Now the endemic species have been grouped into the following categories : The plant species restricted to definite small regions are referred to as **endemics**. According to area of distribution, the species may be **continental endemics** (restricted to a continent), **endemic to a country, provincial, regional** or **local endemics** (restricted to valley, hills, islands, etc.).

(*i*) **Relics or Paleoendemics.** They are the survivors of once widely distributed ancestral forms, for example, *Ginkgo biloba* (restricted to China and Japan), *Sequoia sempervirens* (confined to coastal valleys of California, U.S.A.). *Agathis australis, Metasequoia* (confined to Single valley in China). These species are called *Paleoendemics* or *epibionts*. A great majority of the endemic species belonging to this type have many fossil relatives. Because of little variability the endemics are adapted only to a particular environment and even if they reach new areas, they fail to establish themselves in new environment.

(*ii*) **Neoendemics.** The other endemics may be modern species which have had not enough time for occupying a large area through migration. They are called ***neoendemics***. There are several such genera which are widely endemic or few species of which are endemic. Neoendemics show good variability and have many biotypes, grow in diverse habitats and have wide tolerance for habitats. Some of the well known endemic genera in Indian flora are *Mecanopsis* (Papaveraceae). *Chloroxylon swietenia* (Flindersiaceae, formerly Rutaceae). *Catenaria* and *Butea* (Papilionaceae), *Caesulia* (Compositae), *Petalidium* (Acanthaceae), etc. *Eletteria repens* (Zingiberaceae), *Piper longum* (Piperaceae), *Piper nigrum* (Piperaceae), *Ficus religiosa* (Moraceae), *Shorea robusta* (Dipterocarpaceae), *Venda caerulea* (Orchidaceae), *Salmalia malabarica* (Bombacaceae), *Eleusine coracana* (Gramineae) are the well known endemic species of Indian flora.

There are some special terms to designate the quality of these endemics, *viz.* **Local endemics** which are found in small land features, **progressive endemics** which tend to spread with time, **retrogressive** endemics in which case the area of distribution is contracting and **microendemics** (*i.e.*, the endemics of lower groups).

Pseudo endemics. These endemics arise due to mutation in existing population at a particular place. These pseudo endemics or mutants may or may not persist for long in the particular area where they originate.

Endemism results from the failure on the part of species to disseminate its seeds, fruits, spores or propagules because of existence of great barriers like mountains, oceans and large deserts. The oceanic islands which are isolated from rest of the world by large expanses of waters abound in endemic species and water barrier checks the migration of those species outside their original habitat.

3. **Discontinuous species.** There are plants which occur at two or more distant places separated by overlands or oceans, hundreds or thousands

of miles apart. Such a distribution is called discontinuous or disjunct. The significant phytogeographical causes for discontinuous distribution are as follows :

(*i*) The species might have evolved at more than one place and they failed to migrate outside their original habitats because of barriers.

(*ii*) The species which were once widely distributed in the past disappeared from certain areas and are now surviving in some distant pockets.

(*iii*) **Continental drifts.** The present continents on the earth are not the same as they were in geological past , as for example, during the Mesozoic era South America, Africa, India, Polynesia, Australia and Antarctica were all united to form a large landmass called *Gondwanaland* which was having its characteristic flora and fauna. Similarly, there was a northern landmass called *Laurasia* separated from Gondwanaland by Tethys sea. Because of geological disturbances the large landmasses gave rise to widely separated continents all having some common species.

(*iv*) The climate may also be a reason for discontinuity in distribution of species. Plants having specific climatic requirements are found in widely separated areas with similar environmental conditions, as for example, plants of arctic regions are also found in alpine zone of high mountains in tropics and subtropics. *Salix* and *Silen* species show discontinuous distribution in arctic-alpine regions.

Factors Affecting Distribution of Species

Several factors are known to affect the geographical distribution of plant species, some of which are as follows :

1. Geological history and distribution,
2. Migration, and
3. Ecological amplitude.

1. **Geological history and distribution.** The place where a species first originated is called its centre of origin. Evolution of species is a slow but continuous process. Some of the species in present day flora are quite old while a great majority of them are recent in origin. The process of species differentiation involves (*i*) hybridization between the related species as well as mutation and (*ii*) the natural selection from the hybrid and mutant populations. In the selection process not all the hybrids and mutants are selected by nature and only the fittest individuals which find the habitat conditions within their ecological amplitudes are selected and the individuals least fit are eliminated. Changing climate has also played important role in the origin of new species. In the course of evolution several old species became extinct, some of which can be found even today as fossils. The fossils provide direct evidence for the existence of various taxa in the past.

2. **Migration.** The newly evolved species starts migration to new areas and side by side it undergoes further evolutionary changes. The dispersal of germules and propagules is brought about by several agencies like wind, water, glaciers insects, animals, even man. The dispersal is followed by *ecasis*. Migration may be adversely affected and sometimes even totally stopped by some factors called ***migration barriers***. Barriers in the dispersal of species may be classified as **ecological or environmental** and **geographical**. The climate, an ecological barrier, plays important role in distribution and establishment of species. Unsuitable climatic condition or change of climate in particular area forces the species to migrate from one place to another and the failure of some species to migration leads them to gradual extinction. Besides climate, there are geographical barriers, as for example, high mountains, vast oceans or deserts. The fresh water plants, for example cannot be dispersed across oceans if their propagules are suitable only for fresh water dispersal and similarly germules or propagules of land plants from one country cannot reach other country separated by vast oceans and mountains. Species are called **native** of the place of its occurrence if they originated there. Outside the area of its origin, the species is referred to as **exotic**. Exotic species reach new area through migration. If any species is introduced intentionally in new area by man then it is called **introduced species**.

3. **Ecological amplitudes and distribution.** Environmental conditions not only influence the life and development of plants but also determine the presence or absence, vigour or weakness and relative success or failure of various plants in a particular habitat. Each plant species of a community has a definite range of tolerance towards physical and biological environment (its **ecological amplitudes**) of the habitat.

The presence of species at a particular place, no doubt, indicates that the environmental conditions of that habitat are within its ecological amplitude but the absence of a species from one place does not necessarily indicate that the environment is not suitable for that species.

The ecological amplitude is governed by genetic set up of the species concerned and thus different species have different ecological amplitudes which may sometimes overlap only in certain respects. Further, some species may occur at different geographical regions as and when the conditions fall within its ecological amplitude. As for example, some plants of temperate region, say conifers, may be found in alpine zone of high mountains in tropical and subtropical regions. The other consideration in ecological amplitude as a factor in plant distribution is its change with time. In sexually reproducing plants the hybridization between related species results in offsprings with new genetic composition. With the change of environment the plant species also make adjustments with new environment by shifts in their ecological amplitudes facilitated by changes in the genotype. Within a species there may occur several genetically different groups of individuals (populations) which are adjusted to particular set of ecological conditions.

These populations are called ecotypes or ecological races or ecological populations. In *Euphorbia thymifolia*, for example, there are two major populations—one is calcium loving or calcicole and the other type is calcium hating or calcifuge. Similarly ecological races of *Xanthium strumarium* and *Ageratum conyzoides* differ in the photoperiodic requirements. The existence of ecotypes within the species widens the area of its geographical distribution.

CLIMATE OF INDIA

Atmospheric and meteorological influences, principally moisture, temperature, wind, atmospheric pressure and evaporation of a region collectively form the climate. Climate has marked influences on the growth, distribution and development of vegetation types in India. India lies north of equator between latitudes 6° and 38°. The Himalaya mountain is present in its north. India is surrounded on its south, east, and west by Indian ocean, Bay of Bengal and Arabian Sea respectively. The country as a whole can be divided into three main parts : (*i*) The mountain wall, (*ii*) The plains of northern India, and (*iii*) The plateau of Peninsular India.

Climate of India is not homogeneous throughout but it is highly variable. The country stands in the tropical and subtropical belts and the climate is greatly modified by oceans and mountain ranges. The climate in South and East is more typically tropical rainy, near temperate at high altitudes in the north (Kashmir), and semiarid and arid (dry hot) in the north-western part. The temperature is usually high throughout the year in most parts of the country except at high altitude in extreme north where snowfall occurs during winter and temperature goes below 0°C for short period.

The amount of rainfall varies greatly in different periods of the year and in different parts of the country; some parts receiving above 400 cm annual rainfall and some receiving as little as 20 cm annual rainfall or even no rains at all in some years. The distribution of annual rainfall in India is shown in Fig. 11.1.

Sir John Elliot was the first man to prepare a detailed climate map of India and later Kendew (1952), C.W.B. Normand (1937), Stamp (1946) and Waheed Khan (1959) also described the seasons and the climates of India. The Meteorological Department of Government of India has adapted the following 4 seasons:

1. Cold weather season (from January to February).
2. Hot weather season (from March to middle of June).
3. Rainy season (from middle of June to middle of September).
4. Season of retreating monsoons (from middle September to December).

1. **Cold weather season.** The season starts in January and persists up to February. In this season the atmospheric temperature goes very down, chilly winds blow from west or north-west to east or south-east direction, air is dry and fresh and the sky is clear. The cyclonic rains are prevalent at the top of Peninsula, foothills of Himalayas and the margins of the plains

in the Punjab and extending up to U.P. and southward into Rajasthan, Maharashtra and M.P. The winter rain, although light, greatly influences the growth of vegetation because runoff is very little, evaporation rate is very low and a large amount of it is available to the root zone.

