuels emits more smoke in comparison to

gaseous fuels. Improper disposal of garbage in the open causes decay of the organic wastes, liberation harmful gases like methane and carbon monoxide into the atmosphere.

6. **Mining System.** In the mining process various kinds of chemical methods are used for explosion. As a result smoke, dust particles and chemical elements are spread in the surrounding area and thus pollute the environment. Mining fields produce a great quantity of waste material/ suspended particulate matter (SPM) polluting the air of that place.

7. **Use of Chemicals in Agriculture.** To solve the food problem of Increasing population various kind of chemicals have been used. Different kinds of manure and pesticides are used even at pre-cultivation level. They are used frequently during the processes. Although they increase the production, these chemicals also spread in the surrounding air. Being a part of our food, they are harmful for our health and along with this, being mixing in water or at the time of sprinkling, they come in contact with air and thus pollute it.

8. **Tobacco Smoke.** In almost every country of the world, tobacco is used in different ways of smoking. Smoking in the form of Biri-Cigarette, Cigar and Chilum releases smoke in air, continuously. This smoke is injurious not only for one who inhales it but others also who are nearby. Besides by mixing in air, it also affects in health of other people.

9. **Production of Thermal Electricity.** In modern time electricity has become very important for human beings. This electricity is produced by using hydro/water power as well as thermal power. In India 29% of the total consumption of coal is used in the production of electricity. In this way, due to electricity, ash, black particles, smoke and other kind of toxic gases are discharged into air and cause many problems.

It becomes clear from the above analysis that the problem of air pollution is increasing with the growth and expansion of industries and automobiles. It is high time all of us know the harmful effects of air pollution and also evolve technology to control it.

Effects of Air Pollution. Pollution and smog unveil before us a spectre of dreaded diseases wrecking havoc on our health. Prolonged exposure to toxic pollutants from various sources affects the normal functioning of life. Growing level of nitrogen dioxide and other corrosive gases have caused multiplication of the incidence including allergic diseases like nausea, vomiting and chronic skin and eye irritations. The toxic elements in the atmosphere are responsible for asthma, bronchitis and related respiratory disorders. Nearly 80 per cent of cancer cases are attributed to environmental pollution with toxic and hazardous chemicals. Organic lead emitted from automobiles gets absorbed in brain, liver, kidney and blood, causing convulsions, muscular paralysis, brain damage and even death. Radon gas introduced into the atmosphere from Uranium-containing soil can result in lung cancer after long exposure. More and more people are falling prey to digestive ailments

are weakening of the body's immune system. The victims of airborne pollutants are mostly infants and children.

1. **Effects on Human Health, Animals and Plants.** Some environmental poisons can immediately cause acute illness and even death. Other may be harmful, but the disease may take years or even decades to appear. Air pollution mainly affects the respiratory system. Bronchitis, emphysema, asthma and lung cancer are some of the chronic diseases caused due to exposure to polluted air. It is feared that lung cancer is caused mainly due to polluted air because carcinogens are found in the polluted air. Its mortality rate is higher in urban areas. Sulphur dioxide is the most serious and widespread air pollutant. Its lower concentration is a cause of spasms in the smooth muscle of bronchioles and its higher concentration induces increased mucus production. Sulphur dioxide is also considered to cause cough, shortness of breath, spasm of the larynx and acute irritation to the membranes of the eyes. SO_2 also acts as an allergenic agent. When it reacts with some compounds, sulphuric acid is formed which may damage lungs.

Carbon monoxide often affects the oxygen carrying capacity of blood. Nitric oxide is reported to be a pulmonary irritant and its excess concentration may cause pulmonary haemorrhage. Hydrogen sulphide is also toxic. Lead emitted from automobile exhausts is a cumulative poison and is dangerous particularly to children and may cause brain damage.

Among the metallic contaminant arsenic, lead and molybdenum are important. Fluoride is another pollutant which causes fluorosis among animals. A number of livestock have been poisoned by fluorides and arsenic in North America. Lesions in animals occur due to excessive flourides.

Air pollution has caused widespread damage to trees, fruits, vegetables, flowers and in general vegetation as a whole. Fluorides are responsible for various types of injuries to plants. The leaves of apple, apricot, peach, prune are more susceptible to air borne fluorides. Fluorides seem to interfere with the photosynthesis and respiration of plants. Smog also causes injury to plants. Similar impact of ozone can be seen in the lesions to plants. Chlorine, ammonia, hydrogen sulphide etc., are also harmful to vegetation.

2. **Global Warming.** The temperature at the surface of the earth is maintained by the energy balance between the sun's rays that strike the planet and the heat that is radiated back into space. Some of the heat is absorbed and retained by the earth or objects on the surface. Much of this does not pass through the air envelope to outer space but it absorbed by the carbon dioxide and water vapour in the atmosphere and adds to the heat already present. Thus, carbon dioxide acts like the glass of a greenhouse, and on a global scale, tends to warm the air in the low levels of the atmosphere. This is called the greenhouse effect which is also responsible for the increase in temperature over the earth's surface volcanic eruptions are also responsible for the increase of carbon dioxide.

The mean surface temperature of the earth has been rising at a much faster rate in the recent years. According to Inter-Governmental Panel on Climate Change (IPCC), jointly established by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP), the mean surface air temperature has increased by about 0.3-0.6 degree Celsius. The average rate of warming would probably be the highest seen in the recent past. Between 1960 and 1980, the world has generated more green house gases (GHGs) like carbon-dioxide, methane, nitrogen dioxide, chloro flurocarbons (CFCs) etc., than was done in its entire earlier history. In the world scenario, India is placed sixth in production of carbon dioxide. Sea level is also anticipated to increase by 15-95 centimeters by beginning of 21st century, with disastrous consequences for islands like Maldives and low level coastal areas like Bangladesh. Unprecedented temperature rise in the last twenty years is only due to change in the prevailing climate. The macabre truth is that anticipated global warming could produce permanent climatic changes by during up monsoon rains which would affect agriculture adversely. Hence all the forms of animal life and vegetation will be affected.

3. **Depleting Ozonosphere.** Ozone is normally present in the atmosphere at about 0.05 ppm at sea level. It is produced naturally in the atmosphere by the action of electric discharges on oxygen. Until 1974, atmosphere scientists were proceeding in their research on possible impacts of nitrogen oxide jet engine exhausts on the ozone layer. But later it was found that a new threat to the ozone layer has emerged from synthetic chemicals called chlorofluorocarbons. Recent scientific studies indicate that if chlorofluorocarbon production continues to grow at the present rate, the compound will enter the stratosphere in quantities capable of seriously depleting the ozone layer, normally termed as 'holes' in ozone layer.

The use of chloro-fluorocarbon is increasing because of the demand of 'personal care products' such as deodorants, hair sprays, shaving creams and countless other consumer cosmetic products as well as in refrigeration. The ozone layer serves as a shield protecting the troposphere and earth's surface from most of the ultra violet radiation found in the sun's rays. If these ultra violet rays reach the earth's surface in full intensity, all exposed bacteria would be destroyed; plants and animal tissues would be severely damaged. In this protective role, the presence of the ozone layer is an essential factor in man's environment.

4. **Acid Rain.** Pronounced as the most dreaded effect of air pollution, acid rain, as the name suggests refers to the precipitation of carbonic, sulphuric, sulphurous and nitric acids during rainfall. Acidic fumes of sulphur dioxide and trioxide, carbon dioxide and nitrogen dioxide emitted from industrial establishments combine with rain water and snow in the atmosphere to form corresponding acids which come down as rain. The

analysis of rain water in polluted regions would confirm acidic character with pH value less than 7.

Acid rain pollutes the drinking water sources, such as wells, ponds and lakes. It causes fertile lands to grow barren since excessive acidity is deterrent to plant growth. Acid rain is highly corrosive in action and causes blisters and burns, if it comes in contacts with skin. The Taj Mahal at Agra was prone to corrosion due to sulphuric acid rain.

5. **Smog.** 'Smog' is the name given for 'smoke fog'. The most irritating and injurious components of smog are the products of reactions in the atmosphere between oxygen, ozone and emission pollutants. The mixture of these products is called photo-chemical smog. These are reactions in which oxygen, ozone, nitrogen and hydrocarbons produce those compounds which are toxic and irritating.

The constituents of smog are quite toxic and are responsible for respiratory and cardiac difficulties Eye irritation is the most common symptom of smog injury. It is also injurious to animals and plans and one of the main causes of environmental degradation.

6. **Photochemical Smog.** The classical example of secondary pollutant, photochemical smog is formed in traffic—congested metropolitan cities where warm conditions and intense solar radiations are present. Photochemical smog is composed mainly of ozone (O3), peroxyacetyl nitrate (PAN) and No_x. It is often called brown air where solar radiation, smog formation is incomplete and the air is referred to as grey air. Automobile exhaust contains HC and NO and these play an important role in (O3) and PAN formation in urban environment.

Smog ozone may damage plant as well as animal life. In plants, the main damage occurs in leaf. Ozone aggravates lung diseases in humans. Ozone, an effective oxidant, corrodes the heritage building surfaces and damages marble statues and other cultural assets. Several plant species are also very susceptible to PAN in smog. PAN damages chloroplasts and, thus, the photosynthetic efficiency and growth of plants are reduced. It also inhibits electron transport system and interferes with enzyme systems that play important role in cellular metabolism. In humans, PAN causes acute irritation of eyes.

Classification of Air Pollutants. Air pollutants may occur in gaseous or particulate form and may be organic or inorganic in nature. On the basis of origin of pollutants they can be classified as primary or secondary pollutants.

(a) **Primary Pollutants.** These are emitted directly from the point source (identifiable source) e.g., carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulphur (SO_x), hydrocarbons, radioactive substances etc.

(b) **Secondary Pollutants.** These are formed by interaction of primary pollutant(s) with other primary pollutant(s) or with some natural

constitutenents of atmosphere, e.g., ozone (O_3), peroxyacetyl nitrate (PAN), photochemical smog etc.

Indoor Air Pollution. The most important indoor air pollutant is radon gas. Radon gas and its radioactive daughters are responsible for a large number of lung cancer deaths each year. Radon can be emitted from building materials like bricks, concrete, tiles etc., which are derived from soil containing radium. Radon is also present in groundwater and natural gas and is emitted indoors while using them.

Many houses in the under-developed and developing countries including India use fuels like coal, dung-cakes, wood and kerosene in their kitchens. Complete combustion of fuel produces carbon dioxide which may not be toxic. However, incomplete combustion produces the toxic gas carbon monoxide. Coal contains varying amounts of sulphur which on burning produces sulphur dioxide. Fossil fuel burning produces black soot. These pollutants i.e., CO, SO_2, soot and many others like formaldehyde, benzo—(a) pyrene (BAP) are toxic and harmful for health. BAP is also found in cigarette smoke and is considered to cause cancer. A housewife using wood as fuel for cooking inhales BAP equivalent to 20 packets of cigarette a day.

Outdoor Air Pollution. The sources of outdoor air pollution are :

- Burning of fossil fuels :

(i) in automobiles, domestic cooking, and heating.
(ii) in power stations and industries (primarily the chemical, metal, and paper industries).

- Mining activities leading to dust as well as fires.
- Burning nuclear fuels, biofuels, tropical rainforests, wastes of all kinds.
- Natural emissions from animals and decaying organic matter.

Effects of Outdoor Air Pollution. At low levels air pollutants irritate the eyes and cause inflammation of the respiratory tract. If the person already suffers from a respiratory illness, air pollution may lead to the condition becoming chronic at a later stage. It can also accentuate skin allergies.

Many pollutants also depress the immune system, making the body more prove the infections. Carbon monoxide from automobile emissions can cause headaches at lower levels and mental impairment and even death at higher levels.

Particular matter can reduce visibility, soil clothes, corrode metals, and erode buildings. On a larger scale, air pollution leads to acid rain, ozone layer depletion, and global warming.

Means to Control Outdoor Air Pollution. Outdoor air pollution can be reduced by adopting cleaner technologies, reducing pollution at source,

implementing laws and regulations to make people pollute less, introducing appropriate transportation policies, etc.

Automobiles emissions can be reduced through various measures :

- Making cleaner and fuel-efficient cars.
- Using lead-free petrol in existing cars.
- Introducing policies that encourage the building and use of mass transit systems and discourage the use of personal transport. For example, efficient and low-cost public transport, congestion charges in city centres, separate lanes for car pools, heavy tax on personal cars, tax incentives on electric cars, etc.
- Shifting from diesel to natural gas (CNG) as a fuel for trucks and buses.

Levels of Air Pollution in India

The air is severely polluted in many Indian cities, with excessive concentrations of suspended particulate matter (SPM), nitrogen oxide, and sulphur dioxide. The World Health Organization (WHO) had consistently ranked Delhi as the fourth most-polluted city in the world. The main cause for this was vehicular emissions followed closely by industrial pollution.

The number of motor vehicles in India increased from 300,000 in 1951 to 37.2 million in 1997. Of these, over 30 per cent are in the 23 metropolitan cities. Delhi alone accounts for 8 per cent of the total.

The exponential growth of vehicles, outdated vehicle technology, bad fuel quality, poor maintenance of vehicles, poor traffic management and planning, etc., all contribute to vehicular pollution. The problem is compounded by the unwillingness on the part of vehicle owners and the auto industry to accept emissions norms, and the lack of efficient public transport.

The older vehicles still use leaded petrol although unleaded petrol is now increasingly available. Trucks and buses run on diesel, which has a high sulphur content. The old engines emit vast quantities of SPM, leading to heavy air pollution over many cities.

Polluted air is affecting the peoples' health, particularly that of children. Between 1991 and 1995, the annual number of premature deaths that can be traced to air pollution, increased from 40,000 to 52,000. In Delhi, one out of every 10 school children suffers from asthma.

In rural areas, indoor pollution is taking a toll on the health of women. Traditional stoves that use wood or coal spew out poisons that women inhale directly. This is equivalent to smoking 100 cigarettes a day! Many deaths take place in North India during the winters when doors and windows are closed and poisonous smoke from the stove collects indoors. There have been campaigns to substitute these inefficient and polluting stoves with smokeless chulhas. The effort has, however, failed to make an adequate dent in this huge problem.

Regulations on Automobile Emissions in India. The Indian government began regulating automobile emissions in 1991. In the year 2000, the government introduced the Bharat Emission Norms modelled on the basic Euro Norms of the European Union. Since then it has been gradually making these limits more stringent.

Bharat-III norms for passenger cars will come into effect from April 2005 in 11 metros—Bangalore, Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agra. This will account for 40 per cent of the total cars sold in India. The rest of the country will shift to Bharat-II norms.

In the 11 designated cities the new Bharat-III petrol cars would have 28 per cent lower emissions than current Bharat-II cars and 89 per cent lower emissions than cars manufactured in 1991. Similarly, there would be an almost 30 per cent reduction in emissions among Bharat-III diesel cars as compared with the Bharat-II cars. Compared to 1992 diesel cars the reduction in emissions would be 72 per cent.

Lead has been phased out of automobile fuel with effect from February 2000. New stringent norms for petrol and diesel will come into effect from 2005.

The Supreme Court of India has taken a special interest in keeping the air clean, particularly in Delhi. Thanks to the orders of the court, implemented by the Delhi government, the air quality in Delhi has improved.

Controlling Air Pollution. The following steps should be taken to control air pollution :

- The forest cover should be protected by restricting deforestation and through adoption of afforestation programmes. Trees are the best controllers of air pollution. It must be ensured that 33 per cent of the land area remain under forest cover. It will help in controlling air pollution and also help in maintaining the ecological balance.
- There must be a 'green belt' around every township and village. Similarly, industrial areas should be surrounded by green belts.
- The main source of air pollution is the automobiles, therefore, their engines should be redesigned in such a way that their emissions cause minimum pollution. Several steps has been taken and some technology has also been developed, but still it is in a preliminary stage.
- In developing countries traditional use of fuelwood should be controlled.
- In industries arrangements for pollution control should be done. Only after full arrangement of effluent treatment is done, permission for production should be given.
- Minimize activities which cause pollution like transportation and

- Modification of process and/or equipments.
- Use of appropriate material.
- Using low sulphur coal in industries.
- Removing sulphur from coal (by washing or with the help of bacteria).
- Removing NO_x during the combustion process and controlling the flow of air and fuel in industrial boilers.
- Vehicular pollution can be checked by regular tune-up of engines; replacement of more polluting old vehicles; installing catalytic converters; by engine modification to have fuel efficient (lean) mixtures to reduce CO and hydrocarbon emissions; and slow and cooler burning of fuels to reduce NO_x emission (Honda Technology).
- Using mass transport system, bicycles etc.
- Shifting to less polluting (clean) fuels (hydrogen gas).
- Using non-conventional sources of energy.
- Using biological filters and bio-scrubbers.
- Planting more trees.
- Reduction of pollution at source.

Reduction of Air Pollution at Source. Air pollution can be reduced at the source place in the following way :

(i) **Gaseous Pollutants.** Gaseous pollutants can be reduced by physical adsorption on porous solid materials like activated charcoal, silica gel, Fuller's earth, etc. Effluent gases can be absorbed in liquid absorbent, e.g., SO_2 absorbed in ammonia solution. They can be removed by condensation which is carried out by cooling medium in tubes where the gases in contact condense and can be collected thereafter. Combustion can be used to reduce pollution by burning the pollutants in combustion equipment at optimal conditions of oxygen and temperature.

(ii) **Particulate Matter.** Many devices are available now-a-days, choice of which depends on characteristics of particulate, flow rate, collection efficiency, costs, etc.

(iii) **Setting Chambers.** These are nothing more than large places in the flues, similar to settling tanks in water treatment. These chambers remove only the large particulates.

(iv) **Cyclones.** These are widely used for removing large particulates. The dirty air is blasted into a conical cylinder, but off the centreline. This creates a violent swirl within the cone, and the heavy solids migrate to the wall of the cylinder where they slow down due to friction and exit at the bottom of the cone. The clean air is in the middle of the cylinder and exists out the top. Cyclones are widely used as pre-cleaners, to remove the heavy material before further treatment.

(v) **Bag Filters.** They operate like the common vacuum cleaner. Fabric bags are used to collect the dust which must be periodically shaken out of the bags. The fabric removes nearly all particulates. Bag filters are widely used in many industries, but are sensitive to high temperature and humidity.

(vi) **Wet Collectors.** They come in many shapes and styles. The simple spray towe is an effective method for removing large particulates. More efficient scrubbers promote the contact between air and water by violent action in a narrow throat section into which the water is introduced. Generally, the more violent the encounter, and hence the smaller the gas bubbles or water droplets, the more effective the scrubbing.

(vii) **Electrostatic Precipitators.** These are widely used in power plants. The particulate matter is removed by first being charged by electrons jumping from one high voltage electrode to the other, and then migrating to the positively charged electrode. One type consists of a pipe with a wire hanging down the middle. The particulates will collect on the pipe and must be removed by banging the pipes with hammers. Electrostatic precipitators have no moving parts, require electricity, and are extremely effective in removing submicron particulates. They are expensive.

(viii) **Gas Scrubbers.** These are simply wet collectors as described above but are used for dissolving the gases.

(ix) **Adsorption.** It is the use of a material such as activated carbon to capture pollutants. Such adsorbers may be expensive to regenerate. Most of these work well for organics and have limited use for inorganic pollutants.

(x) **Incineration.** It is a method for removing gaseous pollutant by burning them to CO_2, H_2O and inerts. This works only for combustible vapours.

(xi) **Catalytic Combustion.** It involves the use of a catalyst to adsorb or chemically change the pollutants. It is again important to emphasize the dependence of effectiveness of a treatment device on particle size.

Noise Pollution

Noise is defined as unwanted sound and it is an irritant and a source of stress. Most of the noise one hears originates from human activities. Noise has become a permanent part of our lives these days because of the development of machinery, industry and technology. Noise harms the body and mind. Noise not only causes irritation or annoyance but it constricts your arteries, increases the flow of adrenaline and forces your heart to work faster.

The word noise (Latin nausea) is usually defined as unwanted or unpleasant sound that causes discomfort. Noise is also defined as "wrong

sound, in the wrong place at the wrong time." Noise pollution means "the unwanted sound dumped into the atmosphere leading to health hazards."

Formerly noise was limited only to the industry. This too was not much as there were only few industries. These days there has been rapid industrial growth. Moreover, there has been population explosion, due to which there is heavy traffic, urban crowd and electric equipment (luxury items and end entertainment). All these have added to the noise nuisance in environment. In our country, besides these the two other factors are the religious and social functions which increase the gravity of situation.

Causes of Noise Pollution. Sources of noise pollution can be divided in the following three parts :

(1) **Natural Sources.** Nature plays a vital role in noise pollution. The main thing about this pollution is that it is not permanent and bitter and harsh. In the temporary noise pollutants, we include thunder cap, storm and windfall, heavy rain drops, hailstorm, volcanic eruptions and earthquakes etc. In permanent noise pollutants, we include the sound of waterfall, sea waves, ebb and flow of rivers and blowing of winds in some regions etc. Both these pollutions are related to a limited area or short termed. Secondly nature itself can control such kind of pollution.

(2) **Biotic Sources.** All these creatures produce some kind of sound or sound is produced due to their various activities. Roaring of lions, trumpeting of elephants, braying of ass, lowing of cows, barking of dogs and chirping of birds are natural sounds. Moreover, sound is produced during animals fighting and running etc. The humans laughter, speaking, crying, fighting or singing without any instrument also fall in this category. This pollution is also not very dangerous and it is also short term and limited.

(3) **Man-Made Sources.** This pollution is the most dangerous type of noise pollution. The main reason of this pollution are the things of comfort and employment made by human beings. This pollution is continuous, unlimited and harsh. Man is responsible for this, it is also called artificial source. The description of these sources are as follows :

(i) **Industrialization.** In medieval era man's comforts and requirements were limited. In the modern time, man stepped into the direction of industrialization. First of all small machines and tools were made, afterwards heavy machines and factories took their place. These factories go on working round the clock. They produce much noise. In these factories every kind of mechanical and production works keep on going. This noise not only affects the workers in the factory but also nearby area.

(ii) **Means of Transportation.** Industrialization and modernization have changed the nature and number of means of transport to a great extent. In modern time, we use two wheeler vehicles, three wheeler vehicles,

motorcar, truck, train and aircraft etc. as the main means of transportation. These means have developed rapidly due to urbanisation. All these means produce higher and greater amount of noise. The people dwelling near bus stand or railway station are very much aware of this noise. One motorcar or truck produces more than 100 DB sound while a train produces more than 140 DB sound. Aeroplanes and Jet planes sometime produce more than 180 DB to 200 DB sound. These means of transport not only produce sound while transporting but also use horns. This sound is more bitter and harsh than normal sound.

(iii) **Social and Religious Activities.** Man is a social animal. Social gatherings, public functions etc. are common because they provide a new charm and energy to the monotonous life of the people. They are social and religious customs. They also provide some kind of peace. But the other aspect of these activities is that loud speakers are used for prayers, hymns, religious ceremonies etc. Their sound is very loud and it covers and affects a large area.

(iv) **Means of Recreation.** Man from the very beginning entertaining himself in one way or the other. But in modern times due to electronic devices there are changes in musical instruments and their sound. New music system is much higher in volume than the earlier ones. New generations like western music. Likewise the radio and TV volume is also set high in many of the families. People only care for their comfort and satisfaction without thinking about others. So, means of recreation also produce noise pollution.

(v) **Other Causes.** Besides these, some other factors also causes noise pollution. Such as :

- Various festivals, specially Diwali are responsible for noise pollution as well as these spread some harmful chemicals in the atmosphere also.
- In mining area, the workers and a great number of chemical explosions produce noise pollution.
- Agricultural equipments and machines also create noise pollution.
- Crowded area like market is also responsible for noise pollution.
- To celebrate regional, state level or national festivals, noise pollutants are used.
- Loudspeakers are used in various rallies, processions, canvassing etc.
- In army also, during training and using of various arms, noise is produced.
- For the advertisement of any produce in the market, sound instruments are used on large scale.

We come to the conclusion after considering all these factors that man is the most responsible factor for noise pollution. Moreover, it is the most dangerous also. Unfortunately, inspite of the controlling of noise pollution, it is increasing day by day.

Effects of Noise Pollution. The different effects are categorised as (a) auditory effects (affecting hearing faculty); and (b) non-auditory effects (other than auditory ones).

(a) **Auditory Effects.** These include auditory fatigue, and deafness. Auditory fatigue appears in the 90 dB and may be associated with side effects as whisling and buzzing in ears. Deafness can be caused due to continuous noise exposure. Temporary deafness occurs at 4000-6000 hz. Permanent loss of hearing occurs at 100 dB. Mumbai and Kolkata are the noisest cities in the world. Many persons have risk of deafness.

(b) **Non-Auditory Effects.** These are—(i) interference with speech communication, (ii) annoyance, (iii) loss of working efficiency and (iv) physiological disorders.

(i) **Interference with Speech Communication.** A noise of 50-60 dB commonly interferes with speech; sound of warming (signal) may be misunderstood.

(ii) **Annoyance.** Balanced persons express great annoyance at even low level of noise as crowd, highway, radio etc. The effects are ill temper, brickering etc.

(iii) **Loss in Working Efficiency.** There develop tiredness and those doing mental work may put to deterioration in their efficiency or even complete loss of ability to work.