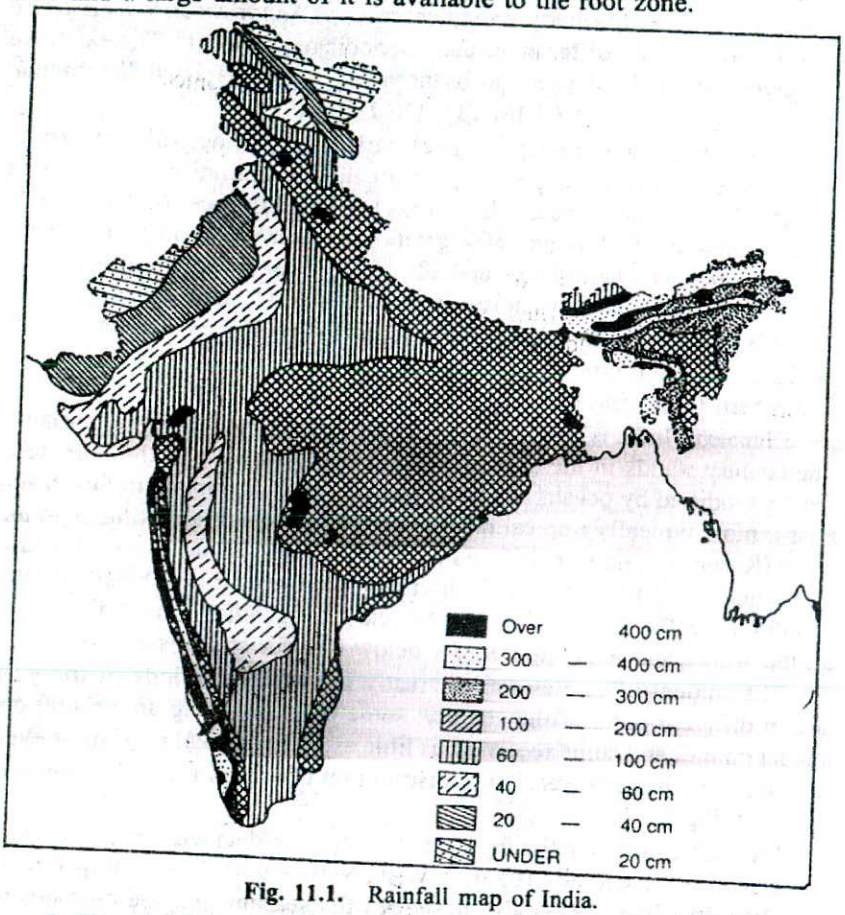


Fig. 11.1. Rainfall map of India.

2. **Hot weather season.** In the beginning of March, temperature starts rising and humidity decreases. The onset of summer season is indicated by leaf-fall and almost simultaneous appearance of new leaves and blooming in many plants as Mango, Amaltas (*Cassia fistula*), Gulmohar (*Delonix regia*) and so on. The temperature continues to rise till middle of June when mercury level may touch 45° to 49°C in upper Gangetic plains. The high temperature causes decrease in atmospheric pressure in most parts of the country. This results in hot winds which blow from south and south-east to north and north-west. These winds carry clouds with them.

3. **Rainy season.** This season starts with the bursting of the advancing monsoon winds during the middle of the June or beginning of July. The

monsoon winds arising in the Indian Ocean and passing over the Bay of Bengal enter the Gangetic plains and produce maximum rains in the north-eastern parts of the country and heavy rains in the plains of Bengal, Bihar, U.P., Orissa, Punjab, part of M.P. Kashmir, etc. The amount of rainfall decreases towards west. The annual rainfall in these regions ranges between 100 and 200 cm. Parts of Punjab, Rajasthan, Gujarat and Maharashtra receive only scanty rainfalls and a part of Rajasthan west of Aravalli ranges shows arid desert conditions with almost no rains in some years. The monsoon winds arising over Arabian sea produce heavy rains in South India and western coasts and lesser rains in the interior. The rain in not continuous throughout the season but it continues upto middle or end of September interrupted by bright or cloudy rainless days. The mountain ranges play significant role in the distribution of rainfall. Aravalli ranges are largely responsible for the arid climate in western Rajasthan.

4. **Season of retreating monsoons.** Towards the end of September the monsoon winds start retreating and produce only occasional showers. The sky becomes clear. The temperature decreases gradually and by the end of December cold sets in. Due to sudden variations in temperature local cyclones develop in the region of Bay of Bengal and the east coast of Tamil Nadu and cause isolated rains in certain areas.

Climatic Regions of India

On the basis of rainfall, India can be roughly divided into the following four climatic zones:

1. **Wet zone.** The average annual rainfall in this zone is more than 200 cm. Wet zone comprises western ghats including western coastal part of Mumbai, Karnataka and Kerala, Assam, eastern half of Bengal, Tarai region of U.P., Orissa, Parts of M.P. and north Bihar. Natural vegetation includes normally evergreen and semi-evergreen tropical forests in the west coasts and Assam but dry deciduous forests (mostly *Shorea robusta*) in other parts. Rice is the main agricultural crop.

2. **Intermediate zone.** The mean annual rainfall in this zone is above 100 cm but less than 200 cm. The zone comprises south-west Bengal, Bihar, Orissa, Part of M.P., east U.P., north-eastern Andhra Pradesh, eastern slopes of western ghats and east Tamil Nadu. Natural vegetation includes dry deciduous forests and dry deciduous thorn forests and scrubs. Rice is the major agricultural crop.

3. **Dry zone.** This zone receives annual rainfall between 50 and 100 cm and includes western U.P., N-E. Punjab, Delhi, S-E. Mumbai, Eastern part of Rajasthan, and western half of Andhra Pradesh. Natural vegetation includes shrubs and thorn scrubs. Wheat and millets are the major agricultural crops.

4. **Arid zone.** This zone receives rainfall less than 50 cm in year and includes south-western parts of Rajasthan and Punjab, N-E. Mumbai, and N-E. Gujarat. Natural vegetation includes thorny scrubs and short-lived herbs.

VEGETATION OF INDIA

Vegetation is the total plant cover of a region or area or place. Geographically, India is a tropical country but whole of the Gangetic plain lies outside the tropics. It has strong monsoonic climate and it differs from other tropical regions of the world. As pointed out earlier, there are four climatic regions in India which are characterised by different types of natural vegetation. Several factors are responsible for the occurrence of a variety of vegetational types in this country . Besides the climatic factors, soils upon which vegetation is found greatly determine the nature of vegetation. Vegetation in this subcontinent may be influenced by biotic factors as well as human culture for a long time. The plant formations determined by specific and continuous operation of man himself are called anthropogenic formations.

Some of important criteria in the classification of vegetation are physiognomy, structure, function, composition, dynamics (successional phenomenon), habitat relations and history. Fosberg (1961) found that the structure and function are the most satisfactory criteria for classification of vegetation. Champion (1938) gave the first complete classification of vegetation of India. Since then many workers have modified Champion's classification and some of them have given their own classification. Fosberg (1961) recognised the following three major structural groups in the vegetation of India.

1. Closed vegetation.
2. Open vegetation
3. Sparse vegetation.

Indian vegetation presents a varied assemblage of plant communities and includes several exotic elements, especially from China, Japan, Malaya, Africa, Tibet and Siberia. The following recognised plant formation types cover whole of India:

1. Forests,
2. Grasslands,
3. Vegetation of ponds and lakes, and
4. Vegetation of sea-shore.

1. Forests

Hanson (1962) defines forest as "a stand of trees growing close together with associated plants of various kinds". The following types of forests are found in India which cover nearly 17 per cent of the total area of Indian territory.

I. **Tropical forest.** A great majority of the forests found in India are of this type. Tropical forests are of two types:

(A) Tropical moist forests.

(B) Tropical dry forests.

A. **Tropical moist forests.** These are further classified into the following three types on the basis of relative degree of wetness:

(*i*) Tropical moist evergreen forests,
(ii) Tropical moist semi-evergreen forests, and
(*iii*) Tropical moist deciduous forests.

(*i*) **Tropical moist evergreen forests.** These are also called tropical rain forests. In India such forests are found in very wet regions receiving more than 250 cm average annual rainfall. These are climatic forests having luxuriantly growing lofty trees which are more than 45 metres in height. The shrubs, lianas (woody climbers) and epiphytes are abundant because of high rainfall. These forests are found in Andaman and Nicobar Islands, western Coasts and parts of Karnataka (N. Canara), Annamalai hills (Koorj), Assam, Bengal. The Detail account of this is given in the description of mesophytes.

(*ii*) **Tropical moist semi-evergreen forests.** These forests are found along the western coasts, eastern Orissa and upper Assam where annual rainfall is between 200 and 250 cm. They are characterised by giant and luxuriantly growing intermixed deciduous and evergreen species of trees and shrubs. The important plants in theses forests are the species of *Terminalia, Bambusa, Ixora, Dipterocarpus, Garcinia, Sterculia, Mallotus, Calamus, Albizzia, Elettaria, Pothos, Vitis, Shorea, Cinnamomum, Bauhinia, Albizzia*, etc. Orchids, ferns, some grasses and several other herbs are also common.

(*iii*) **Tropical moist deciduous forests.** These cover an extensive area of the country receiving sufficiently high rainfall (100 to 200 cm) spread over most of the year. The dry periods are of short duration. Many plants of such forests show leaf-fall in hot summer.

The forests are found along the wet western side of the Deccan plateau *i.e.* Mumbai, N-E. Andhra, Gangetic plains and in some Himalayan tracts extending from Punjab in west to Assam valley in the east. The forests of Southern India are dominated by Teak (*Tectona grandis*), *Terminalia paniculata, T. bellenica, Grewia tillaefolia, Dalbergia latifolia, Lagerstroemia, Andina cordifolia*, etc. are the other common species in forests of South India. In north, they are dominated by shal (*Shorea robusta*). Some other common associates of shal are *Terminalia tomentosa, Dellenia species, Eugenia species, Boswellia species, Mallotus philippinesis.* These forests produce some of the most important timbers of India. Grasses become important both in seral stages and in the areas under fire.