(iv) **Physiological Disorders.** There develop a number of physiological disorders due to imbalance in functioning of the body. These are neurosis, anxiety, insomnia, hypertension, hepatic diseases, behavioural and emotional stress, increase is sweating, giddiness, nausea, fatigue etc. Noise also causes visual disturbance, and reduces depth and quality of sleep thus affecting overall mental and physical health. Other effects are undesirable changes in respiration, circulation of blood in skin and gastointestinal activity. Noise pollution also causes incidence of peptic ulcers.

Continuous noise causes an increase in cholesterol level resulting in the constriction of blood vessels making you prone to heart attack and strokes. These may be still births and usually low weight children born to mothers living near airports.

Supersonic air planes create a shock wave called sonic boon, which produces a startle effect that can be more harmful than a continuous noise. The sonic boon may spread in an area of 10 to 80 miles and when it hits the ground it damages windows pans and building structures. This may also

fasten the human fetus heart beat rate. Some of the important health hazards of noise are as follows :

Table 10.2

Noise Intensity (dB)	Health Hazards
80	Annoyance
90	Hearing damage
95	Very annoying
110	Stimulation of reception in skin
120	Pain threshold
130-135	Nausea, vomiting, dizziness
140	Pain in ear
150	Burning in skin
160	Rupture of tymphanic membrane
180	Major permanent damage in short time

What is the state of noise pollution in India? In urban as well as rural areas, noise pollution is on the rise. Public meetings, festivals, marriage receptions, the sound of televisions, etc., have all become louder.

A study conducted in 2003 by the National Physical Laboratory, New Delhi, showed that the noise generated by crackers sold in the market was much higher than the prescribed levels. This was the case with almost all the brands. The noise was more than the sound of aircraft and deleterious to health.

Another study made in 2002 showed that noise levels at three busy traffic junctions in Chennai were above the permissible limits prescribed by the Central Pollution Control Board and the Bureau of Indian Standards. Automobile horns were found to be a major source of noise.

In the 1980s and 1990s there were several court judgements in India restricting the generation of noise by industries, fire crackers, electric horns, etc. Finally, in 2000, the Indian government notified the Noise Regulations Rules under the Environment (Protection) Act of 1986.

The rules regulate noise levels in industrial (75 db), commercial (65 db), and residential zones (55 db). They also establish zones of silence within a radius of 100 m of schools, courts, hospitals, etc.

The rules specify that no permission could be granted by any authority for use of a public address system in the open after 10.00 p.m. and before 6.00 a.m. Permission may be given for the use of loudspeakers during day time, but the sound levels must be within the limits prescribed in the rules. The rules also fix different noise levels for firecrackers and industrial activities.

Control. Following are the ways to control and reduce the noise menace.

At Source Control. This can be done by (i) designing and fabricating silencing devices in air-craft engines, automobiles industrial machines and home appliances and (ii) by segregating the noisy machines.

There could be developed gadgets to control noise at source.

Transmission Control. This can be achieved by covering the room walls with sound absorbers as acoustic tiles and construction of enclosures around industrial machinery.

To Protect Exposed Person. The workers exposed to noise can be provided with wearing devices as ear plugs and ear muffs.

To Create Vegetation Cover. Plants absorb and dissipate sound energy and thus act as buffer zone. Trees should be planted along high ways, streets and other places. Ashok, Neem, Tamarind etc., are good for this purpose.

Noise Pollution Through Law. Silence zones must be created near schools, hospitals and indiscriminate use of loudspeakers at public places may be done by laws. Adequate restrictions must be put on unnecessary use of horns and vehicles plying without silencers. There are already laws in some countries as U.K. and U.S.A. In India, we have Motor Vehicles Act which provides restriction on trucks using double sirens while passing through some localities. But this is not enough. In Delhi passing through some localities. But this is not enough. In Delhi and Mumbai, there are flights round-the-clock at airport. Delhi is closely following Mumbai in noise pollution and if adequate steps are not taken to reduce sound level, more than 50% of Delhi will be affected by 2000. Restriction may be put on air craft flight at mid-night. In Delhi, areas affected most by vehicular noise pollution are, Daryaganj, Chandni Chowk, Karol Bagh, Subzi Mandi, Connaught Place and Shahdara where noise levels are 90 dB.

There is Indian Penal Code that has some provisions to which resort can be made on the ground of nuisance. These are Sections 268 and 290. Fortunately, noise has now been included under Air Pollution in the Air Pollution Control Act.

Education. Public must be made aware and educated about noise nuisance through adequate news media, lectures and other programmes. The movement against noise pollution is very weak in India. The main reason being that most of us do not consider noise as a pollution but as a part of routine life.

11
Environmental Pollution-II

Water Pollution

Pollution of water bodies has adversely affected the growth of aquatic fauna and flora. Water is polluted by four kinds of substances : traditional organic waste, waste generated from industrial process, chemical agets of fertilizers and pesticides used for crop protection and silt from degraded catchments.

What is Water Pollution? Water pollution simply means contamination of water due to any external material, or in other words introduction of something to natural water which makes it unsuitable for human consumption.

- **According to WHO,** "Water pollution means, due to natural or any other sources, the entrance of those elements in water which pollute it, make it harmful for life, make it more salty, decrease the quantity of O_2, destroy its taste and spread communicable diseases."
- **In the words of P. Viver,** "Pollution is that state in which natural or man-made factors change the quality of water in a way that it becomes unfit and dangerous for food, health of human beings and other living beings, fishing or recreation."
- **According to National Pollution Control Board (NPCB),** "Water pollution means the changes in the physical, chemical or biological virtue of water which occur due to the mingling of shit or other industrial waste material or any other element. Such water is harmful for human health and it cannot be used for domestic, professional, industrial or agricultural purpose."

  To put simply, water pollution is a state in which water becomes impure, unfit for drinking and harmful for health.

Causes of Water Pollution. Water pollution is caused by several sources, which are not independent in nature but interact with one another. Generally one or two factors become prominent and may be considered the primary source of water pollution. The various causes of water pollution are :

(a) **Natural Sources.** There are certain natural elements which cause water pollution. These are gases, soil, mineral, humus material, waste

created by animals and other living organisms present in the water. During rains, one can observe the open imprint of soil on the water of rivers, tanks and other water bodies. The brown and dirty water is the result of mud mixed in the water, which becomes clear after some time.

In the same way, different types of natural, suspended and colloidal impurities are also there in the water. These elements may be organic or inorganic and may even be harmful. The minerals like sodium, potassium, magnesium, iron, etc., are also present in the water, and if their quantity is more than the permissible limit, these are harmful. Some poisonous minerals such as nickel, beryllium, cobalt, lead, mercury cadmium, etc., are very harmful and are responsible for pollution.

Table 11.1 : Fish Kill Incidences in Indian Waters due to Water Quality Deterioration

Place	Year	Pollutant
Kankaria lake, Ahmedabad	1982	Domestic waste
Nani Lake Nainital	1980-81	Domestic waste
R. Gomati, Lucknow	1983-84, 86	Distillery waste
R. Chaliyar, Alwye	1974	Pesticide
R. Tungabhadra, Harihar	1984	Rayon Polyfibre
R. Ganga, Allahabad	1981	Fertilizer effluent
R. Ganga Monghyr	1968	Oil refinery
R. Adyar	1981-82	Tannery
Rihand reservoir	1970, 78, 80	Chemical & Thermal Effluent.

Colloidal impurities are also there in the water. These elements may be organic or inorganic and may even be harmful. The minerals like sodium, potassium, magnesium, iron, etc., are also present in the water, and if their quantity is more than the permissible limit, these are harmful. Some poisonous minerals such as nickel, beryllium, cobalt, lead, mercury cadmium, etc., are very harmful and are responsible for pollution.

(b) **Humans Sources.** The rapid growth of population, urbanization, industrialization and increasing use of chemicals have resulted in water pollution and this problem is increasing day by day inspite of several measures taken. Major human sources of water pollution are :

1. **Domestic Effluents and Sewage.** Men, for their different domestic intent such as drinking, preparation of food, bathing, cooling etc., use large amount of water. About 70 to 80 per cent of the water used by the men for their daily purposes are discharged and drained out, which through municipal drains pours into a many cases, a river, tank or lake. This water is known as domestic waste water in which when other waste material such as paper, plastic, detergents, clothes and other waste materials are mixed, is known as municipal waste or sewage. The domestic waste water and sewage are

the main sources of the water pollution. This is the inevitable and unfortunate fallout of urbanization. As it decays, this organic waste depletes the oxygen from water and upsets the natural balance of the aquatic ecosystem.

Most of the sewage receives no treatment before discharge. In Delhi alone, 120 crore litres of water is consumed per day out of which 96 crore litres waste water is drained into the Yamuna river through 17 big drains.

All the 47 towns located on the bank of river Ganga drain their sewage into it. With the growth of population the quantity of waste water is also increasing in addition to the production of large quantities of sewage.

2. **Industrial Effluents.** Industrial activities generate a wide variety of waste products, which are generally discharged into water courses. Major contributors are the pulp and paper, chemicals, petro-chemicals and refining, metal-working, food processing, textile, distillery etc. The wastes, broadly categorized as heavy metals or synthetic organic compounds, reach bodies of water either through direct discharge or by leaching from waste dumps.

3. **Agricultural Effluents.** The use of various types of pesticides and insecticides in agriculture is also one of the causes of water pollution. Their presence in water is highly toxic to man and animals, because all these have a high persistence capacity, i.e., their residues remain for long periods. The farm animal wastes often pose serious problems of odour and water pollution. These wastes also contain pathogenic organism which get transmitted to humans.

Ground Water Pollution. Ground water forms about 6.2% of the total water available on planet earth and is about 30 times more than surface water (streams, lakes an estuaries). Ground water seems to be less prone to pollution as the soil mantle through which water passes helps to retain various contaminants due to its cation exchange capacity. However, there are a number of potential sources of ground water pollution. Septic tanks, industry (textile, chemical, tanneries), deep well injection, mining etc., are mainly responsible for ground water pollution, which is irreversible. Ground water pollution with arsenic, fluoride and nitrate are posing serious health hazards.

Eutrophication of Lakes. A lake or a pond that has clear water contains minimal levels of nutrients and supports small populations of aquatic organisms. Eutrophication is the enrichment of such a standing water body by nutrients such as phosphorus and nitrogen. It occurs when sewage and fertilizer run-off bring large amounts of nutrients into the water body.

In eutrophic lakes, there is increased photosynthetic activity. This results in cloudy water covered with a slimy, and smelly, mat of algae and cyanobacteria. When the excessive numbers of algae die, they are deposited on the bottom of the late and are decomposed. Since this process uses up a lot of the dissolved oxygen, some fish species die. They are replaced by other species that can tolerate lesser amounts of oxygen.

Eutrophication is undesirable, since it changes the species mix in the water body. Reducing phosphorus and nitrogen inputs is the best way of controlling eutrophication.

Arsenic Pollution. According to P.K. Sikdar and S. Banerjee, "the excessive use of pesticides, rodenticides and fertilizers is chiefly responsible for the arsenic crisis in West Bengal and Bangladesh. Here the ground water sources got contaminated when wells were dug indiscriminately during 1970s, leading to the teaching out of arsenic from rocks."

The researchers visualised that arsenic has come from the extensive of lead arsenate and copper arsenite based rhodenticides and pesticides for jute cultivation. According to them the arsenic compounds got dissolved in rainwater and then percolated into the aquifers. After reacting with iron and magnese compounds in presence of organic material, they contaminated the groundwater. In fact for the toxic chemical to leach out, the water should be acidic in nature.

Phytofiltration is the Solution to Arsenic Pollution. Recent research reveals that 'Pteris vittata', a fern plant, can easily purify water poisoned with arsenic. This particular fern species reduced the concentration to below the safety limit. The procedure, called 'phytofiltration', could provide a cheap way to remove arsenic from water supplies. The ferns would be grown directly in the water, similar to the reed-bed systems currently used to remove organic waste.

Arsenic pollution of drinking and irrigation water has emerged as a massive health threat in India and Bangladesh. Where wells drilled into aquifers have turned out to be tapping poisoned water, when the water is used to irrigate rice paddies, arsenic also accumulates in the crops. According to one estimate, 3000 people may be dying in Bangladesh each year because of arsenic contamination.

Unlike most other arsenic-removal strategies, phytofiltration does not produce any arsenic-rich chemical sludge, which is hard to dispose. Instead, squeezing the sap from the plants in presses removes about three-quarters of the arsenic, which can then be extracted for industrial uses.

Effects of Water Pollution. Following are some important effects of various types of water pollutants :

(1) **Effects on Human Beings.** Water is the basis of human life and of life in general. Life cannot be even imagined without it. We have no substitute of it. Every day an individual uses 135 litre water on the average. Polluted water causes in many diseases to human beings. The 1987 World Health Organisation (WHO) presented a report on the effects of polluted water with some of the following points :

(1) Polluted water causes death of at least 25,000 persons every year in the world.

(2) 30% of the total population of the world or almost 20 millions of the people are unable to get pure water.

(3) In developing countries, the 80% of child death is due to the diseases caused by polluted water.

(4) Almost 10 million people of the world are suffering from diseases like cholera, dysentery and other harmful diseases caused by polluted water.

(5) The harmful effects of polluted water are increasing by 10% (average) every 5 years.

This report truly highlights the dangerous effects of water pollution. The main diseases caused by polluted water are as follows :

(a) Cholera and typhoid are water-borne diseases.

(b) Skin and eye diseases also occur due to the contact with polluted water.

(c) Hepatitis, jaundice, polio, diarrhoea, hernia etc. are due to polluted water containing types of virus and microorganisms.

(d) Water accumulated in a place becomes dirty and it produces mosquitoes, flies, worms etc. which are a cause of diseases like malaria, dengue, yellow-fever and fileria etc.

(e) Chemical contaminated water dissolves lead, fluorides and mercury. By drinking this water the haemoglobin level falls in the body and body cannot get sufficient oxygen. It produces diseases related to digestive system, excretive system, lungs and kidney diseases. Likewise it weakens the bones and teeth and results in various diseases.

(f) Polluted water causes many blood diseases.

So it is quite clear that polluted water and human health cannot go together. Therefore, it is our responsibility to control this situation; otherwise, our own existence threatened.

(2) **Effects on Other Animals.** As the polluted water is dangerous for human beings, so is it for other creatures. It is more dangerous for other creatures because they are not conscious beings. Many experiments are done. Sometimes, we do not understand and know the reason of sickness. As result some living beings and species of creatures starts disappearing. For instance, from the regions of Haryana, kites and vultures have become extinct while there is a decrease in the population of sparrows and crows. Same is the case of wild animals.

(3) **Effects on Plants and Agriculture.** Besides human beings and other animals water pollution affects adversely plants and agriculture also. Polluted water hinders the food process in the roots of plants, hot water spoils the roots. Likewise dirty water produces many plant diseases. If the food process in plants is not proper then the photosynthesis process also suffers. In the lack of proper food, leaves get dry, withered and their branches become weak. Sometimes due to excess of water in the roots of plants, moss gathers there and it hinders the growth of plants. The polluted water by assimilating in the soil, weakens its fertility power. As a result instead of the progress in the agriculture, it is degrading day by day. Moreover, the

grain, fruits and vegetables produces in such environment are also harmful for human health.

(4) **Ecological Imbalance/Crisis.** Polluted water creates every kind of hazards to ecological system. By drinking polluted water, many animals die as a result their food chain suffers. So biodiversity also falls in danger. Polluted water also creates problems for the inter-dependence of animals, plants and human beings. The water pollution on the earth is not a danger for a particular field or area but causes universal problems.

Measuring Water Quality. Here are three ways in which water quality can be measured :

- **Biological Oxygen Demand (BOD).** This parameter measures the degree of water pollution from oxygen-demanding wastes and plant nutrients. BOD is the amount of dissolved oxygen needed by the decomposers to break down the organic material present in a certain volume of water, when it is kept in darkness over a five-day incubation period at 20°C.
  BOD is measured in parts per million (ppm). A BOD level of 1-2 ppm is considered very good. It indicates that there is not much organic waste present in the water supply. A water supply with a BOD level of 3-5 ppm is considered moderately clean. Any water with a BOD level of 6-9 ppm is considered somewhat polluted, with the presence of organic waste and the bacteria that decompose this waste. At BOD levels of 10 ppm or more, the water supply is considered very polluted, containing large quantities of organic waste.
- **Presence of Disease-Causing Organisms.** The number of colonies of coliform bacteria present in a 100 ml sample of water is another measure of water quality. There should be no caliform colonies in drinking water, while water in a swimming pool could have up to 200 colonies per 100 ml.
- **Chemical Analysis.** The presence of chemicals like pesticides can be measured by analysis. This constitutes another measure of water quality.

Control of Water Pollution. Biodegradable pollutants alone are not responsible for water pollution, though these indicate level of pollution (through BOD values). Besides these, a substantial pollution load is contributed by nondegradable or slow degrading pollutants, such as heavy metals, mineral oils, biocides, plastic materials etc., that are dumped into water. For biodegradable pollutants, pollution may be controlled at source by their treatment for reuse and recycling. The nondegradable toxic substances can be removed from water by suitable methods. In addition to these methods, some standards, conditions and requirements are to be legally enforced by the government through Acts.

The various ways/techniques suggested for control of water pollution are as follows :

(a) **Stabilisation of the Ecosystem.** This is the most scientific way to control water pollution. The basic principles involved are the reduction in waste input (thus control at source), harvesting and removal of biomass, trapping of nutrients, fish management and aeration. Various methods may be used (biological as well as physical) to restore species diversity and ecological balance in the water body to prevent pollution.

(b) **Reutilisation and Recycling of Waste.** Various kinds of wastes which include industrial effluents (as paper pulp or other industrial chemicals), sewage/sullage of municipal and other systems and thermal pollutants (waste water etc.) may be recycled to beneficial use. For instance, urban waste (sewage/syllage) may be recycled to generate cheaper fuel gas and electricity. The NEERI, Nagpur could develop technology for management of radioactive wastes and chemical wastes of atomic power plants, reclamation of waste water and to supply cheap piped gas and generated electricity by recycle of urban waste. In Okhla, New Delhi, one large treatment plant for sewage recycle is already in operation. NEERI is also involved in development of suitable technology for waste water reclamation through aqua-culture, utilisation of domestic and industrial waste water in agriculture and detoxification of phenol, and cyanides in waste by biological means. One distillery in Gujarat is able to treat 4,50,000 litres of water daily and generating energy equal to that produced by 10 ton of coal.

(c) **Removal of Pollutants.** Various pollutants (radioactive, chemical, biological) present in water body can be removed by appropriate methods such as absorption, electrodialysis, ionex change, reverse-osmosis etc. Reverseosmosis is based on the removal of salts and other substances by forcing the water through a semipermeable membrane under a pressure exceeding the osmotic pressure. Due to this, flow occurs in reverse direction. For this, we use a power membrane, that attracts the solvent and repulses the solute. Reverseosmosis is commonly used to desalinate the brackish water and can also be used for purifying water from sewage.

Council of Scientific and Industrial Research (CSIR), New Delhi could devise the following techniques for successful removal of pollutants from water :

(i) **Ammonia.** This could be removed from waste water of industry by ion exchange technique. There is developed a weak acidic cation exchange, which removes NH_x in the form of ammonium sulphate. This can be used for fertilisers.

(ii) **Mercury.** This could be removed from chlor-alkali effluent plans by using mercury-selective ion exchange resin.

(iii) **Phenolics.** These could be removed from waste waters of pulp and paper mills, carbonisation plans, petroleum refineries, tanneries and resin plants by use of polymeric absorbents.

(iv) **Decolonisation of Water.** The waste water from printing and sari dying industries could be decolonised by an electrolyte decomposition technique.

(v) **Sodium Salts.** These could be removed by reverse osmosis method. Sodium sulphate from a rayon mill effluent could be easily removed. The water for reuse could also be recovered by this method. From cheese why, we may recover 80% of protein and 80% of lactose by this method.

Very recently, researchers of some American laboratories (reported by the Wall Street Journal) have claimed to use solar power for cleaning up polluted waters cheaply. Experiments showed that a combination of sunlight and a catalyst such as titaniumdioxide can break down chemical toxicants of water. Such photocatalytic reactions can destroy pesticides, explosives, solvents, PCBs, dioxins and cyanides.

Picture of Indian Rivers. Many large rivers are closely associated with the Indian culture and heritage. Water pollution in India has now arrived at a crisis point. Almost every river system in India is now polluted to a considerable extent. As assessed, nearly 70 per cent of water in India is polluted. The Ganga, the most sacred and important river of India, is regarded as the cradle of Indian civilization. The Ganga considered as a self-purifying and fast-flowing river, also has significantly high organic pollution load. At Kanpur, 45 tanneries and 10 textile mills are the major sources of liquid wastes discharged into the river Ganga. The wastes contain heavy organic load. It is estimated that 1,400 million litres of sewage and 200 million litres of industrial effluents are being discharged everyday into the river Ganga.

The river Hoogly at Kolkata receives wastes from various types of factories dealing with pulp and paper distillery, tannery, textile, heavy chemicals paints and varnishes, shell, matches, pigment insecticides and fungicides. River Godavari at Rajahmundry (Andhra Pradesh) is polluted by the effluent of Andhra paper mill. They river Kalu in Mumbai receives highly acidic and untreated wastes from Amar Dye and chemical company.

Industries generate a significant quantity of waste water which ultimately finds is way to a stream/river. Industrial discharges containing toxic and hazardous substance contribute to the severe kind of pollution in the aquatic systems. Industrial Development is largely because of the production of chemicals resulting in the generation of toxic and hazardous substances which have been continuously on the increase during the last three decades. Industrial effluents, though comparatively less in volume but cause serious menace to aquatic environment and the biotic communities including fish and ultimately affect human through food chain.

The Central Pollution Control Board's data shows that the Ganges, one of the major rivers in India with the stretch of 1760 km., is severely polluted in terms of Biochemical Oxygen Demand (BOD). It is followed by Tapti,

Narmada, Indus, Mahi and Sabarmati. The Board's ten years of data indicates that 14 per cent of the entire reverine length in the country (6,086 km) is severely polluted with BOD level of more than 6 mg a litre. About 19 per cent of the rivers are moderately polluted with BOD level between 3-6, while 67 per cent of rivers (30,242 km) are relatively clean.

Maharashtra has the longest riverine length that is the most polluted in terms of BOD load in the river waters. It is followed by Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Orissa and Gujarat who have more than 6 BOD levels. The river Yamuna maintains a reasonably good quality of length from Yamunotri in the Himalayas to Wazirabad in Delhi (about 375 km). However, the discharge of waste water through 15 drains between Wazirabad barrage and Okhla barrage renders the river almost a sewage drain with BOD values ranging from 14 to 28 mg/1 and high coliform content without any dissolved oxygen.

In India about 1,35,000 polluting industries generate about 13,000 million litre a day of waste water of which only 60 per cent generated from large and medium industries is treated. Distilleries generated the largest amount of pollutant load followed by the textile industries, engineering and pulp & paper industries.

On the other hand, domestic sewage is the most important pollution source contributing pathogens, the main source of water born diseases along with depletion of oxygen in water bodies. A large part of the domestic sewage is not even collected. This result in stagnation of sewage within the city, which becomes the breeding ground for mosquitoes and contaminate the groundwater. In the domestic area, 299 class I cities and 345 class II towns generate about 23,000 m/d of waste water, of which only 6,000 m/d is treated.

Gomti River. Over the years, Gomti, one of the major sources of water for Lucknow, has become the most polluted river in Uttar Pradesh. Monitoring by the state pollution control board reveals the water is unfit for consumption. The fish had died as dissolved oxygen level of the water had dipped too low. All this have virtually converted this sacred river into the river of sin.

For some people, it is industrial effluents discharged by paper mills, sugar factories and distilleries in the upstream areas of Sitapur and Lakhimpur-Kheri that spelt doom for the aquatic life. The extent of pollution is such that the river's biodiversity is being affected. Two organisms—Solariella (molluscs) and Hemicypris arorai—that survive in polluted water were found in Gomti river. The presence of hyacinth is another factor to bring down the dissolved oxygen level.

The Central Ganga Authority was established in 1985 to lay down policies for projects to be taken up under the Ganga Action Plan (GAP). In July

(3) **Effects on Ecology.** Ecology can be said to be in control when hydro-land and atmosphere, all these spheres, are in mutual equilibrium. Marine pollution destroys this balance; as a result the food chain of nature breaks down. When the sea water becomes oily, it can absorb more sub heat and result the temperature of surface water increases, thus enhancing the possibility of melting sea-ice and creating the situation of uplifting sea level. Polluted acidified water falling on earth in the form of rain drops or acid rain also contributes to marine pollution. Its bad effects we have already stated. The increase and decrease in sea temperature changes the cycle of various monsoon winds. Due to this change both climate and whether change.