B. **Tropical dry forests.** These are classified into the following types:

(*i*) Tropical dry evergreen forests,
(*ii*) Tropical dry deciduous forests, and
(*iii*) Tropical thorn forests.

(*i*) **Tropical dry evergreen forests.** These forests are found in the areas where rainfall is in plenty but dry season is comparatively longer. The trees are dense, evergreen and short (about 10 to 15 metres high). These forests are found in eastern part of Tamil Nadu, in east and west coasts. The

common plant species are much the same as in Tropical moist evergreen forests. Species of *Maba, Calotropis, Pabatta, Feronia, Canthium, Zizyphus, Randia* etc. are most common. Bamboos are absent but grasses are common.

(*ii*) **Tropical dry deciduous forests**. These forests are distributed in the areas where annual rainfall is usually low ranging between 70 and 100 cm, such as, Punjab, U.P., Bihar, Orissa, M.P. and large part of Indian peninsula. The largest area of the country's forest land is occupied by Tropical dry deciduous forests. The dry season is long and most of the trees remain leafless during that season. The forest trees are not dense, 10 to 15 m in height, and undergrowth is abundant. In north, the forests are dominated by shal and in south by teak (*Tectona grandis*). The common constituents of these forests in South are *Dalbergia, Terminalia, Dillenia, Acacia, Pterospermum, Diospyros, Anogeissus, Boswellia, Chloroxylon, Bauhinia, Hardwickia, Gymnosporia, Zizyphus, Moringa, Dendrocalamus*, and so on. The other species of trees and shrubs of Sal dominated forests of northern region are *Terminalia, Semicarpus, Buchnania, Carissa, Modhuca, Acacia, Sterculia, Launea, Salmalia Adina, Bauhinia, Aegle, Grewia, Phyllanthus* etc.

(*iii*) **Tropical thorn scrubs.** These forests occur in the areas where annual rainfall is between 20 to 70 cm, dry season is hot and very long. They are found in South Punjab, most of Rajasthan and part of Gujarat. The vegetation in these region occurs only along the rivers. The land away from the rivers and devoid of irrigation is mostly sandy and devoid of trees. The vegetation is of open type consisting of small trees (8 to 10 m high) and thorny or spiny shrubs of stunted growth. The forests remain leafless for most part of the year and are sometimes called thorn scrub or scrub jungles. There is luxuriant growth of ephemeral herbs and grasses during the rainy season. Towards the desert region the vegetation diminishes and in arid parts there is almost no vegetation. The species of *Acacia, Cassia, Calotropis, Randia, Albizzia, Zizyphus, Erythroxylon, Euphorbia, Cordia, Prosopis. Salvadora, Aegle, Gymnosporia, Atriplex, Grewia, Asparagus, Berberis, Butea, Kochia, Leptadenia, Capparis, Adhatoda*, etc. characterise the plant formations of semiarid regions of India.

Champion (1938) named the natural vegetation of desert as *tropical thorny forest*. Bharucha (1955) divided the Rajasthan desert into the following vegetational zones:

(*i*) Area of shifting sand dunes at and around Jaisalmer and Bikaner.
(*ii*) Area of established sand dunes near Jodhpur.
(*iii*) Sand stone rocks covered by xerophytic plants like *Euphorbia nerifolia.*
(*iv*) Area of halophytic vegetation.
(*v*) Sandy-loam soil vegetation.

II. **Subtropical forests.** These forests are found in the region of fairly high rainfall but where temperature differences between winter and summer are less marked. Winter generally goes without rains. They are found upto the altitude of about 1500 metre in south and up to about 1800 metre in the north. In composition, subtropical forests are almost intermediate between tropical forests and temperate forests and a sharp demarcation can seldom be made between tropical and subtropical or subtropical and temperate forests. These forests have been grouped into the following three types:

(*i*) Wet hill forests,

(*ii*) Dry evergreen forests, and

(*iii*) Pine forests.

(*i*) **The wet hill forests.** They are found in Mahabaleshwar, Coorg, Karnataka, parts of Assam, Panchmarhi and other parts of M.P. The important plants found in the wet hill forests of south are the species of *Eugenia, Randia, Terminalia, Eleganus, Murraya, Gymnosporia, Atylosia, Ficus, Pterocarpus, Lantana,* etc. While those of the north are *Castonopsis, Calamus, Almus, Quercus, Betula, Schima phoebe, Cedrella, Garcinia, Populus* etc.

(*ii*) **Dry evergreen forests.** They occupy the foot-hill areas of Himalayas. The common constituents of vegetation are *Acacia modesta, Olea cuspidata*, etc.

(*iii*) **Pine forests.** They are found mostly in western and central Himalayas and in Assam hills. The forests are dominated by species of *Pinus* (*Pinus khasya* and *P. roxburghii*). Species of *Quercus, Berberis, Carissa, Bauhinia* may also occur rarely in pine forests.

III. **Temperate Montane forests.** These forests occur in the Himalayas at the altitude from 1800 to 3800 metres where humidity and temperature are comparatively low. Montane forests have been classified into the following three types on the basis of moisture regime :

(*i*) Wet temperate forest,

(*ii*) Moist temperate forest, and

(*iii*) Dry temperate forest

(*i*) **Wet temperate forests.** These are found in Himalayas extending from Nepal to Assam at the altitude of 1800 to 3000 m, as well as in some parts of South India (Nilgiris). The forests in south are evergreen and are called **sholas**. The forests are dense with closed canopy and the trees may be 15 to 20 m high. Epiphytes are in abundance. Important plants constituting the vegetation in Eastern Himalayas are species of conifers, *Hopea, Balanocarpus, Elaeocarpus, Artocarpus, Pterocarpus, Myristica, Hardwickia, Salmelia, Dioscoria*, members of family Compositae, Rubiaceae, Acanthaceae and Leguminosae form the undergrowth.

(*ii*) **Moist temperate forests.** These forests develop in the areas of lesser rainfall. The trees are high, sometimes up to 45 metres tall. The

dominant elements of vegetation are Oak and Conifers. Undergrowth is shruby and consists of deciduous species of *Barberis, Spiraea, Cotaneaster*, etc.

(*iii*) **Dry temperate forests.** These forests dominated by Rhododendrons, oaks and conifers from a narrow belt at the altitude from 3000 to 4000 m in the western Himalayas extending from a part of U.P. through Himanchal Pradesh and Punjab to Kashmir. The other commonly found species belong to genera *Daphne, Desmodium, Indigofera, Artemisia, Cannabis, Plectranthus, Fraxinus*, several epiphytic mosses, Lichens, etc.

(*iv*) **Alpine forests.** Alpine vegetation has been classified into the following three types:

(*a*) Alpine forests,

(*b*) Alpine moist scrubs, and

(*c*) Alpine dry scrubs.

(*a*) **Alpine forests.** Plants growing at the altitude of 2900 to 6000 m are called alpine plants. In India, alpine flora occurs in Himalayas between 4500 and 6000 metres. At lower level, alpine forests consist of dwarf trees with or without conifers and at higher level scrubs and only scattered xerophytic shrubs are left to merge with alpine meadows. The common plants of alpine forests are *Abies, Pinus, Juniperus, Betula*, shrubby Rhododendrons, *Quercus, Pyrus, Salix* etc.

(*b*) **Alpine moist scrubs.** This type of vegetation is distributed extensively throughout the Himalayas above 3000 metres. It is most often dense and composed of evergreen dwarf *Rhododendron* species, some birch and other deciduous trees. Mosses and ferns cover the ground with varying amounts of alpine shrubs, flowering herbs and ferns. Alpine pastures include mostly mesophytic herbs with very little grass.

(*c*) **Alpine dry scrubs.** These are open xerophytic formations spread in U.P., Himachal Pradesh, Punjab and Kashmir. Species belonging to *Artemisia, Potentilla, Kochia, Juniperus* predominate in the vegetation which develops generally on lime stone rock.

2. Grassland Vegetation

According to Ecological Society of America (1952), "grassland is a community dominated by grasses or grass-like plants". Natural grasslands occur in temperate zone with annual rainfall 25 to 80 cm, while in tropics they may be found in areas receiving rainfall up to 150 cm. The favourable conditions for development of a stable grassland are frequent rainfall and sufficient warmth during the growing season. Grasslands do not form a prominent feature of vegetation in tropical part of India because of the following reasons :

(*i*) In the moist lowlands, grasses face very tough competition from trees and shrubs.

(*ii*) In the drier parts, the conditions are so severe that they do not permit the extensive development of grasslands. Indian grasslands are not

climax formations but they have developed secondarily under the influence of two factors, namely edaphic and biotic. In most cases, grasslands are maintained in their present seral stage due to biotic influences. Fire alone or fire coupled with grazing and browsing may be very potent factors causing the development of grasslands in forest areas. If a grassland exists in forest territory for a number of years, the forest growth cannot eliminate it even if the fire factor is absent. There are several grassy flats and grassy plains of seral nature in Nilgiri, Khasi hills and Naga hills. At elevations higher than 800 metres, the rainfall is heavy, the soil is dark in colour and rich in humus, and the vegetation consists of grasses which grow forming tufts at lower altitude and a turf at higher altitude. In swampy places above 1800 metre elevations, species belonging to Cyperaceae are in abundance. In the regions where forests are destroyed by fire, vegetation consisting of tall grasses with scattered trees (*i.e.*, Savannah) develops.

The tropical grasslands of India may be classified into the following types:

(*i*) **Xerophilous grasslands.** These are found in dry regions of North-West India under semidesert condition. The common species of xerophilous grasslands are *Andropogon contortus, Cenchrus ciliaris, C. barbatus,* etc.

(*ii*) **Mesophilous grasslands.** They are also called Savannahs. They are extensive grassy flats or grassy plains typically occurring in moist deciduous forests of U.P. Dominant species of such grassy lands may be *Saccharum munja, S. narenga,* etc.