International Initiatives to Control Marine Pollution. Since 1972, a number of international agreements and programmes have focused on controlling marine and coastal pollution :

- **The 1972 London Dumping Convention and its 1996 Protocol.** The purpose of the London Convention is to control all sources of marine pollution and prevent pollution of the sea through regulation of dumping of waste materials into the sea. The 1996 Protocol, which is set to replace the convention, is more restrictive and adopts the 'precautionary principle'. That is, it prohibits all dumping unless explicitly permitted. Further, it prohibits the incineration of wastes at sea and the export of wastes for the purpose of dumping or incineration at sea.
- **The 1989 Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal.** Until 1999, the convention was principally devoted the setting up a framework for controlling the movement of hazardous wastes across international frontiers. It has now expanded its scope to include the active promotion and use of cleaner technologies and production methods and the prevention and monitoring of illegal traffic.
- **The Convention on the Prevention of Pollution from Ships (MARPOL).** It is the primary international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.
- **The 1995 Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA-LBA).** This programme was adopted in Washington D.C., in the US, by over 100 countries, including those of the European Union (EU). The aim is to control contaminants like sewage, persistent organic pollutants, radioactive substances, heavy metals, oils, nutrients, sediments, and litter that enter the ocean from the land.

- **The Regional Seas Programme of the United Nations Environment Programme (UNEP).** This programme has fostered regional cooperation on the marine and coastal environment. It has stimulated the creation of various Action Plans for sound environmental management in each region. India, Bangladesh, the Maldives, Pakistan and Sri Lanka are partners in the South Asian Seas Programme.

  India is a party to all the above mentioned agreements and programmes.

Thermal Pollution

Most of the thermal and electric power plants also discharge considerable quantities of hot effluents. This has resulted in thermal pollution of our water courses. Thermal pollution is undesirable for several reasons. Warm water does not have the same oxygen holding capacity as cold water. Therefore, fishes like black bags, trout etc., which require a minimal oxygen concentration of about 4 ppm, would either have to emigrate from the polluted area or die in large numbers.

Causes of Thermal Pollution. Many factors are responsible for this pollution. Their description is as follows :

(1) **Thermal Power Centre.** Today, man has created new sources of energy and thermal power centre is one of that. 70% of the total coal found in the world is used for this purpose. In the world there are 5,000 and in India 16, centres where electricity is produced. In India alone approximately 22,000 metric tonne coal is used everyday in these centres. As a result 5,20,000 pound sulphur dioxide 4,50,000 pound nitrogen oxide, 11,300 pound carbon monoxide and 5,000 pound hydrocarbon; these pollutants and poisonous gases spread in the atmosphere. One thermal power house can increase the temperature of the atmosphere in an area of 10 km. Likewise sulphur dioxide and coal ash also blow with the wind and fall on the land. So it covers not only the crust of earth but due to some heat, these elements become very hot. Moreover, discharge of heated water from these power houses increases the temperature of that area and pollutes it.

(2) **Thermal Pollution by Industrial Units.** Like thermal power houses, other industrial units also promotes this pollution because they too release gases, smoke, ash, filth, dirty and hot water. Constant use of machines and other activities also produce much heat and this heat increase in the nearby temperature.

- The released smoke, ash, vapour, and fire through chimney, result in hot atmosphere. During summer, this situation becomes more dangerous and critical.

- The water released from industrial units is very hot. If thrown in open, it scorches the upper layers of the earth and soil rendering them useless. This water by flowing to pond, lake or river, makes their water hot. So, their animals and other creatures suffer and sometimes dying. Likewise this hot water affects sea water also and as a result, the temperature of sea water increases.

(3) **Vehicle Created Thermal Energy/Heat.** There is a constant increase in the vehicles in every part of the world from the very start of 20th century. The fuel used in such vehicles not only produce air pollution in the form of smoke and gases, but the contact of its tyres also produces heat. The air polluted by smoke and poisonous gases, do not allow the heat to variate out; as a result the temperature of that area increases. It is often seen that where there is more transportation, there due to heat we feel exhausted and smothered with temperature is also higher than other places.

(4) **Mining Work.** Various metal and things for daily use are found through mining process. Initially this mining process affected the temperature of that area. But now various kinds of chemical reactions are used. So there is spread of dust in the nearby area and the particles of that chemical also spread over the layer of earth and in the atmosphere and all these factors increase temperature. In modern time such method is adopted by almost every country of the world. Even in small areas such methods are used on a large scale. For example even in Sohna (Gurgaon) in Haryana, Khanak (Tosham) and for stone cutting in Shivalik regions, such methods are used.

(5) **Other Human Activities.** Besides above reasons, there are some human activities which are responsible for Thermal Pollution. Such as :

- In every country of the world, army training and wars practicles are done. On one hand they cause destruction and on the other hand it spoils flora and funna. Moreover, due to their trespassing and activities heat is produced.
- Air Conditioner uses oxygen and releases carbon dioxide, monoxide and chlorofluoro carbons. It increases temperature. We can feel ourselves by standing near such equipments or machines that these internal cooling equipments, produce so much heat.
- Due to development in scientific fields, nuclear power can be used in various forms. All activities of this increase the temperature of all land, water and air.

(6) **Natural Factors.** Nature plays a major role in thermal pollution. Sun itself is a large circle of heat. The sun rays fall straight, the temperature of that place is quite high. Their temperature may get so high that it becomes unbearable. The countries of the world whose climate is warm, the situation becomes more critical. In some parts of the world, temperature rises to 60°C while human activities get affected after 40°C temperature. This affects all places, water, land, agriculture, residential, industrial and commercial.

- Sometimes due to natural reasons forests catch fire which is called forest fire. To control such fire is almost impossible and unsuccessful. Once the fire in the part of Masopotamia was controlled in 6 years, the fire in Austria, which happened in October, 2002 has not been controlled till today. So the temperature of that area is increasing continuously.
- There is continuous thinning of ozone layer allowing more sun rays to reach earth's surface. This leads to raise in temperature of the earth.
- Due to volcanic eruptions, lava and other hot gases are released which increase the temperature. Sometimes its affect reach hundreds of km.

Effects of Thermal Pollution. Effects of thermal pollution are very destructive. We can study its effects in the following points :

(1) The pollution results in high temperature. It destroys ecosystem's equilibrium and this imbalances all kinds of equilibrium.

(2) Increase in temperature create drought problem and animals, human beings and vegetables suffer from various diseases, even causing death also.

(3) Increase in the temperature of the atmosphere results in the depletion of ozone layer; the weaker ozone layer will cause more ultraviolet rays reaching the earth as a result heat will increase and the diseases like cancer will spread more and more.

(4) The possibility of melting ice increases due to high temperature in marine area. Moreover, there is a danger of submerging the land in the sea. Various researches claim the fact that sea level is upgrading to 2 to 3 cm every year. If the process goes on, then after 100 years 1/4 of the total world will be submerged in the sea.

(5) In the high temperature both flora and fauna may not survive. In some parts due to improper harvest cycle and lack of plans and vegetables life will be in danger.

(6) High temperature will dry up the water sources or it will speed up vaporization process. Along with this whole world will be affected by acid rain and its consequences will be disastrous.

(7) Thermal Power Houses not only enhance the temperature but also produce noise pollution. Thus increases our problems.

Control of Thermal Pollution. The following methods can be employed for control of thermal pollution :

(i) **Cooling Ponds.** Water from condensers is stored in ponds where natural evaporation cools the water which can then be recirculated or discharged in nearby water body.

(ii) **Spray Ponds.** The water from condensers is received in spray ponds. Here the water is sprayed through nozzles where fine droplets are formed. Heat from these fine droplets is dissipated to the atmosphere

(iii) **Cooling Towers.** These are :

(a) **Wet Cooling Tower.** Hot water is sprayed over baffles. Cool air entering from sides takes away the heat and cools the water. This cool water can be recycled or discharged. Large amount of water is lost through evaporation and in the vicinity of wet cooling tower extensive fog is formed which is not good for environment and causes damage to vegetation.

(b) **Dry Cooling Tower.** The heated water flows in a system of pipes. Air is passed over these hot pipes with fans. There is no water loss in this method but installation and operation cost of dry cooling tower is many times higher than wet cooling tower.

Soil Pollution

Soil pollution refers to any physical or chemical change in soil conditions that may adversely affect the growth of plants and other organisms living in or on that soil.

Soil pollution and water pollution are closely connected. Acid rain and excessive use of chemical fertilizers result in the soil's inability to hold nutrients. This in turn allows toxic pesticides or atmospheric fallout to rapidly seep into the groundwater or to run off into rivers and coastal wastes. Some of the persistent pollutants remain in the soil and degrade it.

Most soil pollutants are agricultural chemicals, primarily fertilizers and pesticides. It is now known that these chemicals attach themselves to soil particles and persist for long in the soil, continuously releasing contaminants into the surface water, groundwater, and topsoil. Dumping of waste (including garbage, untreated sewage, industrial effluents, nuclear waste, and mining waste) pollutes the soil when dangerous substances from the dumps leak into it.

Causes of Soil Pollution. Like other types of pollution, this pollution is also not due to one reason but various human activities and natural incidences work in this direction. These have been described in the following ways :

(1) **Physical Causes.** Physical causes means those factors which bring changes in the quality of soil causing degradation. Both natural and human factors play their role in it. The deforestation on very large scale, changes the natural processes like rain, climate, temperature and natural power of soil. Due to the lack of trees or forests, due to heavy rain, the surface soil of earth mixes in sea by flowing with water or it flows away in distant regions. In fact only the crust of earth or the upper layer of earth has fertility power. It takes centuries for its reformation. Such problems arises mostly in developing countries.

(2) **Domestic Wastes.** We use many goods in our daily life. After using these goods we throw in open their packing, wrappers or other waste material by contacting earth's upper layer changes its composition, fertility and other qualities. These things include home garbage, kitchen garbage,

foul paper, soft board and chinabone wares, metallic cans, stove's ash, cloth rags, wood's worn out furniture, the broken tools of motors, vegetables seeds and peels, wasted food and other things in marriages and other social ceremonies. All these things produce soil and land polluted. In most of the countries, there is no proper system for the release of waste material. According to one survey, in America, every individual throws out 50 kilogram of domestic garbage. Likewise, in other countries of the world, the garbage is thrown out on a large scale.

(3) **Urban Wastes.** Urban waste is somewhat similar to domestic waste. In urban area, garbage, newspapers, market waste and polythene etc. are thrown in open in great amount and then this by mixing in drainage water spreads on the large part of the earth. Out of these, polythene cannot be decomposed. So the link between various layers of earth breaks down due to this and the lack of air or gas and therefore the fertility of earth/soil weakens day by day.

There is no proper system to destroy this garbage or to reuse it properly. Developed countries have evolved some kind of recycling of garbage, but now they too are facing problems in dumping massive amounts of waste and garbage, so much so that they are having to export them! In India everyday 2 lac/tonne garbage is released just from 4 metropolitan cities. Besides, about 60 cities, with more than 3 lakh population, each are producing the huge amounts of garbage.

(4) **Chemical Sources.** Use of chemicals is increasing rapidly. Maximum use of chemicals is to be seen in agriculture in order to increase production and to control pests. All these chemicals are toxic. They accumulate in the soil. Constant use of these chemicals changes physical composition of the soil. The toxic elements reach the grain, causing harm to human health.

To solve the food problem which is caused due to over population, the use of chemicals is essential but the excessive use of chemicals is causing a threat to life. In other words, the life-giving soil is gradually becoming life-taking soil. On the other hand, the fertility power is weakening. In India, the places where green revolution has been occurred, soil has become toxic and the day is not very far when even after using every kind of fertilizers, crop production cannot be increased. So the excessive use of chemicals is a major factors of soil pollution.

(5) **Industrial Wastes.** Industrial factors are not only responsible for water and air pollution but they also play an important role in soil pollution. Textile mills, thermal power plans, fertilizer industries, petrol and oil industries, rubber and plastic industries are such industries which generate a large quantities of waste material. These waste materials are unfit for habitation and agriculture. Various kinds of carbon, toxic acid, minerals and oxides, calcium sulphate and various acids are dumped in the land in increasing amounts.

Effects of Soil Pollution. Sewage and industrial effluents which pollute the soil ultimately affect human health. Various types of chemicals like acids, alkalis, pesticides, insecticides, weedicides, fungicides, heavy metals etc., in the industrial discharges affect soil fertility by causing changes in physical, chemical and biological properties.

Some of the persistent toxic chemicals inhibit the non-target organisms, soil flora and fauna and reduce soil productivity. These chemicals accumulate in food chain and ultimately affect human health. Indiscriminate use of pesticides specially is a matter of concern.

Sewage sludge has many types of pathogenic bacteria, viruses and intestinal worms which may cause various types of diseases. Decomposing organic matter in soil also produces toxic vapours.

Radioactive fallout on vegetation is the source of radio-isotopes which enter the food chain in the grazing animals. Some of these radio isotopes replace essential elements in the body and cause abnormalities e.g., strontium-90 instead of calcium gets deposited in the bones and tissues. The bones become brittle and prone to fracture.

Radiosotopes which attach with the clay become a source of radiations in the environment.

Nitrogen and phosphorus from the fertilizers in soil reach nearby water bodies with agricultural run-off and cause eutrophication. Chemicals or their degradation products from soil may percolate and contaminate ground-water resources.

Controlling Measures of Soil Pollution. Following measures can be applied :

(i) Effluents should be properly treated before discharging them on the soil.
(ii) Solid wastes should be properly collected and disposed off by appropriate method.
(iii) From the wastes, recovery of useful products should be done.
(iv) Biodegradable organic waste should be used for generation of biogas.
(v) Cattle dung should be used for methane generation. Night-soil (human faeces) can also be used in the biogas plant to produce inflammable methane gas.
(vi) Microbial degradation of biodegradable substances is also one of the scientific approaches for reducing soil pollution.

Nuclear Hazards

Though radioactivity is a physical type of pollution, it is appropriate to think about radioactivity as independent by reason of the appearance of man-made radioactive materials in nature and in the economy as an offshoot

of industrialisation and the nature of pollution and the consequence are notably different from other types of pollution.

Environmental radiation may be divide into two types : naturally occurring radiation and man made radiation. Naturally occurring radiation are :

- Cosmic radiations from the outer space reading the earth's surface;
- Terrestrial radiation from natural radio-isotopes present in the earth's court.

Cosmic-ray bombardment of the atmosphere continuously produces a few radioactive materials of short half-life. Among them the important nuclides are carbon-14 and hydrogen-3 (tritium). Carbon-14 is formed by the action of cosmic-ray neutrons on atmospheric nitrogen, and hydrogen-3 by the splitting of atoms when they are struck by high-energy cosmic ray particles. Both these are oxidised to carbon dioxide and water as they enter into the biosphere and hydrosphere.

The primary sources of natural radiations are the ores of uranium and thorium which contain a wide variety of radioactive nuclides. They differ in chemical nature, half-life and type and energy of radiations.

The other radionuclides found in nature are potassium-40 and rubidium-87. Potassium-40 constitutes about 0.012 per cent of natural potassium and rubidium-87 forms about 28 per cent of natural rubidium. Potassium-40 is responsible for about 20 to 76 per cent of the natural radioactivity of soil. Since potassium-40 contributes radioactivity to all potassium-containing systems, for each miligram of potassium there will be two radioactive disintegrations per minute. Therefore, an environmental part will be radioactive in proportion to its potassium content including an additional contribution from biological materials. Due to its less abundance in the earth's crust rubidium-87 is considered relatively unimportant.

There are numerous possibilities for water to get contaminated with the above mentioned radioactive nuclides when the water runs through soils and rocks. Radon-222 and its immediate daughters, radium-A through radium-C, are the common nuclides found in radioactive springs.

Table 11.3 : Important Health Hazards of Noise

Intensity (dB)	Health Hazards
80	Annoyance
90	Hearing damage
110	Stimulation of reception in skin
120	Pain threshold
130-135	Nausea, vomiting, dizziness
140	Pain in ear
150	Burning of skin
160	Rupture of tymphanic membrane
180	Major permanent damage in short time

Table 11.4 : Zone-wise Permissible Ambient Noise Levels

Zones	Day (6-21 hr.)	Night (21-6 hr.)
Industry	75 dB	70 dB
Commercial	65 dB	55 dB
Residential	55 dB	45 dB
Silent zone	50 dB	40 dB

Mad-Made Radiation. Man-made radiation originate from the activities of man involving the use of radioactive materials. They are used for the production of nuclear weapons, nuclear fuel and for the production of electric power. One of the most harmful uses of radioactive material is in the nuclear weapons, especially in atom bombs. The world has already seen the nature of destruction as well as impact of radioactivity on man and environment during the second world war when atom bombs were dropped over Hiroshima and Nagasaki. During the last fifty years, a number of nuclear weapons have been tested, resulting in the increase in level of radiation in the environment.

Nuclear fuels used in operation of reactors also contribute to pollution in nuclear reactors, the heat liberated during fission and activation process is converted into electricity. During this process two types of wastes are formed (i) the fission products remaining in both the primary and secondary fuels, and (ii) extraneous activation products in the coolant. The disposal of radioactive or nuclear wastes is a great problem and a cause of grave environmental pollution.

Increasing Background Radiation. Two major activities which are behind the increase in background radiation are ore processing, operation of reactors, Nuclear Weapon Testing, Use of Radio Tracer, Mobile phones etc.

(a) **Ore Processing.** The primary natural materials used in nuclear processes are uranium and thorium. Uranium-238 and thorium-232 are used as artificial fission materials. The only element in which natural fission occurs is uranium-235. Mining of these materials which are the first steps in nuclear technology and their processing contributes to background radiation.

(b) **Operation of Reactors.** The processed nuclear fuel is introduced into the reactor to carry out fission activation and thermal processes. A partial transformation of primary fuel into secondary occurs in the fission process with the simultaneous appearance of fission products. Two types of wastes are found in these processes : fission products, remaining in both the primary and secondary fuels and extraneous activation products in the coolant. Thus, the fuel elements and coolants constitute the sources of radioactive pollution. Fission is said to release radioactive gases, such as xenon and crypton, into the atmosphere.

(c) **Nuclear Weapon Testing.** Nuclear explosion tests threaten the world since the natural background radiation of the environment is increased. The tests including fission and fusion processes employ uranium-235 and plutonium-239 as fission materials and hydrogen or lithium as fusion materials. Explosion, a non-moderate chain reaction, in due course results in the appearance of a very large neutron flux, which makes the surrounding matters radioactive.

Due to the force of explosion and accompanying high temperature, the radioactive products are transformed into gases and ejected high into the atmosphere as fine particles, resulting in atmospheric pollution. This primary pollution is followed by a secondary pollution through radioactive fallout. These particles are subsequently carried out or otherwise settle down on soil and water due to rains and get dispersed over the surface. Thus radioactive pollution occurs not only at the test sites but also in the remote corners.

As radioactivity in the soil is available to plants, it enters the food-chain, resulting in the possibility of eventual ingestion by humans. When a stream receives radioactivity from fission products, through rains, the aquatic flora and fauna absorb and accumulate radioactivity. Thus, once again, aquatic flora and fauna used as food by man could contain dangerous amounts of radiostopes.

(d) **Radio Tracers.** Radio tracers are extensively used in medicine, industry, agriculture and biology to determine the course of chemical and biochemical reactions. Among them, C14 and 1125 are the most important tracers. They are also used to determine the rate and direction of ground water of low.

When waste water containing radio tracers are discharged into sewers and rivers, some isotopes such as radioactive idodine and radioactive phosphorus accumulate in biological slimes and sludge.

Effects. Different forms of radiation have different effects. Visible light and infrared heat rays and certain kinds of radiation are generally beneficial. Some of the other forms of radiation, for example X-rays, are more energetic and are therefore, biologically injurious because of their destructive action on cells and tissues. Because the highly energetic forms of radiation tend to split substances, including living matter, into ions, they are called ionizing radiation. Ultra-violet radiation is highly injurious to the tissues of some organisms. It is well recognized that sub-burn is caused largely by the ultra violet content of the sun's radiation and that excessive exposure can cause serious injury to both the superficial and deep layers of the skin.

The ill-effects of radioactive pollution are numerous. Radiation can cause cancers, abnormal births, skin diseases, mutations etc. Chronic exposure to radiations leads to leukaemia in an individual and even affects an urban child in the womb.

The main characteristics of all radio-nuclides are decay and subsequent emission of radiation. Each radio-nuclide has a characteristic decay constant, known as half-life. 'Half-life' may be defined as the time needed for half the atoms to decay. This period may range from a few seconds to years. Thus a radio-nuclide with a short half-life vanishes quickly and a radio-nuclide with a long half-life remains for years, emitting radiation. These emissions are of three types :

- Alpha rays consisting of positively charged particles;
- Beta rays having negatively charged particles;
- Gamma rays identical to X-ray, without any charge.

Alpha rays have less penetrating power, beta rays have more penetrating power than X-rays and gamma rays have the highest penetrating power. Energy of these radiations varies from a low value to several million electron-volts. Thus the effects of every radioactive contaminant on living organisms depend primarily on the type of radiations and their penetrating power.

The ill-effects due to radioactive pollution are numerous. Radiations can cause cancers, abnormal births and mutations. Though these effects are common in plants and animals, such abnormalities are eliminated by evolutionary processes of natural selection, i.e., survival of the fittest. Since natural selection does not operate in man, radioactive pollution can cause immense human misery. There is no threshold or safe dose for radiation effects. Even the smallest increase in radiation above the natural background radiation is reported to carry risks. Chronic exposure to radiation leads to leukaemia in an individual and even affects an unborn child in the womb. Genetic damage to future generations is possible. Hence, radioactive pollution is primarily a health issue for man when compared with the other environmental pollutants.

Prevention and Control. In spite of certain harmful effects of radioactivity, nuclear power and other uses of radioactive elements have become an integral part of modern development. Many of the environmentally conscious countries in the world depend on nuclear power significantly for electricity generation. It is clean because its impact on the environment is minimal compared to other generating sources. To make it environmentally more safer, there is a need for monitoring and prevention measures.

Prevention and control measures are to be adopted to control radioactive pollutants. All measures should so aim that the level of radioactive pollution should not exceed the maximum permissible limit. The industrial wastes having radioactive elements only be discharged after proper treatment. The highly active wastes should not be discharged. Now, a few techniques have been developed through which these wastes can be used if treated properly. The emission of radioactive pollutants should be controlled. In

uranium mines, wet drilling be employed. Closed-cycle systems with gaseous coolants of very high purity may be mused in the case of nuclear reactors to prevent extraneous activation products. There is a need to control radiation hazard for workers and officials working in reactors or other places having danger of radioactivity. There is a need for regular monitoring and clean-up of surface, careful washing is necessary, apart from this, proper kit to protect the workers from radiation effects and property health care of workers are also necessary. What is more, personnel at power stations must be trained in radiation protection and radiation hazard control measures. The UN and other agencies of the world are in favour of total ban on nuclear weapons but very little progress has been made in this field. Let us hope that the time will soon come when our world will be free from the dangers of atom bombs and other nuclear weapons.

A rigorous monitoring system is necessary by which the nature and level of radioactive pollutants can be determined. Preventive and control measures can then be taken accordingly.

Disposal of Nuclear Waste. The safe disposal of nuclear waste has always been a major problematic task. Now the scientists have succeeded to turn radioactive isotope Iodine-129, a major waste product in the nuclear power industry, into the more friendly isotope Iodine-128 using laboratory lasers.

Iodine-129 is a major waste product from nuclear power plants and has a half-life of 15.7 million years making it difficult and dangerous to dispose of. Today it is encased in glass and buried deep in the earth. Researchers have successfully irradicated Iodine-129 with a laser beam turning it into Iodine-128 with a half-life of just 25 minutes and it can be safely handled and disposed of within an hour. The next step is to develop this technique on an industrial scale and with other radioactive isotopes. Scientists are currently working on a proposal to develop a laser system large enough to cope with the volume of Iodine-129 produced by the nuclear power industry.

The recent discovery shows that we can transmute isotopes using lasers. Now we need to scale up our methods so that we can deal with the sort of volumes likely to be produced by the nuclear power industry in the future. Using lasers is a cheap and efficient way of disposing of nuclear waste. This discovery will also provide an easy way of producing the isotopes needed to operate the PET scanners used in hospitals and in research. These isotopes are currently manufactured in huge machines called cyclotrons. Researches hope to be able to apply this technique to the production of these isotopes quickly and believe that this will be a practical reality within the next five years.

Monitoring Techniques. Unlike other pollutants, radiation doses are measured accurately so as to prepare a rigorous monitoring system, which

could be used as a model for other forms of pollution control. The monitoring techniques are :

- Sampling, and sample preparation for analysis,
- Quantitative and qualitative analysis.

The rate of decay of radioactive materials and the subsequent emission of radiations are unaltered by man, and hence cannot be converted into other non-toxic materials. The preventive measures should be double edged so as to curtail the effects of both occupational exposure and exposure of the population at large. All measures should so aim that the level of radioactive pollution does not exceed the maximum permissible doses.

Industrial wastes may be discharged into the environment only after necessary treatment so that radioactivity is at lower level. Wastes may be discharged into the sewer system or into streams. Before discharge, the low activity wastes are stored for some time so as to reduce the activity. In the case of highly radioactive wastes, they cannot be discharged.

Disposal of wastes into the sea has also been tried. In one type the wastes are sealed in concrete-filled steel drums and discharged to a depth of 1,000 fathoms or more. Since disposal into the sea is a costly process, underground disposal has also been suggested.

The next step in prevention of radioactive pollution is limitation of the emission of radioactive pollutants. This is a fruitful measure and is planned before the commencement of constructions. There are several techniques and according to the nature of the industry or process these techniques are chosen. For example, the chemical and metallurgical industries, the use of radioactive materials may be carried out under a jet of soil (or water) instead of gaseous and powder forms. In uranium mines, wet drilling may be employed in combination with underground drainage.

Dispersal methods make the pollutants in a confined place spread over a large area such that the pollution is weakened and the effects lessened. Use of high chimneys and ventilation at workplaces where radioactive contamination is high are some of the dispersion methods.

In the case of occupational exposure, individual contamination is more and more and this should be prevented by taking the following steps :

1. When working with radioactive materials where it is impossible to reduce the radiation, duration of exposure may be shortened by performing the operations rapidly or by a number of workers to complete it.
2. Radioactive operations may be carried out by remaining at a sufficient distance from the source.

Though external radiation hazard is prevented by some methods, it is very difficult to curtail the internal hazard. Ingestion or inhalation of radioactive material may be prevented by proper working habits and good housekeeping practices, like regular monitoring and clean-up of surfaces,

12
Solid Waste Management

The solid waste includes glass containers as bottles, crokeries, plastic containers, polythene and other packing materials that are used and then thrown away as garbage. These pile up at public places and cause obstruction in daily life. Besides these there are also other used things like automobile spares, machines, cycle parts etc., that are thrown as junk. The wastes from building material (during construction and demolition), sludge, dead animal skeletons, heaps of crop residues also contribute to solid waste.

Solid wastes are causing much problem in developed effluent countries as U.S.A. and European countries. There have been regular voluntary companies for cleaning the environment for solid wastes. A crusade for cleaner environment could collect the following from merely 1 mile stretch of a highway in Kansas, U.S.A.

Table 12.1

Paper cups	—	770	Shirts	—	10
Cigarette packs	—	730	Tyres	—	10
Bear cans	—	590	Bags	—	10
Oil cans	—	90	Auto bumpers	—	4
Livestock feed bags	—	50	Shoes	—	4
Paper cartons	—	30	Undershirts	—	2
Magazines	—	26	Comic books	—	2
Maps	—	20	Bed springs	—	2
Coffee cans	—	16	Miscellaneous	—	270

In India also, several million tonns of solid waste is dumped along high ways and other places in large cities as Delhi, Mumbai, Kolkata, Chennai, Ahmedabad, Jaipur etc. On an average over 2 million tons of solid state is generated in Class I cities, per year, whereas in Class II cities about 0.25 million tons/year.

According to CPCB, waste profile of some Indian Metro cities is as follows :

Table 12.2

Cities	Waste generated (tonnes per day)
Delhi	5,922
Greater Mumbai	5,320
Chennai	3,036
Kolkata	2,653
Bangalore	2,187
Ahmedabad	1,669
Biodegradable	1,302
Compostible fraction	40–62%
Recyclables	11–22%
Moisture content	21–62%

There is problem of disposal of those wastes especially in developed countries where labour is very expensive. In India, most of junk is purchased by hawkers and resold after profit. Used vehicles are creating much problem in western world. In New York, police could find as many as 40,000 abandoned cars in 1966 in the city.

Causes of Solid Wastes

Most disposable wastes are in the form of solids, liquids, or slurries. The main categories of such wastes are as follows :

- **Domestic Waste.** Sewage, wastewater contaminated by detergents, dirt, or grease, household garbage, and bulky waste including packaging material, appliances, furniture, office equipment, and used cars.
- **Industrial Waste.** Solids and effluents from factories of all types; the worst polluters are slaughterhouse, breweries, tanneries, textile mills, paper mills, steel mills, and most chemical industries; power plants discharging heated coolant water, which causes thermal pollution.
- **Waste from Oil Industry.** Oil spills, oil leaks, water used for cleaning tankers, etc.
- **E-waste.** A new form of waste from discarded computers.
- **Construction Waste.** Materials from buildings that are demolished or renovated and materials discarded after completing a building.
- **Waste from Extractive Industries.** Mining, quarrying, and dredging create solid waste (during extraction) and slurries (during processing).
- **Agricultural Waste.** Different kind of waste related to the agriculture can be seen in villages. This include dung, woots of crops, shoots, remains of animal food, chaff and husk.
- **Waste from Food Processing.** Organic solid and liquid waste from discarded food material.

- **Biomedical Waste.** Originates mainly in hospitals and clinics and includes blood, diseased organs, poisonous medicines, etc.
- **Nuclear Waste.** Radioactive waste from nuclear power plants and the manufacture of nuclear weapons.

Apart from these regular sources, waste also comes from special events :

- **Waste from Natural Disasters.** Rubble from earthquake, slag and ash from volcanoes, waste left behind by floods, cyclones and typhoons.
- **Waste from Wars and Conflicts.** Apart from dead bodies and destroyed buildings, wars leave behind exploded and live shells, landmines, etc. In some cases, deadly material used in weapons of war has effects lasting decades. Agent orange used in Vietnam and depleted uranium used in the 1991 Gulf War are examples.

Effects of Solid Wastes

It is very difficult to assess the effects of the various types of waste on the environment. We do not know the total amounts, composition, and dispersal of this waste. Nor do we have enough scientific knowledge of the long-term impact of many substances that form a part of waste. What is considered non-hazardous today may be declared dangerous tomorrow. In fact, environmentalists feel that we must follow the precautionary principle and treat every chemical as being potentially harmful proved otherwise.

Municipal solid wastes heap up on the roads due to improper disposal system. People clean their own houses and litter their immediate surroundings which affects the community including themselves. This type of dumping allows biodegradable materials to decompose under uncontrolled and unhygienic conditions. This produces fuel smell and breeds various types of insects and infectious organisms besides spoiling the aesthetics of the site.

Industrial solid wastes are sources of toxic metals and hazardous wastes, which may spread on land and can cause changes in physico-chemical and biological characteristics thereby affecting productivity of soils. Toxic substances may leach or percolate to contaminate the ground water.

In refuse mixing the hazardous wastes are mixed with garbage and other combustible waste. This makes segregation and disposal all the more difficult and risky. Various types of wastes like cans, pesticides, cleaning solvents, batteries (zinc, leader mercury) radioactive materials, plastics are mixed up with paper, scraps and other non-toxic materials which could be recycled. Burning of some of these materials produce dioxins, furans and polychlorinated biphenyls, which have the potential to cause various types of ailments including cancer.

Control Measures of Urban and Industrial Wastes. In industrialized countries, household waste is separated into categories such as organic material, paper, glass, other containers, etc. This separation is often done in homes by using different bins for the disposal of different items. In developing countries, waste is not separated, though some cities are trying to persuade the public to separate waste.

The simplest and most common method used in the cities is to collect and dump the waste in a landfill. These landfills are located just outside the city. There are now thousands of landfills in the world with huge piles of waste. In industrialized countries, you can also see separate mountains of used cars and tyres. Many countries and cities have run out of space for landfills.

In the poorer countries, rag pickers sift through the waste, collect the reusable and recyclable material and sell it to the scrap traders. They, in turn, take the material to the recycling units. The rag pickers (the majority of whom are women and children) work in extremely unhygienic conditions and yet provide a great ecological service by manually separating thousands of tons of recyclable waste from the garbage dumps.

Often, the waste in a landfill is burnt. While this reduces the volume of garbage, it release deadly dioxins into the atmosphere. Proper incineration of waste needs modern technology and proper management.

With increasing amounts of waste being generated, its management is becoming difficult and expensive.

For waste management we stress on 'three R's'—Reduce, reuse and recycle before destruction and safe storage of wastes.

(a) **Reduction in Use of Raw Materials.** Reduction in the use of raw materials will correspondingly decrease the production of waste. Reduced demand for any metallic product will decrease the mining of their metal and cause less production of waste.

(b) **Reuse of Waste Materials.** The refillable containers which are discarded after use can be reused. Villagers make casseroles and silos from waste paper and other waste materials. Making rubber rings from the discarded cycle tubes which are used by the newspaper vendors, instead of rubber bands, reduces the waste generation during manufacturing of rubber bands. Because of financial constraints poor people reuse their materials to the maximum.

(c) **Recycling of Materials.** A good way of dealing with the solid waste problem is to recycle it. Recycling is the processing of a used item or any waste into usable form. There is a large global recycling industry. In India, we have a thriving unorganized recycling industry, thanks to the intinerant collector, who buys old newspaper, bottles, used clothes, utensils, scrap, motor oil, etc.

Recycling has multiple benefits :

- As against expenditure incurred on disposing of the waste, we now make money out of waste material.
- We save energy that would have gone into waste handling and product manufacturing.

- By taking away some of the waste, it reduces environmental degradation.

Some specific examples of savings through recycling are :

- Every ton of recycled glass saves energy equal to 100 litres of oil.
- Making paper from waste pulp rather than virgin pulp saves 50 per cent energy.
- When aluminium is resmelted, there is considerable saving in cost. The recycling process is, however, energy-intensive.

Safe and profitable technologies for recycling paper, glass, metals, and some forms of plastic are available. Biogas can be produced from landfill waste. Paper factories can also recycle their waste.

For discarding wastes the following methods can be adopted :

(a) **Sanitary Landfill.** In a sanitary landfill, garbage is spread out in thin layers, compacted and covered with clay or plastic foam.

In the modern landfills the bottom is covered with an impermeable liner, usually several layers of clay, thick plastic and sand. The liner protects the ground water from being contaminated due to percolation of leachate. Leachate from bottom is pumped and sent for treatment. When landfill is full it is covered with clay, sand, gravel and top soil to prevent seepage of water. Several wells are drilled near the landfill site to monitor if any leakage is contaminating ground water. Methane produced by anaerobic decomposition is collected and burnt to produce electricity or heat.

(b) **Composting.** Due to shortage of space for landfill in bigger cities, the biodegradable yard waste (kept separate from the municipal waste) is allowed to degrade or decompose in an oxygen rich medium. A good quality nutrient rich and environmental friendly manure is formed which improves the soil conditions and fertility.

(c) **Incineration.** Incinerators are burning plants capable of burning a large amount of materials at high temperature. The initial cost is very high. During incineration high levels of dioxins, furans, lead and cadmium may be emitted with the fly ash of incinerator. Dioxin level may reach many times more than in the ambient environment. For incineration of materials, it is better to remove batteries containing heavy metals and plastic containing chlorine before burning the material. Prior removal of plastics will reduce emissions of dioxine and polychlorinated biphenyls (PCBs).

The Way Out

We have to move from waste management to waste prevention. That is, we should design clean production technologies or zero-discharge systems that use minimum amounts of raw materials, energy, and water and do not generate wastes.

The life cycle of a product should be such that at no stage is any ecosystem adversely affected. This should apply to raw material extraction, design, manufacture, material transport, actual use, and disposal, clean

production technologies do exist and they will be cost-effective if the true environmental costs are taken into account.

Even as we move to clean technologies, there is another way out of the industrial waste problem. If the industries in an area cooperate, they could design a system in which the waste from one industry becomes an input for one or more industries in the neighbourhood.

Role of an Individual in Prevention of Pollution

It is the responsibility of the human race which has occupied the commanding position on this earth to protect the earth and provide conductive environment for itself and innumerable other species which evolved on this earth. A small effort made by each individual at his own place will have pronounced effect at the global level.

It can be done by following some of the following suggestions :

- Use the chemicals derived from peaches and plums to clean computer chips and circuit boards instead of CFCs.
- Lay greater emphasis on pollution prevention than pollution control.
- Do not use polystyrene cups that have chlorofluorocarbon (CFC) molecules in them which destroy ozone layer.
- Cut down the use of chlorofluorocarbons (CFCs) as they destroy the ozone layer.
- The CFC free refrigerators.
- Use ecofriendly products.

The manufacture and operation of such devices should be encouraged that don't pollute. If they cost more then their higher prices may be offset by including environmental and the social costs of pollution in the price of such products which pollute environment.

- Promote Reuse and Recycling wherever possible and Reduce the production of wastes. (3R strategy).
- Save electricity by not wasting it when not required because electricity saved is electricity generated without polluting the environment. Put on warm clothes rather than switching on a heater.
- Use mass transoort system. For short visits use bicycle or go on foot. Decrease the use of automobiles.
- Improve energy efficiency. This will reduce the amount of waste energy, i.e., more is achieved with less energy.
- Reduce your dependency on fossil fuel especially coal or oil.
- Adopt and popularize renewable energy sources.
- Use low phosphate, phosphate-free or biodegradable dish washing liquid, laundry detergent and shampoo. This will reduce eutrophication of water bodies.
- Use pesticides only when absolutely necessary and that too in right amounts. Wherever possible integrated pest management, including

alternate pest control methods (biological control), should be used.

- When building a home, save (don't cut) as many trees as possible in the area.
- Do not litter polythene bags. These do not degrade in the environment and choke sewers, spoil soil quality after they mix up with soil on becoming brittle, cause death of cows which consume these alongwith the garbage contained in them.
- Air pollution can be prevented by using really clean fuel i.e., hydrogen fuel. Hydrogen for that matter should not be produced by passing current in water as for generation of this current, again the environment will be polluted. So solar powered hydrogen fuel is the need of the hour.
- Use less hazardous chemicals wherever their application can be afforded. Banking soda, vinegar and borax can help in cleaning, bleaching and softening. Baking soda can replace modern deodrants.
- Check population growth so that demand of materials is under control.
- The solid waste generated during one manufacturing process can be used as a raw material for some other processes.
- Do not put pesticides, paints, solvents, oils or other harmful chemicals into the drain or ground water.
- Use rechargeable batteries. Rechargeable batteries will reduce metal pollution.
- Use organic manure instead to commercial inorganic fertilizers.
- Plant more trees, as trees can absorb many toxic gases and can purify the air by releasing oxygen.
- Use only the minimum required amount of water for various activities. This will prevent fresh water from pollution.

Model Questions

1. Classify solid waste. What are the sources of urban and industrial solid wastes?
2. What adverse effects can solid wastes cause? How can the solid waste be managed?
3. Why has waste become a major problem in the world?
4. What are the ways of managing waste?
5. What are common effluent treatment plants (CETPs)?
6. How can solid waste be recycled?
7. What is the way out of the waste management problem?
8. How can you, as an individual, prevent environmental pollution? Why such an effort at individual level is important?

Phosphorus Cycle. Phosphorous cycle is another nutrient cycle. The reservoir of phosphorus lies in the rocks, fossils etc., which is excavated by man for using it as a fertilizer. Farmers use the phosphate fertilizers indiscriminately and as a result excess phosphates are lost as run-off, which causes the problem of eutrophication or over-nourishment of lakes leading to algal blooms as already discussed in unit 2. A good proportion of phosphates moving with surface run-off reaches the oceans and are lost into the deep sediments. Our limited supply of phosphorus lying in the phosphate rocks of this earth are thus over-exploited by man and a large part is taken out of the normal cycle due to loss into oceans. So human beings are making the phosphorous cycle acyclic. Sea birds, on the other hand, and playing an important role in phosphorus cycling. They eat sea-fishes which are phosphorus rich and the droppings or excreta of the birds return the phosphorus on the land. The Guano deposits on the coasts of Peru are very rich sources of phosphorus.

Primary Production

The rate at which radiant energy is converted into organic substances by photosynthesis or chemo-synthesis by the primary producers is defined as primary productivity of an ecosystem.

When organic matter is produced by the primary producers (mainly green plants and some microorganisms), some of it is oxidized or burnt inside their body and converted into carbon-dioxide which is released during respiration and is accompanied by loss of energy.

Respiratory loss of energy is a must, because it is required for the maintenance of the organism. Now, the producers are left with a little less organic matter than what was actually produced by them. This is known as the net primary production (NPP) and the respiratory loss (R) added to it gives the gross primary production (GPP).

Thus, NPP = GPP – R.

Primary production of an ecosystem depends upon the solar radiations, availability of water and nutrients and upon the type of the plants and their chlorophyll content.

It is clear that more than 60 per cent of terrestrial primary production occurs in the tropics. Thus tropical ecosystems generally have greater production than comparable ones at higher altitudes. However, there is much variation within the substantial overlap between categories.

Some tropical forests are less productive than some of their temperate or local counterparts. Similar variations in plant production of savannas and grasslands are also found.

The highest rate of primary production occurs in tropical rain forests. This is because tropical forests have abundant rainfall, warm temperature congenial for growth, abundant sunlight and a rich diversity of species.

13
Sustainable Development

Sustainable development is the development that meets the needs of the present without compromising the ability of future generation to meet their own needs. Thus, it is the development that lasts.

Man has continually and at an increasing rate been changing the forms and modes of his interaction with the environment. Natural processes and factors that depend on the structure and other characters of the earth and social processes have been closely interwoven. On the one hand, population of the earth is growing, on the other hand with the technological and scientific revolution, developmental activities have been accelerated to such an extent that in certain areas they have become a threat to the environment. The utilization of natural resources is growing at an alarming rate causing great concern for their conservation. Industrialisation and urbanisation are causing environmental degradation and expansion of human habitat has caused ecological imbalance and destruction of genetic-pool. Such development has made the future unsafe for our posterity.

Defining Sustainable Development

The term sustainable development was used at the time of COCOYOC. Declaration on environment and development in the early 1970's since then it has become the trademark of international organisation dedicated to achieving environmentally benign or beneficial development. The term has served to catalyse debate over the relationship between economic change and the natural resource base in which it is grounded.

The sudden interest in sustainable development is of course, a response to warnings that the world is facing environmental degradation and therefore, social catastrophe in the near future unless mankind radically modifies certain practices and perspectives, which have created the present crisis. The crisis is characterised among the other things, by the poisoning of our rivers, seas and underground water sources, the thinning of the ozone layer, global deforestation and soil degradation, rapid population growth and uncontrolled urbanisation with its attendant social problems.

They exist primarily for the benefit of mankind. Resource exploitation and their mismanagement is the most alarming concern for the mankind.

Mineral resources are not infinite. They are nor renewable. Hence, their conservation or shifting to renewable resource can be tantamount to their sustainability. Energy resources of the world (coal, mineral, oil, etc.) causes environmental pollution also, thus solution lies in using more of solar, wind, geothermal and ocean, wave power and most important the hydel power.

Soil is not a renewable resource too. It takes almost hundreds of years to produce one cm layer of soil. Due to faulty agricultural practices and fertility loss salinity and soil erosion are posing great problems. Soil conservation through certain agronomic practices like bunding, crop-rotation, mulching, etc., holds they key for their future productivity.

Environment degradation has been caused by the man's unsuitable greed which propel him to explore and utilise everything with technological know-how. The expansion of his habitat has caused the shrinking of others habitat and loss of biodiversity. Deforestation on large scale has caused environmental problems and genetic pool destruction. Pollution of air, water and soil is a related phenomena and are essentially caused by man's activity, affecting the nutrient cycles and energy flow.

Climatic hazards like reservoir induced earthquake, flood, drought, famine, etc., are also a sequel of man's interference with the environment.

The population growth and related problems of health, employment, sanitation, the social problems like poverty, unemployment, migration, ethnic clashes, etc., all are basically other side of the same coin.

The problem has taken climatic dimension also. Global warming and climatic change, ozone layer depletion, rise in sea level and drowing of the coastal inhabitate land, melting of ice, loss of genetic pool, etc., they are posing even great threat of human existence and man must start thinking in this direction as soon as possible.

In 1972, at Stockholm Conference man-environment relation was redefined and after that in Rio, Kyoto, Montreal Earth Summits have been organised, where the environmental problems were discussed at length. Verily development without proper management has become a cause of eco-destruction for which sustainable development is the only solution.

Stockholm Conference. The first even was the Stockholm Conference on the Human Environment held in 1972 which brought together representatives from 113 countries, 400 IGOs and NGOs. "Poverty is the biggest polluter", stated Indira Gandhi, the late Indian P.M. The second event was the set up of World Commission on Environment and Development (WCED), also know as Brundtland Commission in 1983. Its report was published in 1987.

Rio de Janeiro. The year 1992 marks a watershed in setting a new global agenda in international relations and economic development. The UNCED or Earth Summit was held at Rio de Janeiro, the capital of Brazil between 3 and 14 June, 1992 to ensure relationship between environment

and development on a global partnership level. It was a historic largest assembly of world leaders ever in which representatives from more than 170 countries including 115 Heads of State and Government participated.

The Rio Declaration aims at "a new and equitable global partnership through the creation of new levels of cooperation among states . . ." Out of its five significant agreements Agenda-21 proposes a global programme of action on sustainable development in social, economic and political context for the 21st century.

These are the key aspects for sustainable development :

(a) **Inter-Generational Equity.** This emphasizes that we should minimize any adverse impacts on resources and environment for future generations, i.e., we should hand over a safe, healthy and resourceful environment to our future generations. This can be possible only if we stop over-exploitation of resources, reduce waste discharge and emissions and maintain ecological balance.

(b) **Intra-Generational Equity.** This emphasizes that the development processes should seek to minimize the wealth gaps within and between nations. The Human Development Report of United Nations (2001) emphasizes that the benefits of technology should seek to achieve the goals of intra-generational equity. The technology should address the problems of the developing countries, producing drought tolerant varieties for uncertain climates, vaccines for infectious disease, clean fuels for domestic and industrial use. This type of technological development will support the economic growth of the poor countries and help in narrowing the wealth gap and lead to sustainability.

Measures for Sustainable Development

Some of the important measures for sustainable development are as follows :

- A production efficiency era of minimum environmental damage costs through energy transition.
- For a stable world population, a demographic transition.
- For non-renewable to renewable resource transition.
- By a global mutually agreed objective between South and North—Political transition.
- Environmental issues and sustainable development in agriculture, irrigation, mining, industries, transportation, forestry, land management and other areas.
- Development of cheaper technology to harness the solar and other non-conventional source of energy.
- There is need of environmental education monitoring, environmental management and also fix accountability and responsibility of damages.

- Use of sewage water for fish forming, sewage is being also exploited for fuel. There is an urgent need to develop an efficient waste management system.
- Sustainable development should essentially be based on maintaining the fragile balance between productivity functions and ecosystem.

For sustainable development, our approach should be holistic on every resource sector and at all level of local, regional and global scale.

Indian Context

To integrate environmental issues into development planning, initiative come not only from the Government but also equally from Non-governmental organisations (NGOs) and individuals. India has a very active movement by NGOs in the area of environment with an impressively large number of them involved in rural development, afforestation programmes, creation of public awareness, tribal welfare and action against polluting industries. Many collaborative and joint programmes exist today between the Government and the NGOs. The problem of sustainable development becomes much complex in a country like India with unique size and diversity. This subject has been given a greater urgency, and there has been increasing emphasis on decentralised decision-making, and the stress on micro-planning. Decisions are taken in decentralised manner, that are appropriate to the particular situation.

Government Efforts. It was at the initiative of our late Prime Minister, Smt. Indira Gandhi that a National Council of Environmental Planning and Co-ordination (NEPC) was set up in 1972. This was followed by Empowered Committee, the Tiwari Committee set up in 1980. On the recommendation of this committee, the Department of Environment was set up in 1980 as the focal agency in the administrative structure of the Central Government for planning, promotion and co-ordination of environmental programmes. This Department became part of the new Ministry of Environment and Forests in 1985.

The Ministry is the apex body under the Government of India for planning, promotion and co-ordination of environmental and forestry programmes. Most of the states have also set up their own Departments of Environment, Pollution Control Boards and other associated bodies. Various other Ministries and Departments including those of Urban Development, Oceanography, Non-conventional Energy Sources, Biotechnology etc., at the State and Central level, are also concerned with environmental management programmes.

Non Government Efforts. The Directory of Environmental NGOs, brought by World Wide Fund for Nature–India (WWF–I) in 1989, lists about 850 NGOs, now active in this field throughout the country. But there are perhaps more than 3,000 such organisations. India's impressively large

body of NGOs is becoming active on the environmental front. The National Environmental Awareness Campaign promoted by the Ministry of Environment and forest has successfully encouraged many NGOs whose primary concerns are rural development, appropriate technology, civil rights, women's development, tribal welfare, afforestation etc.

The NGOs are broad-based and range from clubs which encourage and assist in adventure travel, exploration and dissemination of knowledge on ecosystems to agencies dealing with creation of employment, wastelands development, afforestation, rehabilitation of tribals and preparation of educational materials and aids. They may be small groups of two or three persons or a large organisation of eight-thousand-strong members. NGOs are organisations of scientists, lawyers, farmers, fisherman etc.

India and South-South. To further its efforts towards cooperation and to evolve a common strategy almost the developing countries to deal with global environmental Issues, an International Conference of 21 developing countries was hosted by India in New Delhi in April, 1990. As a follow-up to this, a ministerial-level Conference of Developing Countries was organised by the People's Republic of China in Beijing in June, 1991, the first of this kind of developing world. At this conference 41 participating countries adopted a declaration which articulates the concerns of these countries. India participated actively in putting forward the concerns of the Group of 77 countries. G77's initiatives at the Preparatory Committee Meeting held in Geneva in 1991 have emphasised the centrality of certain developmental considerations in the agenda of United Nations Conference on Environment and Development (UNCED), 1992. Earlier to UNCED India's viewpoint was also presented by Shri Kamal Nath, Minister of State, Environment and Forests at the Special Session of the UNEP Governing Council at Nairobi in February, 1992.