(*iii*) **Hygrophilous grasslands.** These are called wet savannahs adapted to very wet soil.

All these types being biotically controlled are inferior to temperate grasslands and suffer considerably form monsoon nature of climate, and lack of proper legume mixture.

Indian grasslands have been divided into the following major types by R.O. Whyte (1957). The geographical distribution and environments of these grassland types are given in the following table:

Major grassland types	*Environment*	*Regions of distribution*
1. *Schima—Dichanthium*	Black soil	Hyderabad, Mumbai, M.P., Andhra Pradesh, Tamil Nadu, S-E. U.P.
2. *Dichanthium—Cenchrus*	Sandy loam soil	Punjab, Delhi, Rajasthan, Gujarat, Cutch, Eastern U.P., Bihar.
3. *Phragmites—Saccharum*	Marshy areas	Terai of U.P., Bihar, Bengal, Assam, Sunderban and other delta.
4. *Bothriochloa*	High rainfall and low lying areas	Lonavala tract of Maharashtra.
5. *Cymbopogon*	Low hills	Western Ghats, Vindhyas, Satpura, Aravalli ranges, Orissa upto 160 kms belt.

(*Contd...*)

Major grassland types	*Environment*	*Regions of distribution*
6. *Arundinella*	High mountains	Western Ghats, Nilgiris, Himalayas, Eastern Punjab, Hamachal Pradesh up to 3000 metres.
7. *Deyeuxia—Arundinella*	Mixed temperate climate	Himalayas, Kashmir, U.P., Bengal and Assam.
8. *Deschampsia-Deyeuxia*	*Temperate-alpine Climate*	Himalayas, Kashmir, above 2500 metre.

3. Vegetation of Ponds and Lakes

The aquatic vegetation is affected by supply of O_2, CO_2, mineral salts, nature of substratum, depth of water, temperature and light intensity. Some of the common aquatic plants belonging to different types of hydrophytes which are found in the ponds and lakes of India have been discussed in "Hydrophytes" under the chapter "Plant adaptations".

4. Vegetation of Sea Shore

(*a*) **Mangrove or littoral forests.** The mangrove flora occurs near the estuaries. In India, these forests are found near Calcutta in Hooghly river, and Sunderbans. Mangrove vegetation has been discussed in detail in a separate chapter.

(*b*) **Vegetation on sand dunes.** Sand dunes are found on flat coast where only such plants grow as can tolerate the exposure to moving sand, high diurnal temperature, strong winds and some salts and can grow keeping pace with constant accumulation of sand to avoid burial. *Ipomoea pes-caprae* develops in abundance in sand dunes.

(*c*) **Beach jungles.** These are found near sea coast in Andaman, Sunderban, Orissa, Tamil Nadu, Kerala and Mumbai. Soil is sandy having large amount of lime and salts but poor in other mineral contents. The temperature is moderate and water table is only a few metres deep. Succulents and sclerophyllous xerophytes as *Pandanus, Coccus nucifera,* etc. are of common occurrence.

BOTANICAL ZONES OR PHYTOGEOGRAPHIC REGIONS OF INDIA

Vegetation of any place is modified by the environmental factors; climate, geology and biotic factors. The great area of Indian subcontinent has wide range of climate and corresponding diversity in the vegetation. Important contributors who attempted to analyse the vegetation of India are Hooker (1907) and Chatterjee (1939). Hooker (1907) analysed vegetation of India (before partition) into the following Botanical provinces :

(1) Eastern Himalayas,

(2) Western Himalayas,

(3) Indus plain,
(4) Gangetic plain,
(5) Malabar,
(6) Deccan,
(7) Assam, and
(8) Maldives.

Chatterjee (1939) modified the Hooker scheme and suggested the following Botanical provinces in undivided India, excluding Malaya and Ceylon. These provinces are as follows :

(1) Western Himalayas,
(2) Eastern Himalayas,
(3) Central Himalayas (now in Nepal),
(4) Gangetic plains,
(5) Indus plain,

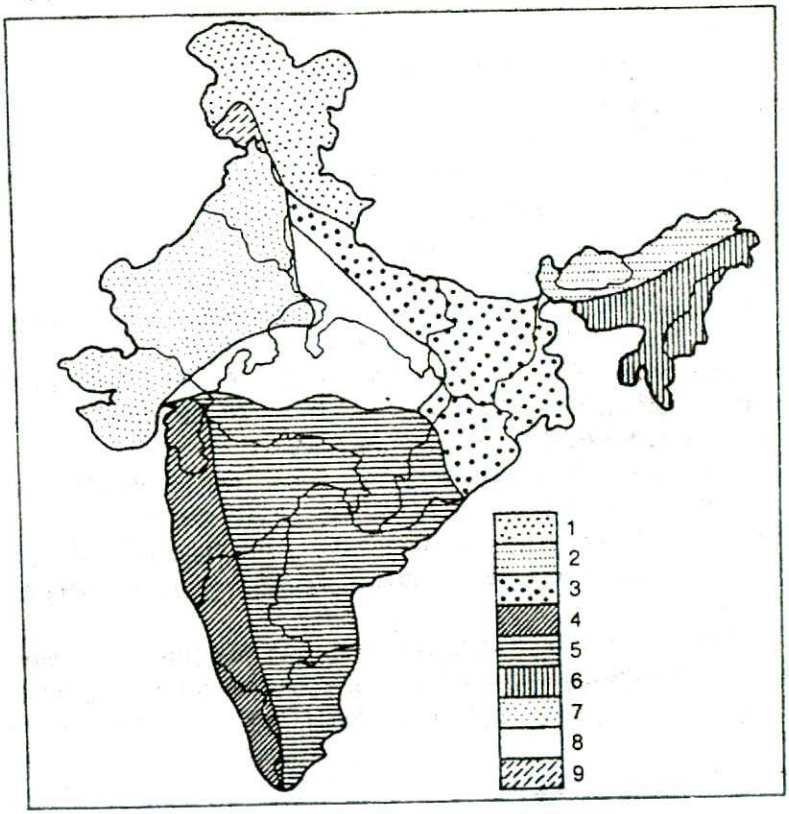


Fig. 11.2. Vegetation of India.

1. Western Himalayas, 2. Eastern Himalayas, 3. Gangetic plain, 4. Western Coasts of Malabar, 5. Deccan, 6. Assam, 7. Indus plain, 8. Central India, 9. Bay Islands of Andaman and Nicobar.

(6) Deccan,
(7) Malabar,
(8) Assam,
(9) Upper Burma, and
(10) Lower Burma.

Recently, India (after partition) has been divided into the following botanical provinces by D. Chatterjee (1962). Fig. 11.2.

(1) Western Himalayas,
(2) Eastern Himalayas,
(3) Indus plain,
(4) Gangetic plain,
(5) Central India,
(6) Deccan,
(7) Western coasts of Malabar,
(8) Assam, and
(9) Bay Islands of Andaman and Nicobar.

1. Western Himalayas

The northern part of our country is bounded by highest ranges of Himalayas and is one of the important botanical regions of the world with climate and vegetation ranging from truly tropical near the low altitudes to temperate arctic types at the high altitudes. The northern mountain division can phytogeographically be divided into western, central and eastern zones.

Western Himalayas consist of north Kashmir, south Kashmir, a part of Punjab and Kumaon. This zone is wet in outer southern ranges and slightly dry in inner northern zone. The average annual rainfall in this region is from 100 to 200 cm. Snowfall occurs in this region during winter season. The region may be divided into three subzones (Fig. 11.3) :

(*i*) *Submontane zone* or *lower region* or tropical and subtropical belts (upto about 1500 metres altitude from the sea level).
(*ii*) *Temperate zone* (from 15000 metres to 3500 metres altitude),
(*iii*) *Alpine zone* (above 3500 metres and upto the line of perpetual snow).

(*i*) **Submontane or lower region or tropical and subtropical belts.** It includes outer Himalayas, particularly region of Siwaliks and adjoining areas where annual average rainfall is over 100 cm. This zone ranges between 300 metres and 1500 metres. In this zone, forests dominated by timber trees of *Shorea robusta* are common. Other important tree species are *Salmalia malabaricum, Butea monosperma, Acacia catachu* and *Zizyphus species*. In the swampy areas, *Dalbergia sisso* (Shisham), *Ficus glomerata, Eugenia jambolana* are common in occurrence. In west dry regions sal trees are replaced by xeric plants particularly *Zizyphus, Carissa, Acacia*, and thorny