Rao in Rio. Our Prime Minister, Shri P.V. Narasimha Rao had honour of opening the three-day Earth Summit (for Heads of State and Government) with a lucid speech on June 12, 1992 in Rio de Janeiro. In a hard-hitting and argumentative speech he took to task recalcitrant nations, which were treating the issues of environment and development as subjects for political posturing and bargaining. He argued that in a world of abundance, plenty brought pollution. There was also a world of want, where deprivation degraded life. Such a fragmented planet could not survive in harmony with nature and the environment indeed with itself. We must ensure, therefore, that the affluence of some is not derived from the poverty of many.

Urban Problems Related to Energy

Cities are the main centres of economic growth, trade, education, innovations and employment. Until recently, a big majority of human

population lived in rural areas and their economic activities centred around agriculture, cattle rearing, fishing, hunting or some cottage Industry. It was some 200 years ago, with the dawn of industrial era, the cities showed a rapid development. Now about 50 per cent of the world population lives in urban areas and there is increasing movement of rural folk to cities in search of employment. The urban growth is so fast that is becoming difficult to accommodate all the industrial, commercial and residential facilities within a limited municipal boundary. As a result, there is spreading of the cities into the sub-urban or rural areas too, a phenomenon known as urban sprawl.

In developing countries too urban growth is very fast and in most of the cases it is uncontrollable and unplanned growth. In contrast to the rural set-up the urban set-up is densely populated, consumes a lot of energy and materials and generates a lot of waste.

The energy requirements of urban population are much higher than that of rural ones. This is because urban people have a higher standard of life and their life style demands more energy inputs in every sphere of life. The energy demanding activities include :

- Residential and commercial lighting.
- Transportation means including automobiles and public transport for moving from residence to workplace.
- Modern life-style using a large number of electrical gadgets in every day life.
- Industrial plants using a big proportion of energy.
- A large amount of waste generation which has to be disposed off properly using energy based techniques.
- control and prevention of air and water pollution which need energy dependent technologies.

Due to high population density and high energy demanding activities, the urban problems related to energy are much more magnified as compared to the rural population.

Conservation of Water

Water is an indispensable component of our ecosystem and the essence of our life. On an average, each individual uses 40 to 50 litres of water per day. Apart from drinking purposes, water is used for irrigation as well as in industries. Wherever available about 12,000 m^3 to 14,000 m^3 water is used annually to irrigate one hectare of land. Monsoon is the main source of water in our country. The oceans are full of water but because of salinity this water is not usable, so also with several inland seas, lagoons and saline lakes. In fact, ready water is very confined and there are areas in the world where water is a scarce commodity. The unhappy position is that wherever water is available, users never think about its proper use and they not only misuse it but waste a large quantity of it too. Therefore, conservation of

water is an necessity for all the countries of the world so that atleast water requirement can be fulfilled.

(a) **Distribution System of Water.** First of all there should be proper distribution system of water. The water distribution system should be such that loss of water should be minimum and it should remain free from pollution. The distribution system of water should be developed according to the regional conditions. A few general steps for distribution of water are :

- As far as possible water distribution be done through pipes so that loss will be minimum and water will remain free from pollutants.
- If water storage place is small it should be cemented and if its size is big, the selection of site be done where non-porous rocks exist.
- The channels and distributors of canals should be cemented, and in fields also either pipes be used or cemented channels (nala) be constructed.
- For irrigation, sprinkle and drip system be used.

(b) **Utilising Waste Water.** Waste water should be used properly to save pure water for the future. The system of the recycling of water be used so that waste water can be used for irrigation purposes. There are several mechanical devices for the waste water treatment, some methods are expensive too. But the government agencies and industrial establishment should establish treatment plants. This will also help in control of water pollution. Waste water should be diverted for use in industries. Thus, pure water can be diverted to some other purpose.

(c) **Judicious Use of Underground Water.** Underground water is also a main source of water particularly in the arid regions. People have wrong perception that underground water is enough to fill the gap between demand and supply. This wrong notion of people resulted in overexploitation of underground water. The overexploitation of underground water often results in the lowering of water table, intrusion of saline water, subsidence of land, etc. The prime need is the proper and limited use of water and also geological and hydrological survey of the region for assessment of water availability and people should adopt water harvesting method for aquifer recharge.

(d) **Pollution Free Water.** Apart from accessibility of water, peculiarity of water is also significant, in other words water should be free from pollution. Nowadays several techniques such as physico-chemical purification methods—hydrolysis, electrolysis, ion-exchange, absorption, coagulation, chlorination, ozonisation, etc., are in use. Similarly, biological purification method is also in use. The conservation of water can be done only by water management system. Apart from the above mentioned procedures, water can be obtained from desalination of sea water. Apart from conservation of water, mutual cooperation in use of water resources is necessary.

(e) **Control over Deforestation.** Dense forest keeps climate homogeneous. The loss of vegetation is also a cause of drought and reduction of rainfall and indirectly a cause of lowering of the water table. In order to maintain humidity in the atmosphere which helps in rainfall and to minimize evaporation rate forest cover should be maintained.

Rainwater Harvesting

Rainwater harvesting is a technique of increasing the recharge of groundwater by capturing and storing rainwater. This is done by constructing special water-harvesting structures like dug wells, percolation pits, lagoons, check dams etc. Rainwater, wherever it falls, is captured and pollution of this water is prevented. Rainwater harvesting is not only proving useful for poor and scanty rainfall regions but also for the rich ones.

Very Effective Way. It rains, it may even pour, but all the water soon disappears into the ground or into the streams and rivers making their way to the ocean. We do not realize how much water really falls on the Earth's surface.

Take the case of the Rajasthan desert, where one can only expect 100 mm of rain annually. If you had one hectare of land there, you could collect one million litres of water in a year. This will be enough to meet the cooking and drinking water needs of about 180 people using 15 litres a day. Even in the worst drought conditions, you can collect substantial amounts of rainwater in most areas.

India receives most of its rain in just 100 hours every year. That is a strong argument in support of 'catching' the rain when and where it falls. We have a long tradition of rainwater. Harvesting, with a wide variety of methods being followed to suit local conditions.

Traditional Rain Water Harvesting. In India, it is an old practice in high rainfall areas to collect rainwater from roof-tops into storage tanks. In foot hills, water flowing from springs are collected by embankment type water storage. In Himalayan foot-hills people use the hollow bamboos as pipelines to transport the water of natural springs. Rajasthan is known for its 'tankas (underground tanks) and khadins (embankments) for harvesting rainwater. In ancient times we had adequate Talaabs, Baawaris, Johars, Hauz etc., in every city, village and capital cities of our kings and lords, which were used to collect rainwater and ensured adequate water supply in dry periods.

Modern Techniques. In arid and semi-arid regions artificial ground water recharging is done by constructing shallow percolation tanks. Check-dams made of any suitable native material (brush, poles, rocks, plants, loose rocks, wire nets, stones, slabs, sacks etc.) are constructed for

harvesting runoff from large catchment areas. Rajendra Singh of Rajasthan popularly known as "water man" has been doing a commendable job for harvesting rain water by building checkdams in Rajasthan and he was honoured with the prestigious Magasaysay Award for his work.

Groundwater flow can be intercepted by building groundwater dams for storing water underground. As compared to surface dams, groundwater dams have several advantages like minimum evaporation loss, reduced chances of contamination etc.

In roof top rainwater harvesting, which is a low cost and effective technique for urban houses and buildings, the rainwater from the top of the roofs is diverted to some surface tank or pit through a delivery system which can be later used for several purposes. Also, it can be used to recharge underground aquifers by diverting the stored water to some abandoned dug-well or by using a hand pump.

All the above techniques of rainwater harvesting are low-cost methods with little maintenance expenses. Rainwater harvesting helps in recharging the aquifers, improves groundwater quality by dilution, improves soil moisture and reduces soil erosion by minimizing run-off water.

Experience in India. In recent years, with increasing water scarcity in many parts of the country, a number of initiatives have been taken by communities to harvest and conserve water. Here are some examples :

- The watershed development and overall village development work of Anna Hazare in Ralegaon Siddhi and the Pani Panchayat initiative of Vilasrao Salunkhe (18.5), both in Maharashtra, are well known.
- Hundreds of checkdams have been built by villagers in Alwar, Rajasthan, under the guidance and inspiration of the Tarun Bharat Sangh. The results have been spectacular.
- The non-governmental organization (NGO), Saurashtra Lok Manch, has inspired farmers in the Saurashtra-Kutch Region to recharge more than 300,000 wells and tubewells using the monsoon rainfall. Jal yatras were organized to ensure people's participation in the programme. Water tables have gone up and bumper crops could be harvested.
- Uthan, an Ahmedabad-based NGO, has built 21 lined ponds in the Ahmedabad and Bhavanagar districts, with the active participation of local village communities, particularly women. This has substantially increased water availability in the area.
- By adding new structures to existing, traditional water harvesting systems, the Mewar Krishak Vikas Samiti has increased water availability in Rajasmand District of Rajasthan.
- The people of Laporiya in Jaipur District of Rajasthan have built dykes around degraded pasturelands to harvest rain and have

brought about a dramatic ecological change. Their unique method involves rectangular plots of land, which store rainwater in the pastures. The water first collects in the lower plots and as the level rises, water flows into the neighbouring plots and so on.

- Jhabua, a poor tribal district of Madhya Pradesh, has become a model of watershed management under the Rajiv Gandhi Mission for Watershed Development. The key success factors were the involvement of people in decision-making, an area-specific approach, and priority given to indigenous knowledge. More than 200 micro-watersheds were developed and 14 million human-days of employment were created. R. Gopalakrishnan, a bureaucrat, played a major role in the project devising ways of cutting the red tape.
- Inspired by the Vivekananda Kendra, villagers in Ramanathapuram District of Tamil Nadu contributed their labour to help renovate several traditional ponds called ooranis. Increased water availability in these villages is encouraging many other villages in the area to follow suit.
- Building bunds and checkdams along with large-scale tree plantation has helped arrest soil erosion in villages around Auroville near Pondicherry.
- The efforts of women in the villages in Sabarkantha District of Gujarat in arresting run-off have yielded good results. They have worked out a system of conserving rainwater and soil using stones. The women, whose husbands work as migrant labour elsewhere, now plant a variety of crops, earn more, and feel empowered.

Watershed Management

Conservation of land, water, flora and fauna is of paramount importance for the 'Sustainable Development' of a nation/region. To this end, watershed, a geographically definable area constitute a basic and vital ecosystem involving intricate interaction between and among its biotic (man, animal, vegetation) components and abiotic components (soil, water, etc.). It is in this respect lies the importance of watershed to be chosen as a Geo-hydrologic ecological unit to plan and execute the development strategy of the region on a sustained basis.

Watershed Concepts. Simply speaking, watershed is any special area from where water is collected and drained to a river i.e., the area from where water to a river comes from. The rainfall draining the uplands follow stopes to converge into small gullies and streams which in turn meet large tributaries and finally the main river course. Any of the constituents of a

river-a tributary, a stream or a gully—has a defined catchment. This catchment area within the ridges and slopes on the drainage basin is defined as the watershed. It may vary from a few hectares to several hundred hectares.

Watershed is a smaller geographical unit of a river system. The river system and its total catchment have a hierarchical relationship with its smaller watershed units :

Table 13.1

The River Basin
↓
Basin of a Tributary
↓
Watershed or Sub-Basin of a Stream
↓
Watershed of a Stream of Lower Order
↓
Micro Watershed of a Monor Stream

Watershed Management. We see that land and water regime in a watershed are so directly and intricately linked with each other that it becomes a Geo-hydrological unit. A watershed is also a social unit where one or more communities depend on the natural resources of the watershed for their livelihoods.

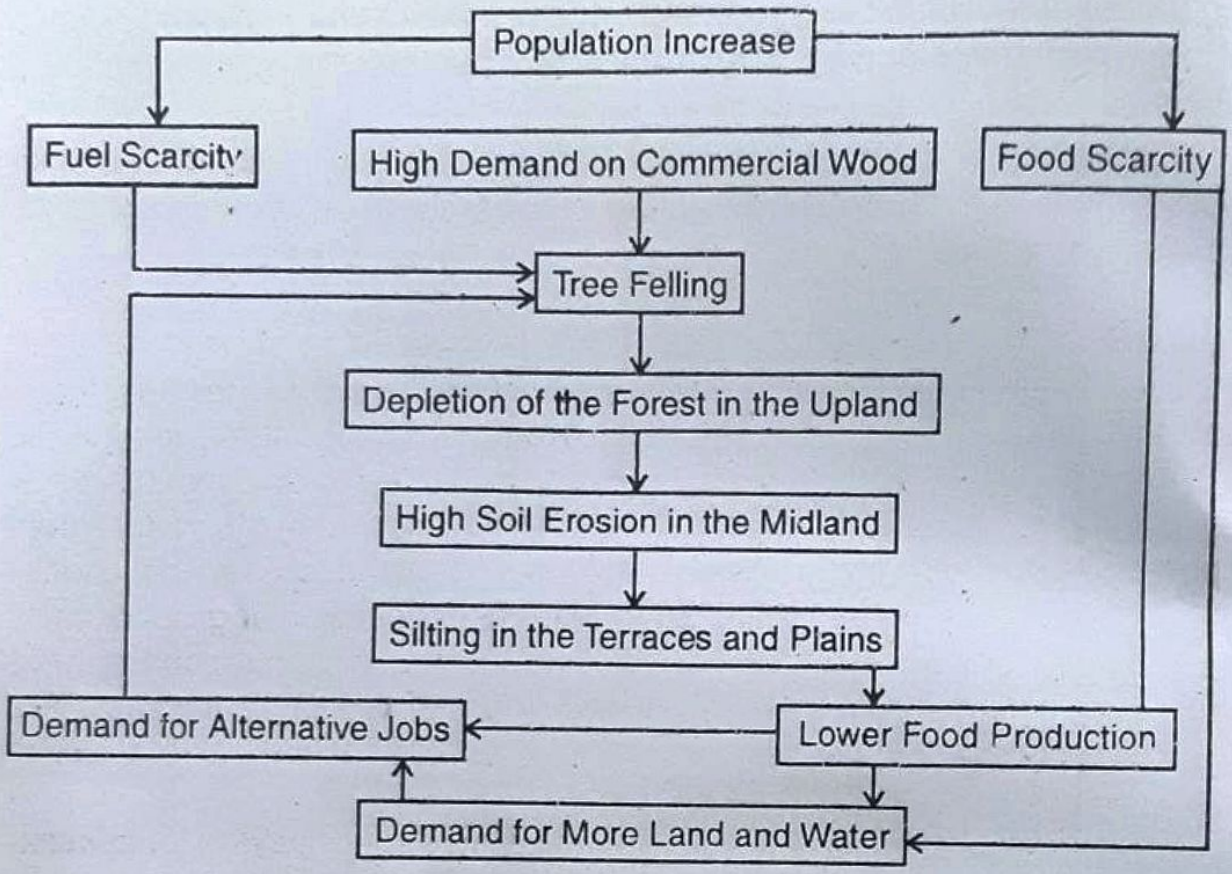
Hence, it is better to treat a watershed as an ecosystem, a unified functional whole, for the better management and utilisation of its resources without disturbing the ecology of the area. Watershed Management is thus a holistic development concept that encompasses conservation, regeneration and judicious use of land, water, agriculture, forestry and all related matters in relation with the people who inhabit the area and their socio-cultural system.

Need. Because of (rapid) population growth, cultivation of slopes and of even more marginal lands in increasing, a trend that only accelerates erosion. Forest and other sources of natural vegetation are being stripped for fuel and fodder.

And lastly the most crucial aspect the shortage of water is being felt almost everywhere, acquiring a global dimension, thanks to mismanagement and wasteful use of water resources.

The following flow diagram depicts a problem chain but in actual situation the problem chains are normally complex.

Table 13.2



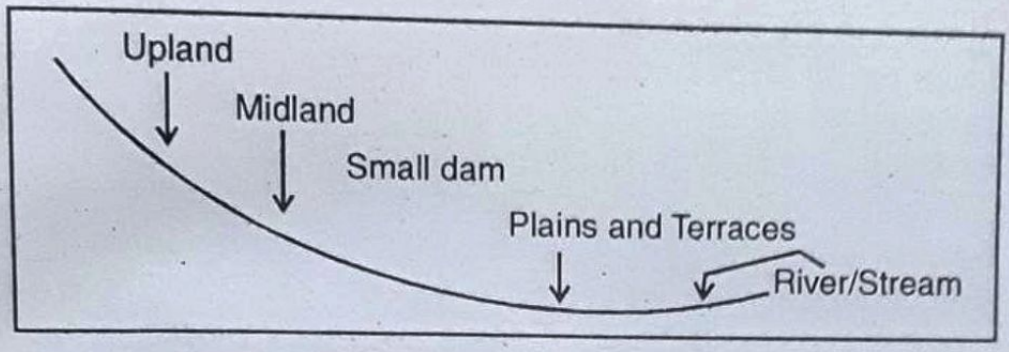
Development of watershed ecosystem offers an eco-friendly way that is effective in arresting degradation of natural resources and promoting economic development of the region involving direct participation of local community.

Advantages. A watershed may constitute a simple or complex agro-ecologies. It is made up of a combination of upland-midland-lowland ecosystems. Each ecosystem in such a complex has its distinct function and land use capacity. Generally upland areas have the potential for horticulture and livestock development, midland represents dry land agroecology and lowland may strengthen their traditional agriculture through proper irrigation and land treatment practices. These are however few suggestions among limitless choices offered by watershed approach.

The main goal of watershed approach is to catch. The Water where it falls, otherside it will run unused carrying away fertile soil simultaneously. Further, it is possible to monitor and regulate the water resources more efficiently within the watershed ecosystem as the system is smaller.

In a watershed approach there is a scope to view the total water resource regime rather than targeting the plot of an individual farmer or for that matter a larger command area. Upland is thus an area for water harvesting, midland an area for water harvesting, midland an area for small dams and springs development and low land for tapping ground water source.

Table 13.3



The framework of watershed as an ecosystem provides the inter-ecological linkages and hence a logical unit for the integration of the substantial use of land and water. It helps augment soil and ground water resources. It joins the biophysical, social and economic inputs which when optimally managed, lead to diversified high agricultural production, control the environmental degradation and help in the recharging of ground water aquifers, thereby avoiding the ecological problems which our country have been facing after the successful introduction of Green Revolution. The approach of watershed ecosystem is the best tool to achieve an Evergreen Revolution (sustainable Agriculture).

Each watershed is presumably a unique ecosystem having its own set of ecological problems, quality of biotic and abiotic resources and prospects/ opportunities, the proper assessment for which has to be made separately and the formulation and execution of the plan is to be done accordingly involving the direct participation of local community. This will lead to efficient and optimal utilisation of the resources of each watershed area on a sustainable basis.

Watershed ecosystem approach gives ample scope as well as warrants community participation and their development especially women empowerment through their participation. It can lead to benefiting use of their traditional wisdom especially the water harvesting techniques and creation of an effective mechanism for transparency, accountability, sharing of problems, benefits and resources and conflict Resolution all these negate individual greed and are vital ingredients of 'Sustainable Development'

Resettlement & Rehabilitation Issues

People who are forced to flee from a disaster or conflict usually receive sympathetic attention and international aid. The same cannot be said about the millions of people worldwide who have been displaced by development, even though the consequences they face may be every bit as grave as those faced by people displaced by other forces.

The World Bank estimates that every year since 1990, roughly 10 million people worldwide have been displaced by development projects for a variety of reasons. During the last 50 years, development projects have displaced

25 million people in India and 40 million in China (of whom, 13.6 million were displaced in the 1990s alone).

The reasons for displacement are often interconnected. For example, a family displaced by the construction of a dam loses its livelihood and hence moves to another place for economic reasons.

When people leave an area, they may leave behind environmental problems like abandoned agricultural land. Their migration may also cause environmental problems in the area into which they move. There are large refugee camps lacking in basic amenities at many places in the world, which have become permanent settlements. In other case, the refugee group upsets the balance of the area by making unsustainable demands on the natural resources.

The United Nations High Commission for Refugees (UNHCR) predicts that economic and environmental refugees will continue to make up a significant percentage of the total refugee populations around the world, and that the number will only increase as more damage is done to the environment and as more countries become globalized and offer better opportunities than their home countries.

(a) **Problems Related to Dams.** The big river valley projects have one of the most serious socio-economic impacts due to large scale displacement of local people from their ancestral home and loss of their traditional profession or occupation.

After a multi-year study, the World Commission on Dams (WCD) listed the following social impacts of dams in its report published in 2000 :

- Dams have physically displaced some 40-80 million people worldwide.
- Millions of people living downstream from dams—particularly those reliant on natural floodplain functions and fisheries—have also suffered serious harm to their livelihoods and the future productivity of their resources has been put at risk.
- Many of the displaced were not recognized (or enumerated) as such, and therefore were not resettled or compensated.
- Where compensation was provided it was often inadequate, and where the physically displaced were enumerated, many were not included in resettlement programmes.
- Those who were resettled rarely had their livelihoods resorted, as resettlement programmes have focused on physical relocation rather than the economic and social development of the displaced.
- The larger the magnitude of displacement, the less likely it is that even the livelihoods of affected communities can be restored.
- Even in the 1990s, the impacts on downstream livelihoods were, in many cases, not adequately assessed or addressed in the planning and design of large dams.

The WCD report noted that the poor and other vulnerable groups and future generations were likely to bear a disproportionate share of the social and environmental costs of large dam projects without gaining a commensurate share of the economic benefits :

- Indigenous and tribal peoples and vulnerable ethnic minorities have suffered disproportionate levels of displacement and negative impacts on livelihood, culture, and spiritual existence. The outcomes have included assetlessness, unemployment, debt-bondage, hunger and cultural disintegration.
- Affected populations living near reservoirs as well as displaced people and downstream communities have often faced adverse health and livelihood outcomes from environmental change and social disruption.
- Among affected communities, gender gaps have widened and women have frequently borne a disproportionate share of the social costs and have often been discriminated against in the sharing of benefits.

India is one of countries in the world leading in big dam construction and in the last 50 years more than 20 million people are estimated to have been directly or indirectly affected by these dams.

The Hirakund Dam has displaced more than 20,000 people residing in about 250 villages. The Bhakra Nangal Dam was constructed during 1950's and till now it has not been possible to rehabilitate even half of the displaced persons.

Same is the case with Tehri Dam on the river Bhagirathi, construction of which was green signalled after three decades of long compaign against the project by the noted activist Sunderlal Bahuguna he propagator of Chipko Movement. The immediate impact of the Tehri Dam would be on the 10,000 residents of the Tehri town. While displacement is looming large over the people, rehabilitation has become a more burning issue.

(b) **Problems Related to Mining.** Mining is another developmental activity, which causes displacement of the native people. Several thousands of hectares of land area is covered in mining operation and the native people are displaced. Sometimes displacement of local people is due to accidents occurring in mined areas like subsidence of land that often leads to shifting of people.

(c) **Creation of National Parks.** When some forest area is covered under a National Park, it is a welcome step for conservation of the natural resources. However, it also has a social aspect associated with it which is often neglected. A major portion of the forest is declared as core-area, where the entry of local dwellers or tribals is prohibited. When these villagers are deprived of their ancestral right or access to the forests, they usually retaliate by starting destructive activities. There is a need to look into their problems and provide them some employment.

Issues Concerning the Resettlement and Rehabilitation of Displaced Groups. The majority of displacement and resettlement programmes involving large populations have occurred in developing countries. The reasons are the massive development projects undertaken in these countries, financed by foreign aid and international agencies, and their high population densities :

The following are some of the problems faced by displaced people :

- The compensation for the lost land is often not paid or the payment is delayed, and even if it is paid, the amount is usually pitifully small. The oustees are rarely able to start new lives with the compensation they receive. To add to the problem, agents and corrupt officials deprive the poor of the full compensation.
- Generally, the new land that is offered is of poor quality and the refugees are unable to make a living.
- Basic infrastructure and amenities are not provided in the new area. Very often, temporary camps become permanent settlements.
- When tribal groups are displaced, they do not get any compensation since they have no legal title to the land.
- Ethnic and caste differences make it difficult for the refugees to live peacefully with the communities already living in the area.

Case Study. A dam on the River Tawa, a tributary of the Narmada, submerged 20,000 hectares and displaced over 4,000 adivasi families in 44 villages. More than half the villages were on forestland and hence the people got no compensation at all.

Normally these oustees would have migrated to other villages or towns in search of livelihoods. This group, however, campaigned for and secured fishing rights in the reservoir created by the dam. The adivasis learnt how to spread nets, use boats, and carry on fishing operations.

They formed the Tawa Matsya Sangh (TMS), a federation of primary fishermen's cooperative societies with 1200 members. In 1996, TMS was given a five-year lease by the government. It was in charge of overall management and was responsible for stocking the reservoir with fishes. It also took care of the transport and sale of the fish catch, regulatory measures for conservation, and member's welfare.

The former hunter-gatheres became good fisherman, their catch was good, and TMS made profits and shared it with its members. It even paid wages to them during the lean season, between June and August when there was an agreed ban on fishing. Moreover, it was also able to pay the agreed royalty to the government.

It was a rare case of dam oustees doing well in a new occupation, but troubles were ahead. When the lease was renewed the government steeply increased the royalty amount. In return, however, the government agency did little to improve the infrastructure. Even the promised ice factory was

no built. Under the new terms. TMS was also subject to greater government control. In fact, the government appointed a review committee to evaluate the performance of TMS, but did not share the report with them.