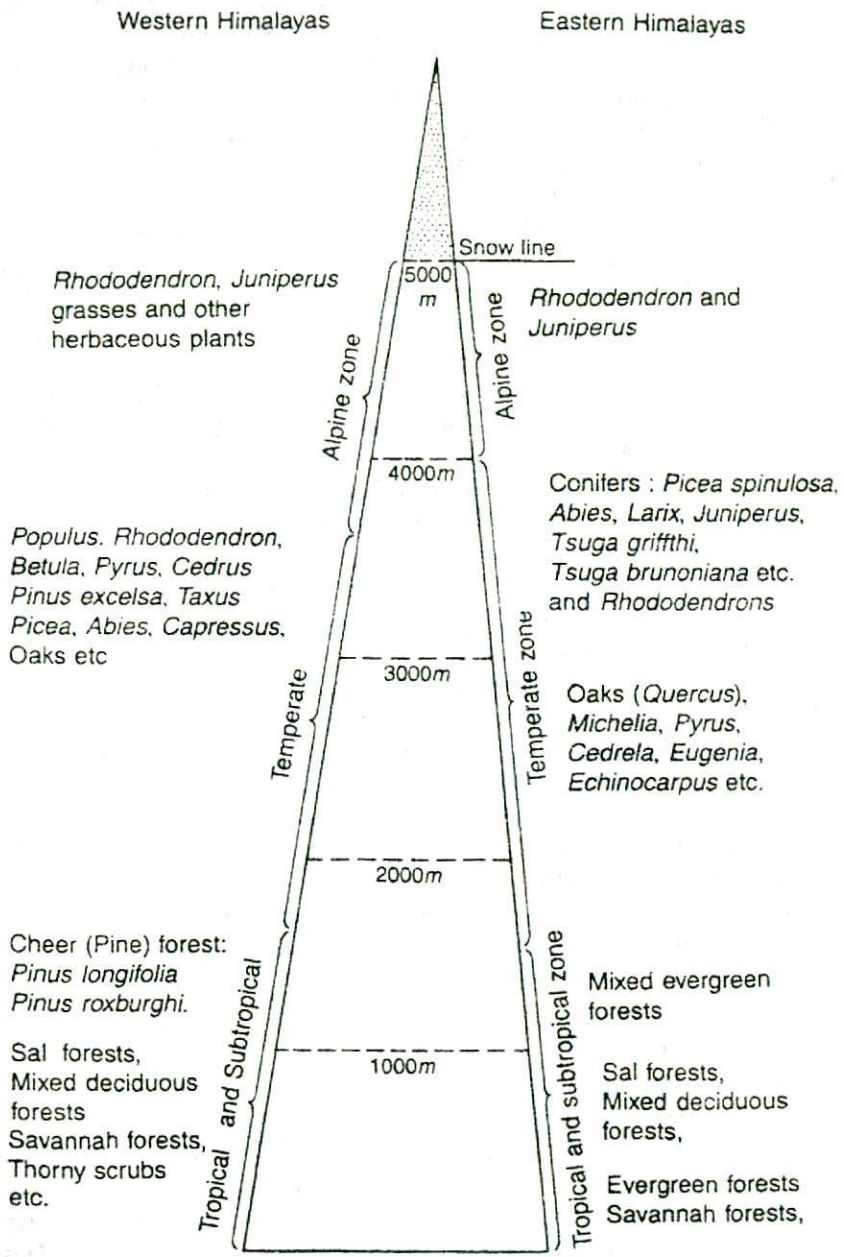


Fig. 11.3. Main types of vegetation at different altitudes in the Western and Eastern Himalayas.

Euphorbias. At higher elevation, around 1000 to 1500 metre altitude, cheer (pine) forests are also found at certain places. The common species of pine are *Pinus longifolia* and *Pinus roxburghii*. Ground vegetation is scanty.

(*ii*) **Temperate zone.** It commonly ranges at the altitudes from 1500 to 3500 metres above the sea level. Oaks are dominant along with *Populus, Rhododendron, Betula* and *Pyrus. Pinus excelsa, Cedrus deodara, Picea, Abies, Cupressus,* and *Taxus baccata* are found in the heavy rainfall region (between 1600 and 1800 m). Herbs are also common in this region. Common herbs are *Ranunculus hirtila, Polygonum, Pedicularia, Potentilla argyrophylla, Primula, Delphinium, Clematis,* crucifers and many members of compositae. In cultivated drylands of Punjab, wheat and barley are main crops. In Kashmir, *Bitula* (birch), *Salix* (cane), *Populus* (poplar) are of common occurrence. Besides these, *Quercus semicarpifolia, Q. dilatata, Aesculus indica* (chestnut) and many conifers are commonly met within this region. In west Kashmir rice cultivation is common. Keshar or saffron (*Crocus sativus*), apples, peaches, walnut, almonds and other fruits are important economic plants of Kashmir region.

(*iii*) **Alpine zone.** Above the altitude of 3500 metres and up to snowline (about 5000 m) is alpine zone. The vegetation consists of evergreen conifers and some low and broad leaved trees. The vegetation of this region is characterized by cushion habit, dwarf nature and gregarious habit. In lower alpine region, shrubby forests are common which may be (*a*) Birch—fir forest which is fairly dense and is mixed with evergreen shrubby *Rhododendron* at higher level and (*b*) Birch—*Rhododendron* forests in which silver fir, *Betula, Rhododendron* and *Juniperus* are common. In the upper alpine region, prominent herbaceous plants are the species of *Primula, Polygonum, Gentiana, Cassiope, Meconopsis, Saxifraga, Potentilla, Geranium, Aster, Astragalus* etc. which form alpine meadows. At about 5000 metre altitude and above snow perpetuates round the year and plant growth is almost nil. This altitude is called snow line or ice line.

Populations of *Draba, Braya, Cortia, Leontopodium* go on increasing with the increase in altitude. Species of *Ephedra, Juniperus, Barberis* are also found scattered. *Poa, Stipa* and *Fectuca* are common grasses of alpine zone.

2. Eastern Himalayas

Eastern Himalayas extend from Sikkim to upper Assam, Darjeeling and NEFA. Vegetation of this region differs from that of western Himalayas. The chief differences are due to changed environmental factors as heavy monsoon rainfall, less snowfall and high temperature and humidity. This region can also be divided into (*i*) Tropical submontane zone (*ii*) Temperate or Montane zone, and (*ii*) Alpine zone (Fig. 10.3).

(*i*) **Tropical or Submontane Zone.** This tropical subzone characterized by warm and humid conditions extends from plain up to the altitude of

about 1800 m. In this zone mostly sal forests, and mixed deciduous forests consisting of important plants, such as *Sterculia, Terminalia, Anthocephalus cadamba* and *Bauhinia* are common. In the savannah forests, common plants are *Albezzia procera, Bischofia, Salmelia, Dendrocalamus.* Evergreen forests of *Dillenia indica, Michelia champaca, Echinocarpus, Cinnamon,* etc. are common.

(*ii*) **Temperate or Montane Zone.** It may be further divided into upper and lower zones. Lower temperate zone is the region between 1800 and 3000 metre altitudes. In the **lower temperate zone**, Oaks (*Quercus), Michelia, Pyrus, Cedrela, Eugenia, Echinocarpus* are common plants. In **upper temperate zone** (3000-4000 metre altitude), conifers and Rhododendrons are common. Important conifers of this region are *Picea spinulosa, Abies, Larix, Juniperus, Tsuga griffithi, Tsuga brunoniana,* etc.

(*iii*) **Alpine Zone (from 4000 metres upto snow line).** Climate is humid and extremely cold. The vegetation in the alpine zone is characterised by complete absence of trees and predominance of shrubs and meadows. Important plants of this zone are *Rhododendron* and *Juniperus.*

Eastern Himalayan vegetation is considered to be one of the richest vegetational units in the world and consists of several species of plants which are native of foreign countries, such as, China, Japan, Burma, Malaya and European countries.

3. Indus Plains

It includes part of Punjab, Rajasthan, Cutch, Delhi, a part of Gujarat. Some part of this plain is now in Pakistan. The climate of this zone is characterised by dry hot summer, and dry cold winter. Rainfall is usually less than 70 cms, but in certain regions it is as low as 10-15 cms. The soil of a wide area except cultivated land, is saline. Much of the land has become desert due to excessive dryness.

Vegetation is mainly bushy and thorny. *Acacia arabica, Prosopis spicigera, Salvadora, Capparis decidua* are very common plants of this region. *Salsola phoetida* and Lunakh grass are found mostly in saline soils. Other plants of this botanic province are *Anageissus, Eugenia, Mango, Dalbergia sisso, Albizzia lebbek, Zizyphus nummularia,* etc.

Historical evidences indicate that the area was covered by dense forest some 2000 years ago, but gradual destruction of vegetation cover either by biotic agencies or by any other agency led to the development of desert in this plain. *Saccharum munja, Cenchrus ciliaris, Prosopis spicigera, Acacia leucophloea, A. senegal* are the important plant species which are grown for checking the spread of desert.

4. Gangetic Plains

This is one of the richest vegetational zones in India. This zone covers flat land of a part of Delhi, whole of U.P., Bihar, West Bengal and also a part of Orissa. Rainfall in this zone is from 50 cm to 150 cm.

A great part of the land is under cultivation. The common crop plants are wheat, barley maize, *Sorghum* (jowar), Bajra, urad, Moong (*Phaseolus mungo*), *Cajanus cajan*, til (*Sesamum indicum*), sugarcane, Pea (*Pisum sp.*), gram (*Cicer arietinum*), potato, *Brassica*, rice.

In western part of U.P. annual rainfall is from 50 cm to 110 cm. Dry deciduous and shrubby forests are common in this part. Important plants of south-western part of U.P. are *Capparis*, *Saccharum munja*, *Acacia arabica*. In the north-western part of U.P. near Himalayas foothills *Dalbergia sisso*, *Acacia arabica* are most common plants.

In eastern gangetic plain, the conditions are cold and wet (annual rainfall, 150 cm in West Bengal). In this part evergreen forests are common. In central part, the annual rainfall is about 100 cm to 150 cm. The vegetation consists mainly of deciduous trees. Sal trees are dominant. Other common trees are *Terminalia tomentose*, *T. belerica*, *Acacia species*, *Bauhinia*, *Diospiros* (Biri Ka patta or tendu) *Eugenia sp.*, neem trees (margosa), *Madhuca indica* (Mahua), *Cordia myxa* (Lasora), *Tamarindus*, Mango (*Mangifera indica*). *Ficus* etc.

In Bihar and Orissa hills, *Rubus*, *Potentilla*, *Fragaria (Rosaceae)*, *Pyrus* etc. are common. Mangrove vegetation is common in tidal regions in West Bengal near Sunderban, and Orissa. *Rhizophora mucronata*, *R. Conjugata*, *Sonneratia*, *Ceriops roxburghiana* and *Acanthus ilicifolius*, *Kandelia rheedii*, *Bruguiera gymnorhiza* are common mangrove plants in those regions.