The United Nations Universal Declaration of Human Rights [Article 25(1)] has declared that right to housing is a basic human right.

In India, most of the displacements have resulted due to land acquisition by the government for various reasons. For this purpose, the government has the Land Acquisition Act, 1894 which empowers it to serve notice to the people to vacate their lands if there is a need as per government planning. Provision of cash compensation in lieu of the land vacated exists in section 16 of the Act.

Rehabilitation Policy. There is a need for a comprehensive National Rehabilitation Policy. Different states are following different practices in this regard. There is a need to raise public awareness on these issues to bring the resettlement and rehabilitation plans on a humane footing and to honour the human rights of the oustees.

Model Questions

1. What is sustainable development and what are the major measures to attain sustainability?
2. Why is urban requirement of energy more than rural requirement?
3. What are urban problems related to energy?
4. Discuss various conserve measures of water.
5. What is community-based water conservation?
6. Why is rainwater harvesting a very effective way of water conservation?
7. What is the recent experience in India with rural water harvesting?
8. What are reasons for displacement of populations?
9. What are the displacement problems created by development projects?
10. What are the special problems with regard to displacement by dams?
11. What are the issues concerning the resettlement and rehabilitation of displaced groups?

14
Climate Change

A planet's climate is decided by its mass, its distance from the sun and the composition of its atmosphere. Earth's climate is unstable and rather unpredictable as compared to other planets. Over the last 400,000 years the Earth's climate has been unstable, with very significant temperature changes, going from a warm climate to an ice age in as rapidly as a few decades. These rapid changes suggested that climate may be quite sensitive to internal or external climate forcings and fedbacks.

According to recent reports of the Intergovernmental Panel on climate change, the global average surface temperature over the 20th century has increased by around 0.60°C. This value is about 0.15°C more than the previous estimates. Global average land and sea surface temperatures in May 2003 were the second highest since 1880.

The 10 hottest years in the 143 year old global temperature record have all been after 1990; with the three hottest being 1998, 2002 and 2001 (in chronological order). Extreme weather events also increased during this period—there were 63 weather-related disaster declarations in 1998, far more than the average 21.7 disaster announcements made per year during the 1980s. For instance, there were 26 flood disaster world wide in the 1990s, but just 21.7 per year during the 1980s. The frequency and intensity of extreme weather events increases due to a change in the distribution of heat, which disrupts the flow of energy through the climate system, altering the circulation patterns of the atmosphere and oceans, and modifying the Earth's hydrological cycle. Higher temperatures increase evaporation and transpiration, and raise the air's capacity to hold moisture, making more of it available to fall as rain and snow.

The global change in temperature will not be uniform everywhere and will fluctuate in different regions. The places at higher latitudes will be warmed up more during late autumn and winter than the places in tropics. Poles may experience 2 to 3 times more warming than the global average, while warming in the tropics may be only 5 to 100% on an average. The increased warming at poles will reduce the thermal gradient between the equator and high latitude regions decreasing the energy available to the heat engine that drives the global weather machine. This will disturb the global pattern of winds and ocean currents as well as the timing and

distribution of rainfall. Shifting of ocean currents may change the climate of Iceland and Britain and may result in cooling at a time when rest of the world warms. By a temperature increase of 1.5 to 4.5°C the global hydrological cycle is expected to intensify by 5 to 10%. Disturbed rainfall will result in some areas becoming wetter and the others drier. Although rainfall may increase, higher temperatures will result in more evapo-transpiration leading to annual water deficit in crop fields.

IPCC Report, 2007

The fourth Assessment Report (AR4) of the United Nations Inter-governmental Panel on Climate Change (IPCC), 2007 has been prepared by more than 2500 scientific expert researchers from more than 130 countries during 6 years efforts. The report will be in 4 volumes prepared by 4 working groups. The schedule of release of the report of working group I has been in Feb. 2007, working group II in April 2007, working group III in early May, 2007, and the Synthesis Report (AR4SYR) will be adopted by mid November, 2007 during the 27th session of the Panel. The report released on April 6, 2007 highlights the unequal availability of water i.e., excess or lack of water leading to increase in droughts and floods. Glaciers in Himalayas will melt and the size and number of glacial lakes will increase. The mid latitude and semi arid regions of the world will experience drier years. Africa will experience water stress. There will be increased availability of water in moist tropics and high latitudes. Rain dependent agricultural produce will get a boost in North America. Sea level and human activities together will contribute to loss of coastal wetlands. Fresh water availability will decrease by 2050. More than a billion people will be at greater risk. The report assesses that 40 per cent species will become extinct. Human health will be affected. There will be increase in number of deaths, diseases like diarrhoea, cardiovascular diseases, etc.

Consequences of Climate Change

Agriculture and Food Security. Global agriculture will face many challenges over the coming decades. Degrading soils and water resources will place enormous strains on achieving food security for growing populations. These conditions may be worsened by climate change. While a global warming of less than 2.5°C could have no significant effect on overall food production, a warming of more than 2.5°C could reduce global food supplies and contribute to higher food prices.

Higher temperatures will influence production patterns. Plant growth and health may benefit from fewer freezes and chills, but some crops may be damaged by higher temperatures, particularly if combined with water shortages. Certain weeds may expand their range into higher-latitude

habitats. There is also some evidence that the poleward expansion of insects and plant diseases will add to the risk of crop losses. The productivity of range lands and pastures would also be affected. For example, live stock would become costlier if agricultural disruption leads to higher grain price. In general, it seems that intensively managed livestock systems will more easily adapt to climate change than will crop systerns.

Sea Levels, Oceans and Coastal Areas. The global average sea level has risen by 10 to 20 cm over the past 100 years. The rate of increase has been 1-2 mm per year—some 10 times faster than the rate observed for the previous 3,000 years. It is likely that much of this rise is related to an increases of 0.6 ± 0.2°C in the lower atmosphere's global average temperature since 1860. Related effects now being detected include warming sea-surface temperatures melting sea ice, greater evaporation, and changes in the marine food web.

Models projects that sea levels will rise another 9 to 88 cm by the year 2100. This will occur due to the thermal expansion of warming ocean water and an influx of fresh water from melting glaciers and ice. Coastal zones and small islands are extremely vulnerable. Flooding and coastal erosion would worsen. Salt-water intrusion will reduce the quality and quantity of fresh water supplies. Higher sea levels could also cause extreme events such as high tides, storm surges, and seismic sea waves (tsunami) to reap more destruction. Rising sea levels are already contaminating underground fresh water supplies in Israel and Thailand, in small atolls scattered across the Pacific and Indian Oceans and the Caribbean sea, and in some of the world's most productive deltas such as China's Yangtze Delta and Vietnam's Mekong Delta.

Sea-level rise could damage key economic sectors making fisheries, aquaculture, and agriculture particularly vulnerable. Other sectors most at risk are tourism, human settlements, and insurance (which has already suffered record losses recently due to extreme climate events). The expected sea-level rise would inundate much of the world's lowlands, damaging coastal cropland and displacing millions of people from coastal and small-island communities. Valuable coastal ecosystems will be at serious risk. Coastal areas contain some of the world's most diverse and productive ecosystems, including mangrove forests, coral reefs, and sea grasses. Low-lying deltas and coral atolls and reefs are particularly sensitive to changes in the frequency and intensity of rainfall and storms. Coral will generally grow fast enough to keep pace with sea-level rise but may be damaged by warmer sea temperatures.

Biological Diversity. Biological diversity—the source of enormous environmental, economic, and cultural value—will be threatened by rapid climate change. The composition and geographic distribution of ecosystems will change as individual species respond to new conditions created by

climate change. At the same time, habitats may degrade and fragment in response to other human pressures. Species that cannot adapt quickly enough may become extinct—an irreversible loss.

Forests play an important role in the climate system. They are a major reservoir of carbon, containing some 80% of all the carbon stored in land vegetation, and about 40% of the carbon residing in soils. Large quantities of carbon may be emitted into the atmosphere during transitions from one forest type of another if mortality releases carbon faster than regeneration and growth absorbs it.

Deserts and arid and semi-arid ecosystems may become more extreme. With few exceptions, deserts are projected to become hotter but not

Barbados Programme

BPOA was created as a follow-up to the 1992 Earth Summit in Rio de Janeiro. The BPOA recognizes that Small Island Developing States (SIDS) have unique problems and vulnerabilities, and need much support in order to overcome them. Secondly, the BPOA is set up on a partnership system, between SIDS and the international community, as well as including essential support from the UN system. The program is the single most important framework for the majority of island countries in determining strategies and policies at all levels—domestic, regional and international. The programme contains a broad range of actions and measures for policy implementation over the short, medium, and long terms. It sets out action in 14 agreed priority areas such as : Climate change, Natural and environmental disasters, Management of wastes, Coastal and marine resources, Fresh water resources, Land resources, Energy resources, Tourism resources, Biodiversity resources, National institutions and administrative capacity, Regional institutions and technical cooperation, Transport and communication, Science and technology, Human resource development.

significantly wetter. Higher temperatures could threaten organisms that now exist near their heat-tolerance limits. Rangelands may experience altered growing seasons. Grasslands support approximately 50% of the world's livestock and are also grazed by wildlife. Shifts in temperatures and precipitation may reshape the boundaries between grasslands, shrublands, forests, and other ecosystems. In tropical regions such changes in the evapo-transpiration cycle could strongly affect productivity and the mix of species.

Mountain regions are already under considerable stress from human activities. The projected declines in mountain glaciers, permafrost, and snow cover will further affect soil stability and hydrological systems (most major river systems start in the mountains). As species and ecosystems are forced to migrate uphill, those limited to mountain tops may have nowhere to go

and become extinct. Agriculture, tourism, hydropower, logging, and other economic activities will also be affected.

Water Resources. Climate change will lead to more precipitation—but also to more evaporation. In general, this acceleration of the hydrological cycle will result in a wetter world. Precipitation will probably increase in some areas and decline in others. Making regional predictions is complicated by the extreme complexity of the hydrological cycle : a change in precipitation may affect surface wetness, reflectivity, and vegetation, which then affect evapo-transpiration and cloud formation, which in turn affect precipitation. In addition, the hydrological system is responding not only to changes in climate and precipitation but also to human activities such as deforestation, urbanization, and the over-use of water supplies.

Many climate models suggest that downspours will in general become more intense. This would increase runoff and floods while reducing the ability of water to infiltrate the soil. Changes in seasonal patterns may affect the regional distribution of both ground and surface water supplies. At the local level, the vegetation and physical properties of the catchment area will further influence how much water is retained. High-latitude regions may see more run-off due to greater precipitation. Runoff would also be affected by a reduction in snowfall, deep snow, and glacier ice, particularly in the spring and summertime when it is traditionally used for hydroelectricity and agriculture. Reservoirs and wells would be also affected. Surface water storage could decline as extreme rainfalls and landslides encourage siltation and thus reduced reservoir capacity. An increase in extreme rainfalls and flooding could also lead to more water being lost as run-off. In the longer term this could also affect aquifers. Reduced water supplies would place additional stress on people, agriculture, and the environment. Climate change will exacerbate the stresses caused by pollution and by growing populations and economies. The most vulnerable regions are arid and semi-arid areas, some low-lying coasts, deltas, and small islands.

Corals in Trouble. By increasing the acidity levels of oceans, global warming could spell doom for corals by 2065, the levels of carbon dioxide (CO_2)—the main culprit behind global warming—are very high. Most of this will eventually be absorbed by sea water, where it will react to form carbonic acid. The normal acidity of the ocean is around pH_8, but because of the above process it will become 74. This increased acidification could have a particularly detrimental effect on corals and other marine organisms, because it reduces the availability of carbonate ions in the water, which are used by corals to make their hard parts. There are 78,000 gigatonnes of carbon locked up in the ocean sediments compared with 750 gigatonnes of carbon in the atmosphere. Global warming could have very serious implications for the water bodies, but unfortunately the climate change research has primarily concentrated on the impacts on land and atmosphere only.

Infrastructure, Industry and Human Settlements. Climate change will affect human settlements. Settlements that depend heavily on commercial fishing, subsistence agriculture or on natural resources are particularly vulnerable. Though climate change will often have less impact on this sector than will economic development, technological change, and other social and environmental forces, it is likely to exacerbate the total stress on settlements. Infrastructure will become more vulnerable to flooding and landslides. Tropical cyclones are expected to become more destructive in some areas.

Warming dryness and flooding could undermine water supplies. Settlements in regions that are already water-deficient—including much of North Africa, the Middle East, Southwest Asia, portions of western North America and some Pacific islands—can be expected to face still-higher demands for water as the climate warms. There are no obvious low-cost ways in which to obtain increased freshwater supplies in many of these regions. In some regions, repeated flooding could create problems with water quality.

Sea-level rise will affect coastal infrastructure and resource-based industries. Many coastlines are highly developed and contain human settlements, industry, ports, and other infrastructure. Many of the most vulnerable regions include some small island nations, low-lying deltas, developing countries and densely populated coasts that currently lack extensive sea and coastal defence systems. Several industries such as tourism and recreation—the principle earners for many island economics—are particularly dependent on coastal resources.

Climate Disasters and Extreme Events. Climate change is expected to increase the frequency and severity of heat waves. More hot weather

Islands in Danger

The pacific island nations of Tuvalu, Kiribati, Nauru, Niue, the Marshall islands and the cook islands may all be wiped out in 50 years due to global warming. The rise in world temperatures means higher melting rate of glaciers and thus release of more water which had hitherto been trapped in the from of ice in the continents. This release of more water from glaciers has led to a rise in sea level and is threatening the very existence of these tiny islands.

The precarious position of these islands can be gauged from the fact that Tuvalu is just five metres above sea level at its highest point.

The six island nations met at the Annual Pacific Islands Forum and came down heavily on the US for not signing the Kyoto Protocol. The issue was discussed in the earth summit held in Johannesburg from Aug. 26–Sep. 4, 2002. Tuvalu is contemplating suing the US and Australia over their failure to ratify the Kyoto protocol.

will cause more deaths and illnesses among the elderly and urban poor. Together with increased summer drying, it will lead to greater heat stress for livestock and wildlife, more damage to crops, more forest fires, and more pressure on water supplies. Other likely impacts are a shift in tourist destinations and a boost in demand for energy. More intense rainfall events may lead to great flooding in some regions. In addition to floods, this could contribute to more landslides, avalanches, and soil erosion.

Major climate patterns could shift. Although centered in the Southern Pacific, the El Nino/Southern Oscillation (ENSO) phenomenon affects the weather and climate in much of the tropics. Climate change could intensify the droughts and floods that are associated with El Niño events in these regions. Similarly, new patterns could emerge for the Asian summer monsoon, which affects large areas of temperate and tropical Asia. Likely impacts would include a greater annual variability in the monsoon's precipitation levels, leading to more intense floods and droughts.

World Response

The First World Climate conference recognized climate change as a serious problem in 1979. This scientific gathering explored how climate change might affect human activities. It issued a declaration calling on the world's governments "to foresee and prevent potential manmade changes in climate that might be adverse to the well-being of humanity." It also endorsed plans to establish a World Climate Programme (WCP) under the joint responsibility of the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), and the International Council of Scientific Unions (ICSU).

A number of intergovernmental conference focusing on climate change were held in the late 1980s and early 1990s. Together with increasing scientific evidence, these conferences helped to raise international concern about the issue. The key events were the Villach Conference (October 1985), the Toronto Conference (June 1988), the Ottawa Conference (February 1989), the Tata Conference (February 1989), the Hague Conference and Declaration (March 1989), the Noordwijk Ministerial Conference (November 1989), the Cairo Compact (December 1989), the Bergen Conference (May 1990), and the Second World Climate Conference (November 1990).

The Intergovernmental Panel on Climate Change (IPCC) released its First Assessment Report in 1990. Established in 1988 by UNEP and WMO, the Panel was given a mandate to assess the state of existing knowledge about the climate system and climate change; the environmental, economic, and social impacts of climate change; and the possible response strategies. In December 1990, the UN General Assembly approved the start of treaty negotiations. The Intergovernmental Negotiating Committee for a Framework Convention on climate change (INC/FCCC) met for five sessions between

February 1991 and May 1992. Facing a strict deadline—the June 1992 Rio "Earth Summit"—negotiators from 150 countries finalized the convention in just 15 months. The 1992 UN Framework Convention on climate change was signed by 154 states (plus the EC) at Rio de Janeiro. Twenty years after the 1972 Stockholm Declaration first laid the foundations of contemporary environmental policy, the Earth Summit became the largest ever gathering of Heads of State. Other agreements adopted at Rio were the Rio Declaration, Agenda 21, the Convention of Biological Diversity, and Forest Principles. The convention entered into force on 21 March 1994.

The Conference of the Parties (COP) held its first session in Berlin from 28 March–7 April 1995. They agreed that the commitments contained in the convention for developed countries were inadequate and launched the "Berlin Mandate" talks on additional commitments. They also reviewed the first round of national communications and finalized much of the institutional and financial machinery needed to support action under the Convention in the years to come. COP-2 was held at the Palais des Nations in Geneva from 8-19 June 1996. The Kyoto Protocol was adopted at COP-3 in December 1997. Because there was not enough time to finalize all the operational details of how the Protocol would work in practice, COP-4, held in Buenos Aires from 2-13 November 1998, agreed a two year plan of Action for completing the Kyoto rulebook. The agenda of COP-5, which took place in Bonn from 15 October–5 November 1999, was based on this plan. A political agreement on the operational rulebook for the Protocol was reached at COP-6. Meeting from 6 to 25 November 2000, COP-6 made good progress but could not resolve all the issues in the time available. The meeting was suspended and then resumed from 16 to 27 July 2001 in Bonn. The resumed session reached agreement on the political principles of operational rulebook for the Kyoto Protocol. This agreement addressed the emissions trading system, the clean Development Mechanism, the rules for counting emissions reductions from carbon "sinks", and the compliance regime. It also outlined a package of financial and technological support to help developing countries contribute to global action on climate change. The work of translating the Bonn Agreements into detailed legal texts was finalized at COP-7, which was held in Marrakech, Morocco, from 29 October to 9 November 2001.

COP-8 on climate change concluded in New Delhi on November 1, 2002. After lots of efforts and several rounds of negotiations, the participating countries arrived at a near consensus to announce the Delhi Declaration. The issues on which there was no consensus were left out. Among the important points which have been left out of Delhi. Declaration are the issues of providing economic aid to countries most severally affected by the global climate change. The emphasis on application of new technology in the field of energy was also left out due to the protests of the oil exporting countries. The Delhi Declaration is also noteworthily for its emphasis on the

need for the United States, Russia and other developed countries, which are yet to ratify the Kyoto Protocol on reduction of GHG emissions, to do so at the earliest.

Un-Convention on Climate Change

The United Nations Framework Convention on Climate Change is the foundation of global efforts to combat global warming. Opened for signature in 1992 at the Rio Earth Summit, its ultimate objective is the "stabilization of green house gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system. Such a level should be achieved within a time-frame sufficient

Important Environmental Conventions

Protocol (1987). CFC production and consumption to be frozen at 1986 levels by 1990; that of Halons from 1994; developing countries with consumption of CFCs less than 0.3 kg. to delay compliance by 10 years; protocol effective from January 1989.

Helsinki Declaration (1989). On protection of ozone layer, phase out CFC production and consumption by 2000.

London Conference (1990). CFC production and consumption to be phased out by 2000 (developed countries) and by 2010 (developing countries).

Copenhagen Conference (1992). Phase out CFCs by 1996, Halons by 2000, Carbon tetrachloride by 1996, HCFCs by 2030.

Rio-Earth Summit (1992). Agenda 21 to prevent environmental degradation.

Kyoto Conference (1997). To cut GHG by 5.2 per cent to 1990 levels by 2008-12; Japan (6% cut), US (7% cut), EU (8.1 cut) India and China face no binding.

Stockholm Conference (1972). It was the international conference on Human Environment which was organised in 1972. 114 countries participated in it. The conference declared June 5 as the World Environment Day.

Nairobi Conference (1982). It was a UN Conference held at Nairobi which adopted a report entitled "The World Environment 1972-82".

World Summit on Sustainable Development (2002). It was held in Johannesburg. Over 4,000 delegates from about 100 countries participated in it.

Stockholm Convention (2004). It was held on May 17 aimed at phasing out 12 dangerous pesticides and industrial pollutants (PoPs). More than 150 countries have signed it and about 60 have ratified it.

to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner." They adopted a national programmes for mitigating climate change and develop strategies for adapting to its impacts. They agreed to promote technology transfer and the sustainable management, conservation, and enhancement of green house gas sinks and "reservoirs" (such as forests and oceans). In addition, the parties will take climate change into account in their relevant social, economic, and environmental policies; cooperate in scientific, technical, and educational matters; and promote education, public awareness, and the exchange of information related to climate change.

Industrialized countries undertake several specific commitments. Most members of the Organisation for Economic Cooperation and Development (OECD) plus the states of Central and Eastern Europe—known collectively as Annex I countries—committed themselves to adopting policies and measures aimed at returning their green house gas emissions to 1990 levels by the year 2000 (emissions targets for the post-2000 period are addressed by the Kyoto Protocol). They must also submit national communications on a regular basis detailing their climate change strategies. Several states may together adopt a joint emissions target. The countries in transition to a market economy are granted a certain degree of flexibility in implementing their commitments. The richest countries shall provide "new and additional financial resources" and facilitate technology transfer. These so-called Annex II countries (essentially the OECD) will fund the "agreed full cost" incurred by developing countries for submitting their national communications. These funds must be "new and additional" rather than redirected from existing development aid funds. The convention recognizes that the extent to which developing country parties implement their commitments will depend on financial and technical assistance from the developed countries.

The convention also establishes two subsidiary bodies. The Subsidiary Body for Scientific and Technological Advice (SBSTA) provides the COP with timely information and advice on scientific and technological matters relating to the Convention. The Subsidiary Body for Implementation (SBI) helps with the assessment and review of the Convention's implementation.

A financial mechanism provides funds on a grant or concessional basis. The Convention states that this mechanism shall be guided by, and be accountable to, the Conference of the Parties, which shall decide on its policies, programme priorities, and eligibility criteria. There should be an equitable and balanced representation of all Parties within a transparent system of governance. The operation of the financial mechanism may be entrusted to one or more international entities. The Convention assigns this role to the Global Environment Facility (GEF) on an interim basis; in 1999 the COP decided to entrust the GEF with this responsibility on an ongoing basis and to review the financial mechanism every four years. In

2001 the COP agreed on the need to establish two new funds under the Convention—a special climate change fund and a fund for least developed countries—to help developing countries adapt to climate change impacts, obtain clear technologies, and limit the growth in their emissions. These funds are to be managed within GEF framework.

Kyoto Protocol. In December 1997, delegates from nearly 160 nations participated in a U.N. Summit on Global Warming held in Kyoto, Japan. During the conference, delegates approved a legally binding treaty for countries to reduce emissions of green house gases. Listed below are some details of the treaty.

Emission Reductions. The treaty sets a goal for 38 industrialized nations to reduce their combined green house emissions by 5.2% below 1990 levels between the years 2008 and 2012. To meet that target, some countries must reduce emissions by greater amounts than others. The 15 member European Union is committed to reducing its emissions by 8% below 1990 levels, while the US is bound to a 7% reduction; Japan would be required to meet a 6% reduction target. The treaty exempts several nations that are considered developed but are in the midst of prolonged economic declines, such as Russia and Ukraine, from any reductions, while other countries, including Norway and New Zealand, have agreed to much higher emission reductions. Developing countries, such as China, India and most African countries, are not bound by emissions mandates but are asked to set their own voluntary targets.

Gases Affected. The treaty covers six gases, including the major green house gases of carbon dioxide, methane and nitrous oxide. Three other synthetic gases—hydrofluorocarbons, parfluorocarbons and sulphur hexachloride—were also included.

Ratification Process. The Kyoto Protocol was approved by a majority of the countries attending the conference. The treaty will take effect when 55 nations, representing those responsible for emitting 55% of the total carbon dioxide released in 1990, ratify the protocol.

Implementation and Enforcement. The treaty tentatively allows for a controversial system of emissions trading. Under the system, countries that fail to reduce their green house gas emissions by their target amounts may buy emissions credits from those nations that are able to reduce their emissions below targeted levels.

However, the United States has abandoned the Kyoto Protocol in March, 2001. Therefore the participation of other G8 nation's have become crucial to get the accord into force. The cynical view of UN summit on global warming was becoming evident since November 2000, at the Hague Summit in Holland, which attracted more businessmen than bonafied environmentalists.

Finally Enter's into Force. On February 16, 2005, the much awaited Kyoto Protocol entered into force, becoming legally enforceable on all parties that have ratified the treaty. The treaty aims to curtail he emission of green-house gases (GHG) into the atmosphere, which is the major culprit of global warming. The enforcement of the treaty was made possible because Russia recently ratified it and deposited its instrument of ratification with the UN Secretary-General on November 18, 2004.

Besides, the first project of Clean Development Mechanism (CDM) was also registered. This project would reduce the emissions of methane from a landfill in Brazil, by capturing the gas and using it to generate electricity. The CDM is a cheap mechanism available to developed countries under the Kyoto Protocol to reduce their GHG, emissions by investing in projects in developing countries rather than in more expensive projects in their own countries.