5. Central India

Central India covers Madhya Pradesh, part of Orissa, Gujarat and Vindhya. The areas are hilly. The average rainfall per annum may be 100-170 cm. Some places are at the altitudes of 500-700 m from the sea level. Biotic disturbances are very common in this botanical province which have led to the development of the thorny vegetation in open areas. In this region teak *(Tectona grandis)* is very common. Other trees are *Terminalia tomentosa*, *Bauhinia*, Mango, *Phyllanthus*, *Ficus glomerata*, etc. Among common shrubs are *Mimosa rubricaulis*, *Desmodium*, *Acacia sp.*, *Zizyphus rotundifolia* and other. Entire forest vegetation of central India may be divided into (*i*) sal forests (*ii*) mixed deciduous forests (*iii*) thorny forests.

At Sarguja (M.P.) many species have been reported to occur. Some of them are *Pyrus*, *Barberis asiatica*, *Rubus*, *elipticus*, etc.

6. Deccan

This region comprises whole of the southern peninsular India including Satpura and southern part of Godawari river. Average annual rainfall in this region is about 100 cm. It may be divided into the following two subdivisions :

(*i*) Deccan plateau

(*ii*) Coromandel coast.

In Deccan plateau, teak forests containing *Diospiros, Acacia, Prosopis spicigera, Santalum album* (chandan tree) and *Cedrela toona* are common. On rocks, *Capparis,* Euphorbias, *Phyllunthus* are common. Teak, *Pterocarpus, Borassus, Foenix silvestris* are also common in this area. In Chhota Nagpur plateau, important species are *Clematis natans, Barberis, Thallictrum* and also many members of Annonaceae, Rosaceae, Compositae, Araliaceae, Apocynaceae, Lauraceae, Amaranthaceae, Orchidaceae. Some ferns are also common.

In Coromandel coast vegetation consists largely of some halophytic species.

7. Western Coast of Malabar

This is small botanical province covering Cape Comorin to Gujarat and Western Ghat. This is a region of heavy rainfall. In this zone, four types of forests are common :

(*i*) Tropical forests (occur at 700 m altitude),

(*ii*) *Mixed deciduous forests* (found at the altitude upto 1600 m).

(*iii*) *Temperate evergreen forests* (occur above 1200 m altitude), and

(*iv*) *Mangrove vegetation.*

In tropical evergreen forest the trees are tall and they have root buttresses. Important species are *Cedrela toona, Dipterocarpus, Mangifera indica, Sterculia alata, Artocarpus hirsuta.* In the mixed deciduous forests, important plants are *Terminalia tomentosa, Terminalia peniculata, Tectona grandis, Dalbergia, Lagerstroemia lanceolata* and bamboo species, particularly *Dendrocalamus* and *Bamboosa arundinacea.* On the Nilgiri hills sub-tropic and temperate conditions exist. Important plants of Nilgiri vegetation are *Rubus, Rhododendron arboreum, Barberis, Thallictrum, Ranunculus, Fragaria, Potentilla.* Many other herbs along with many grasses are also common.

Temperate forests commonly called as "sholas" contain *Gardenia obtusa, Michelia nilgirica. Eugenia* species are also common. In Malabar, plants belonging to family Dipterocarpaceae, Tiliaceae, Anacardiaceae, Meliaceae, Myrtaceae, Piperaceae, Orchidaceae and many ferns are common. The west coast of Malabar region receives very high rainfall. In the coastal region mangrove plants grow luxuriantly.

8. Assam

This botanical province is very rich in vegetation and covers valley of Brahmaputra, Naga hills and Manipur. This is the region of heaviest rainfall. Cherapunji is one of the rainiest places of the world where annual rainfall often exceeds 1000 cm. Excessive wetness and high temperature in this zone are responsible for the development of dense forests. Broad leaved, tall, evergreen angiosperms and some conifers are very common in the forests. Common plants occurring in this region are *Ficus, Artocarpus, Michelia champaca, Sterculia alata, Morus* species. Besides these, bamboos, canes, climbers, and green bushes are also common. Prominent plants in

the northern forests of this zone are *Alnus nepalensis, Betula, Rhododendron arboreum, Magnolia, Michelia and Prunus*. Sal also occurs at Garo hills. Orchids and fern species are very rich in this zone.

9. Bay Islands of Andaman and Nicobar (India)

These bay islands represent elevated portions of submarine mountains. Climate is humid in the coastal region. In Andaman, beech forests, evergreen forests, semi-evergreen forests, deciduous forests and mangrove vegetation are of common occurrence. *Rhizophora, Mimusops, Calophyllum*, etc. are common plants in mangrove vegetation. In the interior evergreen forests tall trees are common. Important species of trees are *Calophyllum, Dipterocarpus, Lagerstroemia* and *Terminalia* etc. Some part is under cultivation. The important crops are paddy and sugarcane.

QUESTIONS

1. What are phytogeographical principles? Discuss in brief the factors which affect distribution of plant species.
2. Write short notes on :
   (*a*) Discontinuous distribution of species
   (*b*) Endemism.
3. Describe the climates of India and their bearing in distribution of plant formations.
4. Describe the various forest communities of India.
5. Give an account on grassland vegetation in India.
6. Describe in brief different phytogeographic regions of India.
7. Describe the vegetation of Eastern or Western Himalayas.

12

ECOLOGICAL INDICATORS

The heredity and environment both are equally important in the expression of phenotypic characters. Heredity performs its action through environment. Species differ in their environmental requirements and establish themselves where conditions are favourable. It is found that certain species of plants, animals and micro-organisms have one or more specific requirements which very much limit their distribution. The occurrence, character and behaviour of a plant are thus indicator of the combined effects of all factors prevailing in a habitat. Since a plant species or plant community acts as a measure of environmental conditions, it is referred to as *biological indicator* or *bioindicator* or *phytoindicator.* In other words, plants which indicate some very specific conditions of environment are called plant indicators.

The knowledge of relationship between plants and ecological factors can be used as an indicator of environment. Many plants are used as indicators of environment. In a plant community some plants are dominant and found in abundance. These plants are important indicators because they bear full impact of habitat. It has been seen, in general, that plant communities are better indicators than individual plants. Individual plants or plant communities are used to determine the types of soil and other conditions of the environment. Sometimes these also indicate past or future conditions of the environment.

The knowledge of plant indicators can be helpful to determine local soil, thus it can be decided which crops should be cultivated in a particular soil and which soil should be left for pasture or other purposes. Plant indicators are also used to determine optimum use of land resources for forest, pasture, and agricultural crops. Many plants indicate the presence of particular mineral or metal. So the presence of precious metal can be detected by the growth of the specific plant in an area.

Characteristic Features of Plant Indicators

The characteristic features of plant indicators are as follows :

1. On the basis of distribution the indicators may be 'steno' species or 'eury' species. The 'steno' is used to indicate narrow limits of tolerance and 'eury' is used to indicate wide limits of tolerance. A plant may show wide limits of tolerance for certain conditions and narrow limits of tolerance

for other conditions. For example, a plant may be indicator of wide limits of tolerance for heat but of narrow limits of tolerance for water. Plants with wide limits of tolerance of heat are called *eurythermal* and those with narrow limits of tolerance for water are called *stenohydric.*

2. Plants of large species are better indicator than the plants of small species.

3. Before relying on a single species or group of species as indicators, there should be abundant field evidence.

4. Numerical relationships between species, population and whole communities often provide more reliable indicators than single species

Different Types of Plant Indicators

Different types of plant indicators have different roles in different aspects which are described below :

Plant indicators for agriculture. Many plant indicators decide whether soil is suitable for agriculture or not. The growth of a particular crop plant is seen under different environmental conditions and if growth is satisfactory in a particular soil that soil is considered to be suitable for agriculture. For example, growth of the short grasses indicates that water is less in the soil. A natural growth of tall and short grasses indicates that soil is fertile and is also suitable for agriculture. Dhawan and Nanda (1949, 50) and some other workers have recorded plant indicators for different types of soils as given in Table 12.1.

Table 12.1

Plant Indicators	*Characteristic of soil*
Salvadora oleoides	High calcium and boron, good soil suitable for crop plants
Zizyphus nummularia	Good soil for agriculture
Prosopis cineraria	Good soil for crop plants provided irrigation is there
Peganum harmala	Soil is rich in nitrogen and salts and good for agriculture
Butea monosperma	Heavy alkaline
Capparis decidua	Alkaline soil
Rumex acetosella	Acid grassland soil
Pinus and Juniperus	Uranium rich soil
Salsola, Sueda spp.	Saline water condition
Andropogon scoparium	Sandy loam type soil
Argemone mexicana	Recently disturbed or flooded soil
Lippia nodiflora and *Rumex* species	Nitrate rich soils

Plant indicators for groundwater : Certain plant communities indicate the depth of ground water. Central Arid Zone Research Institute, Jodhpur

has made the use of certain plant communities to indicate the depth of groundwater and salinity level in the groundwater. Chatterjee and Bhaskar (1977) have listed the plant communities as ecological indicators for ground water in Indian deserts (Table 12.2)

Table 12.2

Plant communities	*Indicated depth of ground-water*	*Indicated total soluble salt ppm in ground-water*
1. *Euphorbia caducifolia*	12—18 m	1,500—7,000
2. *Acacia senegal—Anogeissus pendula*	12—18 m	500—1,500
3. *Salvadora persica —Tamarix sp.*	6m	1,500—3,200
4. *Salvadora oleoides—Prosopis cineraria*	10—20 m	500—2,000
5. *Prosopus cineraria—Zizyphus nummularia-Capparis decidua*	6—18 m	5,000—10,000
6. *Salvadora oleoides—Capparis decidua*	6—12 m	5,00—10,000
7. *Salvadora oleoides—Zizyphus nummularia*	18—28 m	5,000—10,000
8. *Panicum turgidum—Zizyphus complex*	6—18 m	5,000—10,000
9. *Panicum turgidum—Calligonum polygonoides*	6—18 m	1,000—2,000
10. *Crotalaria burhia—Leptadenia pyrotechnica*	6—20 m	500—3,200
11. *Suaeda fruticosa—Alurophus lagopides*	6 m	11,000—12,000
12. *Capparis decidua*	12—20 m	180—15,000
13. *Acacia indica—Prosopis cineraria—Salvadora oleoides*	12—20 m	400—1,500

Plant indicators for Over-grazing. Many plants are over grazed which result in modification of grassland. It has been seen that grasses are removed by overgrazing while others are disturbed and forage production is considerably reduced. Some plants which are vigorous and undisturbed, remain viable and become distinct from rest of the plants. Some plants show characteristic indication of overgrazing which can be recognised. The predominance of annual weeds and short-lived impalatable perennials indicate severe grazing. Examples of such plants are *Polygonum, Chenopodium, Lepidium* and *Verbena*. Some plants are less pronounced and show poor or no over-grazing. Examples of these plants are *Opuntia, Grindelia, Vernonia* etc.