Global Warming

Global warming is one of the most serious global environmental issues. Extensive researches have been carried out to study this phenomena in detail. No doubt, it is a burning issue.

Sunlight reaches the earth as visible radiation of wave length 0.58 to 0.69 nm. A portion of it is absorbed in the atmosphere and earth's surface. This reflected radiation will be having longer wave length (10 nm). Certain ghases like CO_2, CFC, CH_4N_2O present in the atmosphere along with water vapour absorb these radiation and will not let it escape. So the atmosphere gets warmed up as in the case of a "green house". In fact the green house effect is responsible for preventing the atmosphere temperature from falling to sub zero. This phenomenon ensures that there is sufficiently high temperature for the life to exit.

Because of the release of these green house gases in abundance, the equilibrium has been titled and the global temperature started increasing from the normal. There is no doubt that there is an overall warming trend on the earth. In the past 10 years, we have had the 7 of the 8 hottest ever recorded years. The present global mean temperature is 15°C. Global warming due to the green house gases has been increasing at the rate of 0.3°C to 0.6°C over the last 130 years. Global warming in India during the period 1901-1980 has been estimated to be 0.5°C. A rise in the global temperature by just 1 or 2°C would be catastrophic.

The "green house effect" is a phrase popularly used to describe the increased warming of the earth's surface and lower atmosphere due to higher-levels of carbon dioxide and other green house gases, such as methane, nitrous oxides, and the chlorofluorocarbons. Like the glass panels of a green house these gases allow radiation to reach the earth but prevent their going back.

If some of the principal green house gases continue to increase at the present rate, the global temperature can rise by 1.5 to 4.5°C in the next 50 years. Such an increase in atmospheric temperature is expected to trigger off major changes in the patterns of rainfall and seasonal cycles, a significant rise in sea level and a rapid increase in the frequency of the occurrence of extreme natural disasters.

Mechanism of Global Warming. The heat that is radiated back from the rocks and oceans is at a changed wavelength from the wavelength of insolation. Reflected heat is in the form of long-wave radiation. This contrast accounts for the normal green house effect, which shapes life on earth. The long-wave radiation does not travel back through the atmosphere because it is partly absorbed by some naturally occurring substances and gases in the atmosphere. The principal one is water vapour, generally in the well-known form of clouds. Then there are carbon dioxide, methane, nitrous oxide and ozone. These gases are magnified due to absorbing outgoing long-wave radiation than incoming short-wave radiation. They therefore trap the heat; hence the natural green house effect.

Thus the green house effect caused by the difference in absorption rates of long and short wave radiation makes the earth far hotter than it would otherwise be. Estimates vary, but the general consensus is that the earth is 33°C (91°F) warmer than it would be without the natural green house effect, that is with the mixture of gases in the atmosphere which existed before the industrial revolution began in about 1750. If everything else remains constant, an increase in any one of the green house gases would cause more heat to be trapped.

Although at present we understand how our activities have led to the increase in carbon dioxide levels, but what exactly caused the increase or decrease in the level of carbon dioxide in the geological past is still not correctly understood.

Green House Gases. Main culprits—the gases like CO_2, CH_4, N_2O, CFC and water vapour are the elements which absorb the reflected rays and increase the temperature.

(i) **Carbon Dioxide.** It is held that carbon dioxide in geological past was preponderant in atmosphere.

But that is only part of the equation. Carbon dioxide is taken out of the atmosphere by photosynthesis all the time. When plants decay, or when forest are chopped down and burned, or are eaten by animal, the gas is released again. The same process happens at sea. Billions of tiny sea creatures called plankton are also using carbon dioxide to grow. All the time they are living, being eaten and dying in the two thirds of the earth's surface covered by the oceans. Precisely how much carbon is gained on lost in this way is still not known, but it is known that some carbon is being taken out of the system when these creatures die. Their bodies sink to the

bottom of the sea where some of the carbon remains in the mud. Most estimates say that about one third of the carbon dioxide being released into the atmosphere at the moment is absorbed by the oceans.

This process of using and then fixing carbon dioxide into carbon through billions of years has changed the composition of the atmosphere and the face of the planet. If the atmosphere had not changed because of plants and had remained heavily laced with carbon dioxide, it is estimated that the world would be 45°C (113°F) hotter than it is now.

By the time humans had begun to walk upright, nitrogen was by far the dominant gas. Carbon dioxide had shrunk to a tiny proportion of the atmosphere, and the oxygen had grown to about 21 per cent. In fact, carbon dioxide had shrunk to roughly 0.03 per cent of the air. In the last couple of thousand years it appears to have been stable at 280 parts per million by volume.

It made the world warmer than it would be without the green house effect, but not too hot. The problem is that we seem to have upset the balance. In the last 200 years, because of human activities, the proportion of carbon dioxide has risen from 280 parts per million to 360 parts per million at the end of 1995. Thus, in the time since the beginning of the industrial revolution, the proportion of carbon dioxide has risen by 27 per cent. As industrial activity increases, particularly in the developing world, the rate of carbon dioxide release grows too. Currently it is increasing by about 3 parts per million a year.

(ii) **Methane.** Methane is a very scarce gas, measured in parts per billion in the atmosphere rather than parts per million, but it has a much greater warming effect-21 times that of carbon dioxide by volume. While carbon dioxide has increased by 27 per cent in the past 200 years, methane has increased 145 per cent from 700 parts per billion to 1720 parts per

Global Warming : The Cooler Side

Global warming has been painted as a villain. However, some scientists beg to differ. A bunch of scientists have given a very interesting argument which if true will turn global warming into a blessing. According to them, a warming ocean will lead to increased evaporation, thence clouds and precipitation. The greater than normal cloud cover would decrease incoming radiation, lowering temperature at the earth's surface (A Scientist V. Ramanatha has verified this point). The increased precipitation would enlarge the continental glaciers in Antarctica and Greenland, thereby resulting in a falling rather than rising sea level. The greater than normal rainfall would enhance the growth of vegetation, crops and forests, decreasing as a result, the area of arid regions and improving the food supply worldwide!

billion. It is calculated to be responsible for about 15-20 per cent of the enhanced green house effect.

Despite the steepness of the rate of increase of methane and its greater potential for global warming, molecule for molecule, scientists seem less bothered about this rise than that of carbon dioxide. The reason is that carbon dioxide survives longer in the atmosphere than methane, between 50 and 200 years. That means, once the increase in volume of gas has occurred, it is much harder to reverse the process. Methane, on the other hand, is destroyed by chemical processes within 12-17 years, so the damage is potentially more easily reversible.

The amount of atmospheric methane has only started to rise since the industrial revolution, and the increase in quantity follows very closely the growth of human population since that time.

Methane emissions have also been increasing for other reasons. Particularly large quantities come from rice paddies and scientists are trying to find new growing techniques to reduce the production of methane in agriculture. Another source of methane is rotting rubbish in landfills. The methane released from coal mining is also significant.

(iii) **Nitrous Oxide.** Nitrous oxide, known as laughing gas and used as an anaesthetic, is another green house gas. Its role is minor but it has a relatively long atmospheric life of 120 years and is steadily growing since pre-industrial times in volume, and is now at 310 parts per billion by volume in the air. Again the exact reasons for this rise is not clear. The burning of wood and other fuels is partly to blame, plus the production of the gas in the ground following the application of ammonia based fertilizers.

(iv) **Chlorofluorocarbons.** Contribution made by CFCs is an entirely artificial phenomenon. These gases were good servants but appear to have turned into monsters. CFCs or chlorofluorocarbons, did not exist at all until they were invented in the 1930s, as always with the best of intentions. For years they were seen only as a great bonus to industry but they turned out to be created a potential disaster too.

They were created as extremely stable, non-toxic and non-inflammable gases which were easy to liquefy under pressure. This meant that they were particularly suitable for use in refrigerators and air-conditioning and as a propellant in aerosol spray cans. In fact they were a great boon, allowing safe domestic refrigerators to be readily available for the first time. A number of different types were developed for different purposes and given different numbers, CFC 11 and 12 for example. Other uses included blowing agents for foam rubber and rigid polyurethane foam in furniture.

CFCs were designed to make our life simpler but in fact they have made it much more complex, and have left us with serious dangers to health and world food supplies. CFCs have been recognized as responsible for both severe damage to the ozone layer and potentially exacerbating

global warming. They were first identified as harmful to the ozone layer in 1974 but at that stage it was all just theoretical. The United States banned them in aerosols as a precaution in 1978 but it was not until 1985 when a 'hole' in the ozone layer was mapped in the Antarctic that international action began.

Governments reacted surprisingly quickly, worked out what to do and had signed the Montreal Protocol by 1987. Subsequently more ozone depleters were identified and target dates for various chemicals to be reduced or substituted agreed.

But while it was the effect that CFCs had on the ozone layer that grabbed the immediate attention of scientists and politicians alike, it was also

Table 14.1 :

Percentage Increase of Concentration of Green House Gas & Their Warming Capacity			
Gas (%)	Average Increase Rate Rate	Warming Per year (%)	Global Warming Contribution Capacity
Carbon Dioxide	0.5	1	55
Methane	1.0	36	20
Nitrous Oxide	0.3	140	5
Hydro Fluro Carbon	0.4	14600	6
Per Fluro Carbon	0.4	17000	12
Ozone	0.5	430	2
Note : In Kyoto Protocol Sulphur Hexa Floride is identified as a main green house gas.			

recognized that CFCs are global warming gases themselves. The Prime worry was that the chlorine contained in CFCs, once in the upper atmosphere, acts to destroy some of the ozone.

At ground level ozone assumes a different role and is regarded as an unwanted pollutant because it damages human lungs and is toxic to plants. Here, where it is not wanted, quantities are rising. The gases responsible for creating low level ozone are carbon monoxide, the oxides of nitrogen (all found in car exhaust fumes), methane and other hydrocarbons. The added ingredient is sunlight, which is why the smoke and fumes humans emit in going about their daily lives come back to haunt us on sunny day.

Exactly what is the net effect of having CFCs in the atmosphere on global warming over the long term is not yet clear. For the first time in 1995, because of the efforts towards cutting out ozone depleters, the level

Table 14.2 : Key Impacts of Global Warming

Change	Impact
More hot days, intense heat waves	Increased incidence of illness, stress on wild life, damage to crops, more need of energy for cooling purposes, more pests and disease vectors.
	Droughts, damage to building foundations due to ground shrinkage, erosion of water quantity and quality. Forest fires.
More intense precipitation	Increased floods, landslides, avalanches, soil erosion, run off. Intense summers in mid latitude continental heartlands.
Tropical cyclones	Risk to human life, more infectious disease, coastal erosion, damage to infrastructure, damage to coastal infrastructure.
El nino	Droughts and floods in different areas, decrease in agricultural productivity.
Increased Asian summer monsoon	Increase in flood and drought magnitudes.
Increased intensity of mid latitude	Increased rise to human life and health, damage to
Storms	Coastal ecosystems.

of CFCs in the air will reduced considerably and its beneficial influence—will be felt for a long time. Even if all goes well it will be another 50 years before the problems of these synthetic chemicals and the resultant ozone depletion fade into insignificance in the battle to save the planet from ourselves. Meanwhile their effect on climate change will have to be carefully monitored.

One result of the initial priority given to ozone depletion over global warming is that the political responsibility for phasing out CFCs remains with the Montreal Protocol. Because CFCs are dealt with in the that forum

they are specifically excluded from the climate change convention. The one problem it poses for climate is that one group of substitutes, the HFCs, are although not ozone depleters but are global warming gases, but so far the problem is not significant. Hence, a comprehensive approach towards all aspect of climate change is the need of the hour.

Effects of Global Warming. Symptoms of global warming have started manifesting themselves because of their effects on the environment and the ecosystem. The frequent incidents of coral bleaching (because of the increased ocean temperature), the unpredictable changes in the weather/climate, decrease of oxygen content of the atmosphere, uncontrolled bloom of toxic planktons in ocean (red tides), changes of the bonding pattern of alkenes in the marine environment etc., are some of the manifestations or indicators of global warming.

One of the ill effects of global warming is thought to be the rise in the sea level and submergence of low lying geographical regions. It has been estimated that global sea level is rising at a rate of 1-3 mm/year. It is expected that in this century, sea level shall rise by 48 cm. It has been reported that, if the present CO_2 emission rate continues over the next century, earth's climate may heat for about 500 years and there shall be a rise of temperature by 7°C. At that time the thermal expansion of sea water shall raise the MSL by 2m. Along with this, the melting of ice caps at poles will raise the MSL considerably. Increase of MSL by just 2m is enough to wash away whole of Maldives & Bangladesh.

Global warming activates the hydrological cycle along with warming of the environment. It bring forth unpredictable climate changes causing drought at certain places and cyclones and heavy showers at some other places. Another effect of global warming is the CO_2 fertilization—the increase in productivity of plants especially the ones following C^3 photosynthesis (e.g., rice, wheat).

Decisions of Kyoto Protocol

- By 2012, developed countries would reduce their collective emissions by 5.2% from 1990 levels, with each country being committed to a particular figure.
- The emissions covered by the Protocol are not only carbon dioxide, but also methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfer hexafluoride.
- These commitments would be reckoned on a net basis, considering sinks as well as sources, and each country most credibly measure its contribution and meet its commitment.
- Countries may fulfil their commitments jointly (such as with regional agreements) and they may improve the efficiency of compliance through "flexibility mechanisms."

The global warming is likely to reduce the availability of agricultural land as river deltas may be inundated due to rise in sea level. Agricultural pests may prosper to cause widespread damage to crop at increased temperature. The agricultural production would be severely affected due to drought which may become a more common phenomenon in semi arid and arid regions.

Global Warming Cuts Rice Harvest. Global warming has cut rice harvests by at least 10% and possibly much more, scientists in the Philippines reported in July 2004, after studying 12 years of rising temperatures and falling yields. According to the scientists based at the International Rice Research Institute (IRRI), Philippines, the impact could be significant for may of the world's poorest people, because rice production had to rise by 1% a year to meet world demand.

However, temperatures are predicted to rise further, and the scientists calculate that rice yields fall by 10% for every 10 centigrade rise in night temperature. The research used temperature data over 25 years (1979-2003) and harvest over 12 years (1992-2003) at the institute's farm near Manila. Most of the new production has to come from existing crop land to avoid destroying ecosystems which are habits for animals. Daily average night

Arctic Climate Warming

The Arctic Climate Impact Assessment (ACIA), a four year study carried out by the United National Environment Programme (UNEP), provides clear evidence that the climate is warming rapidly now.

Conducted by an international term of 300 scientists, the study projects, larger changes in near future. Increasing concentrations of Greenhouse Gases (GHG) from human activities are projected to contribute to additional warming of 3-9 degrees over the next 100 years. Its global impact, such as sea-level increase, will be staggering, says the report.

The Arctic region, barometer on global climate change, is considered an early warning system on environmental warming worldwide. What happens there is of concern for everyone because Arctic warming and its consequences have global implications.

The ACIA predicts that Arctic vegetation zones and animal species will be affected. Retreating sea ice will reduce the habitat for polar bears, wolves, ice-habiting seeds and marine birds and even threaten some species with extinction. Such changes will also impact on many Arctic indigenous communities who depend on such animals, not only for food, but also as the basis for cultural and social identity, according to the report. And the regions, as the Arctic glaciers melt, it will be the developing countries, with limited means to adopt to environmental changes, that will suffer most.

time temperature has risen at a faster rate in the past century than day time temperature as green house gases have increased. Such gases trap the Sun's heat, creating the "Greenhouse effect". The earth's mean surface temperature rose by about half a degree centigrade in the 20th century and is projected to increase 1.5 degree to 4.5 degree centigrade in the next 100 years. Further, harvest will be affected by increases in green house gases such as carbon dioxide and trace gases such as ozone, along with rising temperature, plant respiration increases as temperature rise, taking energy that otherwise would be devoted to grow and reducing yields.

Global Warming might help to increase rice yields in areas where temperatures are now too cool for year-round production. Many climatologists predict a global rise of 3.5°C this century, could hit yields by a further 30%.

Himachal Glaciers Drying up

Four glaciers of the Baspa may dry up due to global warming. A study indicates that four glaciers of the Baspa basin of Himachal Pradesh face terminal retreat. In other words they may dry up. "If climatic condition remain same as these in 2000, then our climate model suggests that the four glaciers will disappear by 2040. The extent of global warming impact on the Himalayan ice-fields is a matter of great concern. Fifteen glaciers of the basin are also on this list, as they too are losing more than what is getting accumulated. Geologists worldwide consider mass balance as the ideal yardstick of glacial retreat (glacial mass balance means the total loss/gain in glacial ice and show at the end of a hydrological year).

The melting however, is no longer favourable for the environs, with global warming disturbing the equilibrium existing between the seasonal variations.

According to researchers, four of the 19 glaciers are already doomed because they do not have any accumulation area, implying there is no formation of new glacial ice. Rather, 0.2347 cubic km of glacial ice was lost during 2001-02—a fact clearly indicative of a future catastrophe.

Glacial ice is the core of a glacier. The ice is formed during the snow transformation process. Since all the snow of these glaciers is melting due to more than normal temperatures, there is none available to metamorphese into glacial ice. These four glaciers are so susceptible because they face the southern direction and receive more solar radiation than the northern facing ice-bodies.

Baspa glaciers located at an altitude of around 5000 metres have lost 24 percent of their ice cover. While those of 5,400 metres and above have retreated by 14 per cent. At present, the unnatural melting has increased the stream run off of Baspa river.

Checking Greenhouse Effect. Is the growing green house effect inevitable, or is there something we can do to reverse it, stabilise it, or at least adapt to it? To be sure, it is practically impossible to eliminate the green house problem totally, still most researches agree that there is plenty that can be done at least to slow down the pace. The only good thing about the global warming is that it brought many countries around the same table many times.

Efforts to educate the public about global warming started long back. Efforts to reduce the release of green house gases (especially CO_2) has already begun. In 1992, the famous Rio de Janeiro Earth Summit took place. Strategies were framed to reduce green house gas emission. The industrialized nations had to accept the target for stabilizing CO_2 emission (from burning fossil fuel) by the year 2000 A.D. Also they had to provide funds to the developing/underdeveloped countries to reduce their emissions levels.

Following are a few steps to reduce the impact of green house effect :

- Global warming is caused by the pollutants released into the atmosphere. Human beings are nature's greatest pollutants. No pollution control programme can work without a check on our runaway population growth. Plan your family and limit its size, consequently global warming can be reduced to significant degree.
- Plant and protect more trees. Trees are carbon sinks only where they are young and vigorously growing. To be productive, trees must be cut lopped when allowed to rot or burn, they release whatever carbon they have stored.
- To meet the firewood needs, take a recourse to agroforestry. Plant quick dwarf trees on field buns, as hedgerows and as windbreaks. Follow lopping instead of one-time felling of trees.
- Use smokeless Chulhas. They not only emit less smoke but make the best use of the available energy.
- For cooking food, drying agricultural produce and heating water, use solar energy whenever possible.
- Stop forthwith the practice of shifting cultivation and slash and burn agriculture. The currently available alternative cropping and farming systems are not only environmentally friendly but also highly remunerative.
- Restore degraded shrub jungles, glasslands and ecosystem through afforestation and regeneration of grasses.
- Avoid the use of aerosols, push button spray bottles and foam packing. Drastically cut down the use of airconditioners. All these release chlorofluorocarbons, which have a long lifespan of 75-110 years and are 15,000 times as powerful as carbon dioxide in creating a green house effects in addition to being harmful for the ozone layer.

What Governments Can Do?

- Encourage energy conservation and recycling.
- Increase funds for research on alternative energy sources, particularly for the development of low-cost photovoltaic cells.
- Build high efficiency power plants and phase out the conventional facilities which have very low efficiency.
- Launch a massive tree planting programme.
- Educate public on environment friendly technologies.
- Encourage technologies that recover methane from swampy fields and land fields.

Reforestation and greater reliance on renewable sources of energy is the need of the hour. The crop genetic base should be strengthened and we should start looking for adaptive strategies. Further institutional action is needed to build a scientific consensus on physical, biological, and social aspects of atmospheric pollution issues. Even more important is the need for public awareness and undertaking which could lead to demands for political action.

Acid Rain

When atmospheric water droplets combine with a range of man-made chemical air pollutants, acid rain is formed. Other forms of precipitation like mist and snow may also be acidic for similar reasons.

The main pollutants involved are oxides of nitrogen and sulphur. In nature, volcanoes, fires, and decomposing matter emit these substances in small amounts. However, since the advent of the Industrial Revolution, human activities have been releasing such pollutants in large quantities. Such emissions are very high in the major industrial centres and have been increasing rapidly since the mid-twentieth century.

Automobiles and coal-and oil-fired power stations are major sources of acid-forming compounds. In fact, any burning of coal, oil and (to a lesser extent) natural gas produces these compounds.

Acid rain ultimately falls on the ground, sometimes hundreds of kilometres from the area in which it formed and generally one to four days later. The effects of such acid rain are generally quite damaging.

Effect of Acid Rain. When soil is acidified, it leads to a loss of productivity. The acidification damages plant roots and they are not able to draw in enough nutrients to survive and grow.

When trees, particularly confiers, are exposed to acid rain for several years, they begin to lose their leaves and die. This is one of several causes for the decline of forests in Europe, North America, and Japan. Plants like orchids, lichens, and mosses are also very sensitive to acid fallout.

Acid rain falling on lakes and rivers destroys the life forms that live in these water bodies. Thousands of lakes in Sweden, Norway, and Canada,

for example, have been permanently affected by acid fallout. Fish populations have died nand so have species, such as otters, amphibians, and birds that depended on fish for their food.

Acid rain harms people directly when they breathe in the acidic air. Acid rain can also harm people indirectly, when they eat fish caught in affected lakes or rivers.

Old buildings are also threatened by acid rain. Acid fallout has caused the famous St. Paul's Cathedral in London to decay more in the last 50 years than it has in the previous two centuries. Some famous statues, such as the Lincoln Memorial and Michaelangelo's statue of Marcus Aurelius, have started deteriorating because of the effects of acid rain. The same is true of many historic buildings in Europe.

The Taj Mahal was also threatened by acid rain caused by factories in Agra. Thanks to the orders of the Supreme Court many of these industries have been shifted or closed down.

A side effect of acid rain is the leaching of aluminium out of the soil into water bodies. Aluminium is very toxic for fish and the birds that prey on them. Sometimes acidification leads to the leaching of cadmium and this can also have adverse effects on animals.

Control of Acid Rain.

- Emission of SO_2 and NO_2 from industries and power plants should be reduced by using pollution control equipments.
- Limiting of lakes and soils should be done to correct the adverse effects of acid rain.
- A coating of protective layer of inert polymer should be given in the interior of water pipes for drinking water.

Ozone Layer Depletion

Ozone is a poisonous gas made up of molecules consisting of three oxygen atoms. This gas is extremely rare in the atmosphere, representing just three out of every 10 million molecules. Ninety per cent of ozone exists in the upper atmosphere, or stratosphere, between 10 km and 50 km above the Earth.

The ozone layer in the atmosphere absorbs most of the harmful ultraviolet-B (UV-B) radiation from the Sun. It also completely screens out the deadly UV-C radiation. The ozone shield is thus essential to protect life.

Depleting the ozone layer allows more UV-B rays to reach the Earth. The result is an increase in skin cancers, eye cataracts, weakened immune systems, reduced plant yields, damage to ocean ecosystems and reduced fishing yields, and adverse effects on animals.

In the 1970s, scientists discovered that when CFCs (chlorofluorocarbons, used as refrigerants and aerosol propellants), finally break apart in the

atmosphere and release chlorine atoms, they cause ozone depletion. Bromine atoms released by halons (used in fire extinguishers) have the same effect.

The ozone layer over the Antarctic has steadily weakened since measurements started in the early 1980s. The land area under the ozone-depleted atmosphere has increased steadily to more than 20 million sq km in the early 1990s and has varied between 20 and 29 million sq km since then. In 2000, the area of the ozone hole reached a record 29 million sq km.

While no hole has appeared elsewhere, the Arctic spring has seen the ozone layer over the North Pole thinning by up to 30 per cent. The depletion over Europe and other high latitudes varies between 5 and 30 per cent.

International Initiatives. Intergovernmental negotiations for an international agreement to phase out ozone-depleting substances started in 1981 and concluded with the adoption of the Vienna Convention for the Protection of the Ozone Layer in March 1985.

The Vienna Convention encourages intergovernmental cooperation on research, systematic observation of the ozone layer, monitoring of CFC production, and the exchange of information. The Convention Commits the signatories to taking general measures to protect human health and the environment against human activities that modify the ozone layer. It is a framework agreement and does not contain legally binding controls or targets.

The Convention did, however, set an important precedent. For the first time nations agreed in principle to tackle a global environmental problem before its effects were felt, or even scientifically proven.

In May 1985, British scientists published their discovery of severe ozone depletion in the Antarctic. Their findings were confirmed by American satellite observation and offered the first proof of severe ozone depletion. The discovery of the 'Ozone Hole' shocked the world. It is regarded as one of the major environmental disasters of the twentieth century.

Governments now recognize the need for stronger measures to reduce the production and consumption of a number of CFCs and several halons. As a result, the Montreal Protocol on substances that Deplete the Ozone Layer was adopted in September 1987.