Plant indicators of forest. Some plants indicate the characteristic types of forest and they grow in an area which is not disturbed. *Narenga porphyrocoma* is a grass which binds the soil. In such soil sal (*Shorea*

robusta) can be cultivated. *Viola* species in western Himalyas is a suitable indicator for plantation of *Cedrus deodara* and *Pinus wallichiana*. If we know that a particular forest grows better in certain area of specific soil the productivity can be increased. For example, *Quercus stellata* and *Q. mariandica* grow on upland, lowland or on sterile sandy soils.

Sometimes forests is destroyed due to fire, overgrazing and other environmental factors and the area is left to reach up to climax. In this, subdominant species get favourable chances for growth and survival. This indicates the future plants to come and establish.

Plant indicators for humus. Some plants act as humus indicators. *Monotropa, Neottia* and mushrooms indicate the presence of humus in soil. *Strobilanthes* and *Impatiens* indicate the presence of high humus or litter which prevents regeneration of tree species.

Plant indicators for moisture. Plants which prefer to grow in arid area indicate the poor or very low moisture content in the soil. *Saccharum munja, Acacia nilotica, Calotropis, Agave, Opuntia, Argemone* are such plants. Some plants grow in low soil moisture as *Citrullus colocynthis. Eucalyptus* lowers the water table. *Echinops echinatus, Cassia auriculata* are found in the area of deep water table. *Typha, Phragmites*, and *Vetiveria* grow in water-logged soil. Growth of *Typha, Phragmites, Juncus* and *Carex* indicates the swampy condition. Mangrove vegetation and *Polygonum* are found in water-logged saline soils.

Plant indicators for Soil types. Many plants indicate the characteristic soils. For example, *Casuarina equisetifolia, Ipomoea pes-caprae, Citrullus colocynthis, Calligonum polygonoides, Lycium barbarum* and *Panicum* grow in sandy soil. *Saccharum munja* prefers to grow in sandy loams. *Imperata cylindrica* and *Vetiveria zizanioides* grow on clayey soils. Cotton prefers to grow in black soil.

Plants indicators for soil reaction. Many plants indicate whether the soil is acidic or basic. For example, *Rumex acetosa, Rhododendron, Polytrichum* and *Sphagnum* indicate acidic soils. Many forest trees as *Shorea robusta, Pinus roxburghii* are calcium loving. *Tectona grandis* (teak), *Cupressus torulosa, Ixora parviflora* and *Taxus baccata* are calcicoles. Somes mosses *e.g. Tartulla* and *Neckera* grow on lime stones. Halophytes such as *Suaeda fruticosa, Tamarix ariculata, Salicornea, Chenopodium, Salsola foetida* grow in salty soil.

Plant indicators for minerals. Many plants indicate the presence of characteristic minerals in the soils. These plants are called *metallocoles* or *metallophytes*.

The following plants grow in the presence of specific metals :

(*i*) **Diamond.** *Vallozia candida* grows in presence of diamond in Brazil.

(*ii*) **Gold.** *Equisetum arvense, Lonicera confuse, Papaver libonoticum, Alpinia speciosa, Thuja* species indicate the presence of gold minerals in the soil.

(*iii*) **Silver.** *Eriogonium ovalifolium* indicates the presence of silver minerals in soils in U.S.A.

(*iv*) **Mercury.** *Stellaria setacea* grows in Spain in mercury rich soils.

(*v*) **Uranium.** *Astragalus* species grows in USA in uranium rich soils.

(*vi*) **Selenium.** *Astragalus* species, *Neptunia amplexicaulis, Stanleya pinnata, Onopsis condensator,* etc. grow in selenium rich habitat.

(*vii*) **Copper.** *Viscaria alpina* in Norway, *Gymnolea acutiloba* in America, *Gypsophila patrini* in USSR grow in the soil rich in copper.

(*viii*) **Zinc.** *Viola calaminara, V. lutea* in Europe grow in the soil rich in zinc minerals.

(*ix*) **Boron.** *Salsola nitrata, Eurotia cerutoides* grow in boron rich soils.

(*x*) **Cobalt.** *Silene cobalticola* in Congo and *Nyssa sylvatica* grow in America in cobalt rich soils.

(*xi*) **Nickel.** *Lychnis alpina* grows in Sweden in presence of nickel.

(*xii*) **Sulphur.** *Allium, Arabis, Oenothera*, and *Atriplex* grow in soils rich in sulphur minerals.

(*xiii*) **Lithium.** *Lycium Juncus, Thalictrum* grow in soils containing lithium.

(*xiv*) **Iron.** *Damara ovata, Dacrydium caledonicum* grow in Scotland in the soils rich in iron.

(*xv*) **Aluminium.** *Ulex aquifolium* grows in Italy in soils rich in aluminium.

Besides above, the mineral content in a plant tissue can be employed in biogeochemical prospecting. Lyon and Brooks (1969) have found *Olearia rani* to be valuable for the molybdenum. Similarly, silver has been discovered in certain localities in leaves of plants. Sulphate content of leaf can directly be related to SO_2 concentration in air. Farrar (1977) has suggested that high sulphur content in pine needles indicates high concentration of SO_2 in atmosphere. Fluoride content in *Sorghum vulgare* leaves indicates the distance up to which air pollution by a fluoride source can fall out and this distance may be upto 4 km. In some cases higher copper content may be due to high tension copper wires. Mercury concentration in *Festuca rubra* grass may be due to chloroalkali set-up and lead in leaves may increase due to automobile exhaust.

Indicators of fires. Some plants are well adapted to grow in burnt and highly disturbed areas as for example, *Agrortis hiemalis, Epilobium spicatum, Populus tremuloides. Pteris aquilina,* and fungus *Pyronema confluens* grow in areas subjected to fire.

Indicators of petroleum deposits. Some protozoans, as Fusilinds indicate petroleum deposits in the area.

Plant indicators for pollution. The use of vegetation as biological indicator of environmental pollution has a long history. Knowledge of specific resistance to pollutant is of practical significance when plants grow

in industrial or thickly populated areas. Species differ in sensitivity to pollutants. In general, plants are more sensitive to pollutants than human. Therefore, plants can be used for the bioindication of environmental pollution. Sensitive species can serve as indicators and resistant species as accumulators which collect large amount of pollutants without damage. Mosses, lichens and some fungi are much sensitive to SO_2 and halides. Even 1% SO_2 concentration is harmful to higher plants. Lichens do not survive in areas exposed to SO_2 for long time.

Many chemicals, fertilizers, pesticides and fossil fuels release toxic substances into the environment that are taken up by the plants from air, water, and soil. Atmospheric pollutants, particularly SO_2 halides (HF, HCl), Ozone and Peroxi-acetyl-nitrate (PAN) produced from automobiles, industrial fumes and strong radiations are dangerous to plants. Harmful substances that reach plant through the air are SO_2, nitrogen oxides, hydrocarbons, dust, and smoke. Plants growing in water are severely affected by toxic chemicals like cyanide, chlorine, hypochlorate, phenols, benzyl derivatives and heavy-metal compounds of sewage.

The effects of different kinds of pollution can be determined by the nature of pollutants, their concentrations and the period of exposure. Under exposure to high concentration, plants suffer acute injury with externally visible symptoms, such as chlorosis, discolouration, necrosis and death of entire plant. Besides morphological changes, biochemical, physiological and fine structural changes also occur in plants.

Pollution damage can be recognised by the accumulation of toxic material in the plant, changes in pH, reduced or increased activity of certain enzymes, increase in compounds with SH groups and phenols, lowered ascorbic acid level in the leaves, depression of photosynthesis, stimulation of respiration, low dry matter production, changes in permeability, disturbances in water balance, reduced fertility under prolonged exposure. The disturbances in metabolism develop due to chronic injury with irreversible consequences. Plants show reduced productivity and yield and quality is also lowered. Besides above, the structure of wood is changed, branches dry out and gradually the trees die. The symptoms of pollution affected plants are varied and unspecific. A particular pollutant affects different plants in very different ways and a particular symptom can be produced by a variety of substances. The influence of external factors (pollutants) on plants depends on the species, state of development and the organ or tissue involved. Morphological alteration of a plant and floristic composition of a plant community are commonly used to indicate changes in the environment. According to Van Haut and Stratmann (1970), visible plant symptoms are most commonly used to indicate the responses of plants to pollutants. Jacobson and Hill (1970) have studied the effects of common pollutants on plants. It is possible that any part of plant body, if it responds specifically or characteristically to any pollutant, can be used for its indication. Goldstein (1974) emphasized that the number and kind of

biological indicators can be subdivided in order of decreasing biological complexity, such as organism, organ , tissue, cell, cell-free preparation and enzymatic studies. M.U. Beg (1980) from Industrial Toxicology Research, Centre, Lucknow has reported the responses of pollutants as a biological indicator taking several parameters into consideration.