Ninety-six chemicals are presently controlled by the Montreal Protocol and are subject to phase-out schedules under it. The Protocol was designed so that these schedules could be revised on the basis of periodic scientific and technological assessments.

Governments are not legally bound by the protocol until they ratify it as well as the Amendments to it. Unfortunately, while most governments have

ratified the Protocol, ratification of the Amendments, with their stronger control measures, still lags behind.

Results. The Montreal Protocol is working. However, even with full compliance with the Protocol by all parties, the ozone layer will remain particularly vulnerable during the next decade or so.

In 1986 the total consumption of CFCs worldwide was about 1.1 million ODP (Ozone Depleting Potential) tons; by 2001 this had come down to about 110,000 tons. It has been calculated that without the Montreal Protocol, global consumption would have reached about three million tons in the year 2010 and eight million tons in 2060, resulting in massive ozone layer depletion.

Without the Protocol, there would have been a doubling of UV-B radiation reaching the Earth in the northern mid-latitudes and aquadrupling of the amount in the South. The amount of ozone-depleting chemicals in the atmosphere would have been five times greater. The implications of this would have been horrendous : 19 million more cases of cancer and 130 million more cases of eye cataracts.

The bulk of the 1986 total, or about 0.9 million ODP tons, was consumed in developed countries but by 2001 these countries consumed just about 7000 tonnes. The developing countries have reduced their CFC consumption by about 15 per cent between 1986 and 2001.

Scientists predict that ozone depletion will reach its worst point during the next few years and the gradually decline until the ozone layer returns to normal in around 2050, assuming that the Montreal Protocol is fully implemented.

The success of ozone protection has been possible because science and industry have been able to develop and commercialize alternatives to ozone-depleting chemicals. Developed countries ended the use of CFCs faster and with less cost than was originally anticipated.

Protocol Lessons. The efforts of the world community to protect the ozone layer are a fascinating example of how humanity can act as one to face a common danger. The Protocol offers many lessons that could be applied to solving other global environmental issues :

- Adhere to the 'precautionary principle' because waiting for complete scientific proof can delay action to the point where the damage becomes irreversible.
- Send consistent and credible signals to industry (for example, by adopting legally binding phase-out schedules) so that they have an incentive to develop new and cost-effective alternative technologies.
- Ensure that improved scientific understanding can be incorporated quickly into decisions about the provisions of a treaty.

- Promote universal participation by recognizing the 'common but differentiated responsibility' of developing and developed countries and ensuring the necessary financial and technological support to developing countries.
- Base control measures on an integrated assessment of science, economies, and technology.

Nuclear Accidents and Holocaust

Nuclear accidents can occur at any stage of the nuclear fuel cycle. However, the possibility of reactor accidents is viewed more seriously because the effects of reactor accidents are more drastic.

Many estimates of hypothetical accidents in a nuclear power station are made. Such estimates are made taking into consideration various parameters like reactor safety measures which if fail would release large amount of reactor contents, that is, radioactive debris affecting a substantial portion of human population within a particular site in a particular area.

The modern fusion bombs (nuclear bombs) are of the explosive force of 500 kilotons and 10 megatons. In case of a world war, total nuclear exchange of more than 5,000 megatons can be expected. Nuclear bombardment will cause combustion of wood, plastics, petroleum, forests etc. Large quantity of black soot will be carried to the stratosphere. Black soot will absorb solar radiations and won't allow the radiations to reach the earth. Therefore, cooling will result. The infrared radiations which are re-radiated from the atmosphere to the earth will have very less water vapour and carbon dioxide to absorb them. If they leave the lower atmosphere the green house effect will be disturbed and cooling will occur. Due to this cooling effect, water evaporation will also reduce. Therefore, infra-red radiations absorbing water vapours will reduce in the atmosphere. This will also cause cooling. In the stratosphere there won't be significant moisture to rainout the thick soot. So, due to nuclear explosions, a phenomenon opposite to global warming will occur. This is called nuclear winter. It may result in lower global temperature. Even the summer time will experience freezing temperature. It will drastically affect crop production. Crop productivity will reduce substantially causing famines and human sufferings.

The Chernobyl nuclear accident, 1986 has resulted in widespread contamination by radioactive substances (already mentioned in air pollution episodes). The devastation caused by nuclear bombs are not only immediate but may be long lasting. Towards, the end of World War II, bombing of Dresden, Germany caused huge firestorms. This caused particle-laden updrafts in the atmosphere.

Case Study

In the Nuclear holocaust in Japan 1945, two nuclear bombs were dropped on Hiroshima and Nagasaki cities of Japan. One fission bomb was dropped on Hiroshima. This holocaust (large scale destruction of human lives by fire) killed about 100,000 people and destroyed the city. This forceful explosion emitted neutrous and gamma radiations. It had the force of 12 kilotons of trinitrotoluene (TNT). The radioactive strontium (Sr 9o) liberated in the explosion resembles calcium and has the property of replacing calcium of the bones. As a result large scale bone deformities occurred in the inhabitants of these cities. Even after more than 50 years the impacts of the nuclear fallout are still visible.

Wasteland Reclamation

Economically unproductive lands suffering from environmental deterioration are known as wastelands. The wastelands include salt-affected lands, sandy areas, gullied areas, undulating uplands, barren hill-ridge etc. Snow covered areas, glacial areas and areas rendered barren after Jhum cultivation are also included in wastelands. More than half of our country's geographical area (about 175 million ha) is estimated to be wasteland, thus indicating the seriousness of the problem for a country like ours which has to support 1/6th of the world's population.

Maximum wasteland areas in our country lie in Rajasthan (36 million ha) followed by M.P. and Andhra Pradesh. In Haryana the wastelands cover about 8.4% of the total land area and most of it comprises saline, sodic or sandy land areas.

Wastelands are formed by natural processes, which include undulating uplands, snow-covered lands, coastal saline areas, sandy areas etc., or by anthropogenic (man-made) activities leading to eroded, saline or waterlogged lands.

The major anthropogenic activities leading to wasteland formation are deforestation, overgrazing, mining and erroneous agricultural practices. Although deserts are wastelands formed by natural process, but there are many human activities which accelerate the spreading of deserts as we have already discussed.

Wasteland Reclamation Practices. Wasteland reclamation and development in our country falls under the purview of Wasteland Development Board, which works to fulfill the following objectives.

- To improve the physical structure and quality of the marginal soils.
- The improve the availability of good quality water for irrigating these lands.
- To prevent soil erosion, flooding and landslides.

- To conserve the biological resources of the land for sustainable use.

Some important reclamation practices are discussed here.

(a) **Land Development and Leaching.** For reclamation of the salt affected soil, it is necessary to remove the salts from the root-zone which is usually achieved by leaching i.e., by applying excess amount of water to push down the salts. After survey of the extent of salinity problem, soil texture, depth of impermeable layer and water table, land leveling is done to facilitate efficient and uniform application of water. After leveling and ploughing, the field is bunded in small plots and leaching is done. In continuous leaching, 0.5 to 1.0 cm water is required to remove 90% of soluble salts from each cm of the soil depending upon texture. If we use intermittent sprinkling with 25 cm water, it reduces about 90% salinity in the upper 60 cm layer.

(b) **Drainage.** This is required for water-logged soil reclamation where excess water is removed by artificial drainage.

(i) **Surface Drainage.** This is used in areas where water stands on the fields after heavy rains by providing ditches to runoff the excess water. Usually 30-45 cm deep ditches lying parallel to each other at 20-60 m distance are able to remove 5 cm of water within 24 hours.

(ii) **Sub-surface Drainage.** Horizontal sub-surface drainage is provided in the form of perforated corrugated PVC pipes or open-jointed pipes with a envelope of gravel 2-3 m below the land surface. Chances of evaporation of water leading to accumulation of salts almost become nil in this method

The World Bank has funded sub-surface drainage system at Sampla, Rohtak (Haryana) for reducing soil salinity by this method.

(c) **Irrigation Practices.** Surface irrigation with precise land leveling, smoothening and efficient hydraulic design help to reduce water logging and salinity. High frequency irrigation with controlled amount of water helps to maintain better water availability in the upper root zone. Thin and frequent irrigation have been found to be more useful for better crop yield when the irrigation water is saline as compared to few heavy irrigations.

(d) **Selection of Tolerant Crops and Crop Rotations.** Toleration of crops to salts is found to range from sensitive, semi-tolerant, tolerant to highly tolerant. Barley, sugar beet and date-palm are highly tolerant crops which do not suffer from any reduction in crop yield even at a high salinity with electrical conductivity (EC) of 10 ds/m. Wheat, sorghum, pearl millet, soyabean, mustard and coconut are salt-tolerant crops. Rice, millets, maize, pulses, sunflower, sugarcane and many vegetables like bottle gourd, brinjal

etc., are semi-tolerant. These different crop combinations can be grown on saline soils.

(e) **Gypsum Amendment.** Amendment of sodic soils with gypsum is recommended for reducing soil sodicity as calcium of gypsum replaces sodium from the exchangeable sites.

(f) **Green-Manures, Fertilizers and Biofertilizers.** Application of farm yard manure or nitrogen fertilizers have been found to improve saline soils. Green manuring with dhaincha (Sesbania aculeata) sunhemp or guar have also been reported to improve salt-affected soils. Blue green algae have been found to be quite promising as biofertilizers for improving salt-affected soils.

(g) **Afforestation Programmes.** The National Commission on Agriculture (NCA) launched several afforestation schemes in the VIth plan to cope up with the problem of spreading wasteland. The National Wasteland Development Board, in the Ministry of Environment and Forests has set a target of bringing 5 million ha of wasteland annually under firewood and fodder plantation.

(h) **Social Forestry Programmes.** These programmes mostly involve strip plantation on road, rail and canal-sides, rehabilitation of degraded forest lands, farm-forestry, wasteland forest development etc.

Consumerism and Waste Products

Consumerism refers to the consumption of resources by the people. While early human societies used to consume much less resources, with the dawn of industrial era, consumerism has shown an exponential rise. It has been related both to the increase in the population size as well as increase in our demands due to change in lifestyle. Earlier we used to live a much simpler life and used to have fewer wants. In the modern society our needs have multiplied and so consumerism of resources has also multiplied.

Our population was less than 1 million for thousands of years ever since we evolved on this earth. Today we have crossed the six billion mark and are likely to reach 11 billion by 2045 as per World Bank estimates. Let us see how the changing population trends influence consumerism of natural resources and generation of wastes. Two types of conditions of population and consumerism of resources has also multiplied.

(a) **People Over-Population.** It occurs when there are more people than available supplies of food, water and other important resources in the area. Excessive population pressure causes degradation of the limited resources, and there is absolute poverty, under-nourishment and premature deaths.

This occurs in less developed countries (LDCs). Here due to large number of people, adequate resources are not available for all. So there is less per capita consumption although overall consumption is high.

(b) **Consumption Over-Population.** This occurs in the more developed countries (MDCs). Here population size is smaller while resources are in abundance and due to luxurious lifestyle, per capita consumption of resources is very high. More the consumption of resources more is the waste generation and greater is the degradation of the environment.

This concept can be explained by using the model of Paul Enrich and John Hodlren (1972) :

Number of people	×	Per Capita use of resources	×	Waste generated per unit of resource used	=	Overall Environmental Impact

This can be illustrated diagrammatically as shown in Fig. 6.5.

In LDC's—No. of people is very high, but per capita use of resources and waste generated are less.

In MDC's—No. of people is low, but per capita use of resources and wastes generated are very high.

The overall environmental impact of these two types of consumerism may be same or even greater in case of MDC's.

Thus, consumerism varies with the country and USA is known for maximum consumerism. The throw-away attitude and luxurious lifestyle of the West results in very high resource use as compared to less developed countries. With every unit of energy, mineral or any resource used there is waste generation and pollution in the environment.

A comparison of USA and India can illustrate this point more clearly :

Table 14.3 :
Comparison of Consumerism and Waste Generation

Parameter	Percent Global Values	
	USA	India
Population	4.7%	16%
Production of Goods	21%	1%
Energy use	25%	3%
Pollutants/wastes	25%	3%
CFC's Production	22%	0.7%

Model Questions

1. What are greenhouse gases and greenhouse effect?
2. What are the causes and effects of climate change?
3. What are the major implication of enhanced global warming?
4. Is the global climate changing?
5. What is global warming and how does it occur?
6. What is ozone layer depletion?
7. What is acid rain and what are its effects?
8. What can be done about acid rain?
9. What are the international initiatives against the depletion of the ozone layer?
10. What have been the lessons of the Montreal Protocol?
11. What is the Kyoto Protocol?
12. Write a critical note on nuclear holocaust.
13. Discuss various measures for wasteland reclamation.
14. How are population, consumerism and waste production interrelated?

15
Environmental Legislation

Environmental concerns regulation, protection or prohibition—of activities affecting the environment, which includes the air, water, plant and animal life. Like other laws, environmental law is also made to three levels—international, national and local or municipal/domestic laws. Environmental law, like other laws in force in diverse conditions, encounters several problems in its making as well as implementation, both at international as well as national levels.

Provisions of the Indian Constitution

The Constitution (Forty-Second Amendment) Act of 1976 explicitly incorporates environmental protection and improvement. Article 48A, which was added to the Directive Principles of State Policy, declares : 'The state shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country'.

Article 51A(g) in a new chapter entitled 'Fundamental Duties', imposes a similar responsibility on every citizen 'to protect and improve the natural environment including forests, lakes, rivers, and wildlife, and to have compassion for living creatures.'

In addition, Article 21 of the Constitution states : 'No person shall be deprived of his life or personal liberty except according to procedure established by law'. This Article protects the right to life as a fundamental right. The courts have interpreted this Article to mean that the enjoyment of life, including the right to live with human dignity, encompasses within its ambit the protection and preservation of the environment.

Environmental Policy. In 1980, the Union Government established the Department of Environment. It became the Ministry of Environment and Forests (MoEF) in 1985. The Ministry initates and oversees the implementation of environmental policies, plans, laws, and regulations.

MoEF prepared the first National Environmental Action Plan in December 1993, laying down India's environmental priorities. In 2004, the MoEF unveiled a new Draft Environmental Policy.

Beginning of Environmental Legislation in India. Prime Minister Indira Gandhi gave a speech at the UN Conference on the Human Environment held at Stockholm in June 1972. The participating countries agreed to take appropriate steps to preserve the natural resources of the Earth. In consonance with this decision, India began enacting various environmental laws.

Initially, the laws were not very different from the general body of law. For example, the Water Act of 1974 was very much like other laws and created another agency-administered licensing system to control effluent discharges into water.

The Bhopal Gas Tragedy changed the situation. In the 1990s, a spate of laws were passed covering new areas, such as vehicular emissions, noise, hazardous waste, transportation of toxic chemicals, and environmental impact assessment.

Further, the old licensing regime was supplemented by regulatory techniques. The new laws included provisions such as public hearings, citizens' right to information, deadlines for technology changes (in motor vehicles, for example), workers' participation, and penalties on the higher management of companies for non-compliance.

The powers of the enforcing agencies like the various Pollution Control Boards of the states were also enhanced. For example, previously a board would have to approach a magistrate to get a factory shut down. Now, it was given the power to order closure, leaving the polluter to challenge the order in court.

Let us now briefly review the main environmental laws of the country.

The Environment Protection Act, 1986

The genesis of the Environment Protection Act, 1986, thus is in the above two Articles of the Constitution of India.

The Environment Protection Act, 1986, is a addition to the two allied Act—Water (Prevention and Control of Pollution) Act, 1974 and Air (Prevention and Control of Pollution) Act, 1981.

In 1972, the Department of Science and Technology set up a National Committee on Environmental Planning and Coordination to identify and investigate problems of preserving or improving the human environment and also to propose solutions for environmental problems. Soon after the United Nations Conference on the Human Environment held at Stockholm in 1972, the Water (Prevention and Control of Pollution) Act, 1974, came on the Statute Book. The Air (Prevention and Control of Pollution) Act came into being in 1981 and finally this Act came into existence in 1986.

This is an Act to provide for the protection and improvement of environment and the prevention of hazards to human beings, other living creatures, plants and property.

The Act came into force with effect from 19th November, 1986.

The Act is an umbrella legislation. It is an enabling law that provides the executive with powers to frame various rules and regulations.

The Act authorizes the Central Government to protect and improve environmental quality, to control and reduce pollution from all sources, and to prohibit or restrict the establishment and operation of any industrial facility on environmental grounds.

The Act defines terms such as environment, environmental pollutant, and hazardous substance. According to the Act, the Central Government has the power to :

- take measures to protect and improve the environment;
- give directions (for example, to close, prohibit, or regulate any industry, operation on process); and
- make rules to regulate environmental pollution (air and water quality standards, prohibiting or restricting the handling of hazardous materials, sitting of industry, etc.).

The Chapter of the Act on the prevention, control, and abatement of environmental pollution includes : controlling discharge of environmental pollutants, enforcing compliance with procedural safeguards, power of entry and inspection, power to take samples, setting up of environmental laboratories, appointing environmental analysts, and prescription of penalties for contravening the Act.

What are the Environment (Protection) Rules, 1986?

These rules set the standards for emission or discharge of environmental pollutants. In addition, more stringent standards may be laid down for specific industries or locations.

There are rules prohibiting and restricting the location of industries and the carrying on of processes and operations in different areas. Factors to be taken into consideration include : the topographic and climate features of an area, environmentally compatible land use, the net adverse impact likely to be caused by an industry, proximity to areas protected under various other laws, proximity to human settlements, etc.

Air (Prevention and Control of Pollution) Act, 1981

This is an Act to provide for the prevention, control and abatement of air pollution, for the establishment, with a view to carrying out the aforesaid purposes, of Board, for conferring on and assigning to such Boards powers and functions relating there to and for matters connected therewith. The Act came into force with effect from 16th May, 1981. It extends to the whole of India. The Act was being implemented by the Central or State Governments and the Central and State Boards. The Act was thoroughly amended by the Air (Preventive and Control of Pollution) Amendment Act, 1987.

The objective of this Act is to provide for the prevention, control, and abatement of air pollution. The Act defines air pollution as the presence in the atmosphere of any solid, liquid, or gaseous substance (including noise) in such concentrations as may be injurious to human beings, other organisms, property, or the environment.

The provisions of the Act are to be implemented by the Central Pollution Control Board (CPCB) along with the various state boards. The Act lists a number of functions of the CPCB including : Setting of air quality standards, collecting data on air pollution, organizing training and awareness programmes, establishing laboratories, etc. The CPCB can specify air pollution control areas and set standards for vehicular emissions.

The Act lays down penalties for the violation of its provisions. This applies to companies and their owners and managers as well as to government departments. Citizens can file complaints with the CPCB.

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

The water (Prevention and Control of Pollution) Act, 1974 was enacted to provide for the prevention and control of water pollution and maintaining or restoring wholesomeness of water, for the establishment of Board, with a view to carry out these purposes for the prevention and control of water pollution, for conferring on and assigning to such Boards powers and functions relating there to and for matters connected therewith.

This Act came on the Statute Book in pursuance of Article 252(1) of the Constitution, consequent on resolutions passed by all the Houses of Legislature of the States of Assam, Bihar, Gujrat, Himachal Pradesh, Haryana, Jammu & Kashmir, Kerala, Madhya Pradesh, Rajasthan, Tripura and West Bengal. The other states may adopt this particular Act if they pass a resolution under the above Article. The object of the Act, as already mentioned, is to prevent and control water pollution and maintain or restore wholesomeness of water.

The latest amendments were made in this Act through the water (Prevention and Control of Pollution) Amendment Act, 1988.

The Act prohibits the use of streams or wells for the disposal of polluting matters. It completes central as well as State Boards for the prevention and control of water pollution. It provides for Joint Boards for two or more states. It gives to the State Boards powers to carry out certain functions. Moreover, it restricts the opening of new outlets and new discharges into streams or wells by requiring the consent of the Pollution Control Board.

The water (Prevention and Control of Pollution) Act, 1974 (amendment in 1988) empowers the State Governments to take certain emergency measures in case of poisonous or polluting matters being found in any stream or well. In such an urgent situation, the State Board can obtain a restraint order from the competent Magistrate.

It is also to be noted here that any violation of the provisions of the Act or orders issued under its considered as a punishable offence.

The Wildlife Protection Act of 1972

The Wildlife Protection Act of 1972 defines wildlife to include any animal, bees, butterflies, crustaceans, fish, and moths; and aquatic or land vegetation, which form part of any habitat. The Act along with the Wildlife Protection Rules of 1973 provides for the protection of birds and animals and for all matters that are connected to this whether it be the habitat, the waterhole, or the forest that sustains them.

The Indian Board of Wildlife (IBWL) was created in 1952 in our country, which after the enactment of the Wildlife (Protection) Act actively took up the task of setting up Wildlife National Parks and sanctuaries. The major activities and provisions in the Act can be summed up as follows :

(i) It defines the wildlife related terminology.

(ii) It provides for the appointment of Wildlife Advisory Board, wildlife warden, their powers, duties etc.

(iii) Under the Act, comprehensive listing of endangered wildlife species was done for the first time and prohibition of hunting of the endangered species was mentioned.

(iv) Protection to some endangered plants like Beddome cycad, Blue vanda, Ladies slipper orchid, Pitcher plant etc., is also provided under the Act.

(v) The Act provides for setting up of National Parks, Wildlife Sanctuaries etc.

(vi) The Act provides for the constitution of Central Zoo Authority.

(vii) There is provision for trade and commerce in scheduled animals.

(viii) It provides for legal powers to officers and punishment to offenders.

(ix) It provides for captive breeding programme for endangered species.

Several conservation projects for individual endangered species like lion (1972), tiger (1973), crocodile (1974) and brown antlered deer (1981) were started under this Act. The Act is adopted by all states in India except J & K, while has it own Act.

Some of the major drawbacks of the Act include mild penalty to offenders, illegal wildlife trade in J & K, personal ownership certificate for animal article like tiger and leopard skins, no coverage of foreign endangered wildlife, pitiable condition of wildlife in mobile zoos and little emphasis on protection of plant genetic resources.

The Forest Conservation Act of 1980

The Forest Conservation Act of 1980 and the Forest (Conservation) Rules of 1981 provide for the protection and conservation of forests. The Act specifies the requirements that should be met before declaring an area a Protected Forest, a Wildlife Sanctuary, or a National Park.

Under the Act, a state government may regulate or prohibit, in any forest, the clearing of land for cultivation, posturing of cattle, or the cleaning of vegetation for any of the following purposes :

- Protection against storms, winds, floods, and avalanches, for the preservation of the soil on the slopes, the prevention of landslips or the formation of ravines and torrents, or the protection of land against erosion.
- Maintenance of a water supply in springs, rivers and tanks.
- Protection of roads, bridges, railways, and other modes of communication.
- Preservation of public health.

The Act makes it mandatory for the owner of a forest to seek permission before converting it to any non-forest use, such as the cultivation of tea, coffee, spices, rubber, palms, oil-bearing plants, horticultural crops, or medicinal plants.

1992 Amendment in the Forest Act

- In 1992, some amendments was made in the Act which made provisions for allowing some non-forest activities in forests, without cutting trees or limited cutting with prior approval of central government. These activities are setting of transmission lines, seismic surveys, exploration, drilling and hydroelectric projects. The

last activity involves large scale destruction of forests, for which prior approval of the centre is necessary.

- Wildlife sanctuaries, national parks, etc., are totally prohibited for any exploration or survey under this Act without prior approval of central government even if no tree-felling is involved.
- Cultivation of tea, coffee, spices, rubber and plants which are cash-crops, are included under non-forestry activity and not allowed in reserve forests.
- Even cultivation of fruit-bearing trees, oil-yielding plants or plants of medicinal value in forest area need to be first approved by the central government. This is because newly introduced species in the forest area may cause an imbalance in the ecology of the forest. If the species to be planted is a native species, then no prior clearance is required.
- Tusser cultivation (a type of silk-yielding insect) in forest areas by tribals as a means of their livelihood is treated as a forestry activity as long as it does not involve some specific host tree like Asan or Arjun. This is done in order to discourage monoculture practices in the forests which are otherwise rich in biodiversity.
- Plantation of mulberry for rearing silkworm is considered a non-forest activity. The reason is same as described above.
- Mining is a non-forestry activity and prior approval of central government is mandatory. The supreme court in a case T.N. Godavarman Thirumulkpad Vs. Union of India (1997) directed all on-going mining activity to be ceased immediately in any forest area of India if it had not got approval of central government.
- Removal of stones, bajri, boulder etc., from river-beds located within the forest area fall under non-forest activity.
- Any proposal sent to central government for non-forest activity must have a cost-benefit analysis and Environmental Impact Statement (EIS) of the proposed activity with reference to its ecological and socio-economic impacts.

Thus, the Forests (Conservation) Act has made ample provisions for conservation and protection of forests and prevent deforestation.

Model Questions

1. What are the provisions of the Indian Constitution regarding the environment?
2. What powers does the Environment (Protection) Act of 1986 give to the Central Government?
3. What are the objectives and the provisions of the Air (Prevention and Control of Pollution) Act of 1981?
4. What are the objectives of the Water (Prevention and Control of Pollution) Act 1974?
5. What are the objectives of the Wildlife Protection Act of 1972?
6. What does the Forest Conservation Act of 1980 specify?