Attempts have been made to use certain structures and functions of plants, such as seed germination, growth of plant, development of lateral branches, expansion and colour changes in leaf, flower and fruit formation, decolouration of flower, loss of physiological control, mineral composition, chemical constituents of cells, enzymatic activity and pollen germination as indicators of pollution stresses. Important aspects in response to pollution are summarised below.

Seed germination has been used by many workers to monitor pollution responses. Several growth parameters such as percentage of germination, seedling survival, seedling height, cotyledonary expansion and fresh and dry weight have been taken as criteria to assess plant response to a specific pollutant. *Phaseolus vulgaris* has been grown in smoke-free and smoke-affected regions by Sorauer (1899). The toxic effect of thiosulphate has been indicated as germinator inhibition in many plants. Houstan and Dochinger (1977) have evaluated germination inhibition in relation to pollution by sulphur dioxide and ozone. The effects of lead, cadmium, NO and CO_2 have been studied on many plants. Besides seed germination, pollen germination in *Nicotiana* has been used to indicate pollution *sylvestris*.

Some plant species are good indicators of pollution. Polygonum, *Rheum*, *Vicia*, *Phaseolus*, and *Capsella* have been observed as pollution indicators. According to Brandt (1974), a large number of plant species are capable of indicating specific contaminants. Generally, the plants response to pollutants is characteristic rather than specific. Efforts have been made to develop certain plant strains which can specifically be used as indicator for a particular pollutant. Stunting of corn, sweet potato and rye has been reported due to high toxicity. Reduction in root length, shoot length, numbers of tillers, leaves, ears and grains in wheat have been reported under condition of cement dust pollution. Similarly plant height, number of leaves and bolls per plant are reduced in cotton exposed to particulate pollution. Inhibition of lateral growth of forest trees is caused by lime stone dust. Pine trees do not flourish in SO_2 polluted areas. It has been noticed that leaf is the most sensitive organ to pollution. The pollution indicator value of leaf has been exploited by many workers in response to a variety of conditions. Leaf injury is a characteristic symptom to various pollutants. The characteristic symptoms on leaf include pigmentation, chlorosis, yellowing, necrosis etc. The leaves of dicotyledons generally exhibit spotted markings between the veins while monocotyledons usually show necrotic streaks between parallel

veins. Injury may also occur along the leaf margin and tip. Symptoms produced by ozone, oxides of nitrogen and chlorine are almost similar. Reduced expansion of cotyledonary leaves in response to pollution has been observed in several cases.

Recently epidermal morphology has been studied as indictator of different pollutants especially SO_2. Cuticular and epidermal damage can be used to indicate air pollution. Dry weight of leaf, decrease in leaf thickness, cell size, loss of leaves and early senescence may be due to smoke and SO_2 pollution. Yunus and Ahmad (1980) have observed that leaves in the polluted area of cement factory showed higher stomatal and trichome densities, smaller epidermal cells and trichomes as compared to leaves obtained from unpolluted atmosphere.

Table 12.3.

Pollution indicating plants and their characteristic features

Pollutant	*Plant indicator*	*Characteristic features*
Ozone	*Salvia, Dahlia, Pinus.*	Red or brown spots or streaks on the upper surface of the leaves, in presence of more pollution leaf margins are curled, wilting of apical part of pine needle occurs.
SO_2	*Ficus, Xenia, Pinus*	Light spots on the margin or near the veins, killing of tissues.
Hydrogen fluoride	*Gladiolus, Pinus*	Tissues of apical part and margin of leaves are destroyed.
Peroxi-acetyl nitrate	*Petunia, Salvia Chrysanthemum,* Primrose	Destruction of chlorophyll of leaves, and killing of cells of lower surface.

Biochemical and Physiological Changes

Chemical composition of leaf has widely been used to indicate environmental conditions. Among the biochemical estimations, the most important parameter is pigment analysis. Chlorophylls *a* and *b* have been measured as index for response to different types of pollution. In *Cassia and Cynodon,* 5% reduction of chlorophyll has been observed while in *Saccharum* the pigment is least affected. Chemical estimation like proteins, aminoacids, soluble sugars, sucrose, starch, reducing sugars, vitamin C, riboflavin, thiamine and carbohydrate are used to indicate foliar sensitivity to air pollution.

Physiological activities as opening of stomata, and rate of photosynthesis can also be used as indicators of pollution. Photosynthesis as a parameter has been used for mixed exposure of SO_2, NO_2 and dust.

Enzymatic parameters are also used to indicate the presence of particular pollutant. Peroxidase was found to be most sensitive indicator of pollutants in the absence of visible injury. Kellar (1974) and Jager (1975) have reported a differential response of enzymes in areas affected by fluoride, automobile pollution and SO_2. Thus on the basis of enzyme activity, the susceptible species of plants can be identified. Many workers have reported that enzymatic activity has been related to air pollution. Other common enzymatic parameters used are ribulose diphosphate carboxylase, glutamate- pyruvate transaminase, glutamate-oxaloacetate transaminase and peroxidase for SO_2 pollution.

QUESTIONS

1. What are plant indicators ? How indicators can be used in different conditions ?
2. Write short notes on :
   (*a*) Biological indicators;
   (*b*) Pollution indicators;
   (*c*) Plant indicators for agriculture.
3. Describe different kinds of plant indicators with suitable examples.

13

ENVIRONMENTAL POLLUTION

Today millions of people are without basic needs of cloth, shelter, health, education and employment. This is not due to overpopulation alone but also due to environmental consequences. The loss of forests, fertility of soil, productivity and energy crisis have created many problems. The pollution created by industries, technology and over-consumption by the affluent society lead to the rapid depletion of basic natural resources. Many human problems are also due to mismanagement of environment which is created by man himself.

Environmental implications due to pollution are in various aspects. These produce serious problem for human beings to maintain its existence, protection, survival and for the improvement of general standard. The basic needs of human beings have disturbed natural resources and finally led to a situation which has threatened to be disastrous. In the recent years everyone has started thinking over the problem of over-population and its consequences, which is primarily concerned with the environmental pollution and every effort should be made to focus public attention to save mankind from selfdestruction and steps should be taken at national and international levels so that the consequences may not become worse.

The ecological state of biosphere is becoming more and more disbalanced day by day due to technical and industrial advancements as well as population explosion. Vast changes are taking place in the environment due to interaction between human society and environment itself. Man is exploiting the natural resources for its own interest and many such instances are there as clearly indicate that man has disturbed the natural balance for the sake of small benefits and has changed the environment of many places to such an extent that they are not fit for inhabitation by living beings.

The environmental science is concerned with the study of all the systems of air, land, water, energy and life that surround us. Environmental problems are so diverse and diffused that virtually every activity of civilization interacts with the environment. The addition of extraneous

materials or energy in a particular environment in concentrations greater than the normal renders the environment partially or wholly unfavourable for human life. This is referred to as environmental pollution. *"Environmental pollution is the unfavourable alteration of our surrounding, wholly or largely as byproducts of man's action through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitutions and abundance of organisms". These changes may affect man directly or through his supplies, of water and agricultural and other biological products, his physical objects or possessions, or his opportunities for recreation and appreciation in nature.*

—from U.S. Products Science Advisory Committee, Environmental Pollution Panel (1965)

Pollution and *contamination* are two terms sometimes used interchangeably. Contamination is the presence of harmful substances or organisms that may cause diseases or discomfort to human beings. Polluted material need not necessarily be contaminated. Dependent as he is on air, water and food from environment, man is the main culprit in polluting these natural resources to the point of no return.

Pollution is defined as the addition of extraneous materials to water, air or land which adversely affect the natural quality of the environment. In some cases, it may involve the removal, rather than addition, of constituents from the environment. A **pollutant** is a substance which may alter environmental constituents or cause a pollution. A pollutant can also be defined as constituent in the wrong amount at the wrong place or at the wrong time. For example, nitrogen, phosphorus and potassium are extensively used in agriculture to increase crop yields but sometimes they cause pollution of lakes and rivers by promoting algal growth.

The natural sources of pollution are, no doubt, important on a global scale, man generated pollutants may be more important in urban and industrial areas where the adverse effects of pollution are most severe. There is accumulating evidence that many types of pollutants can be distributed over the whole earth in relatively short period of time. Radioactive fallout from atmospheric nuclear explosion test is detectable throughout the world within a few days `or weeks; not even the polar regions are immune from fallout. Comfort giving automobile's are polluting the atmosphere with oxides of C, N, and other noxious gases. Coal, diesel oil and other fossil fuels are emitting suffocating SO_2 and choking our lives. Synthetic chemicals like plastics are adding to the problem of solid waste disposal; while detergents that cannot be decomposed by micro-organisms are making the natural rivers and streams polluted bubble boxes. Some other effects of environmental pollution are problems of health, soil erosion, sanitation, water supply, energy crisis, population and depletion of natural resources.

The law of conservation of mass or material equally applies to the pollutants and while one cannot destroy them, they may be changed from

one state to another or from one compound to a another. The presence of small amount of pollutants may make profound influence on human health even when the level of air pollutants is so low that they cannot be detected except with special instruments. Some pollutants may harm living creatures exposed for long periods of time.

As regards the nature of pollutants, the problem of pollution can be divided into the following categories :

1. Pollution caused by solid wastes
2. Pollution caused by liquid wastes
3. Pollution caused by gaseous wastes
4. Pollution caused by wastes without weights.

1. **Pollution caused by solid wastes.** A number of materials constitute solid wastes which are either domestic or industrial. Urban people dispose off garbage and other solids to some public places or in open dumps.

The solid wastes include the following pollutants :

(*i*) *Garbage*, such as, wastes from kitchen, slaughter houses, canning and freezing industries.

(*ii*) *Rubbish*. Combustible wastes, such as leaves, grasses, plants from the garden and non-combustible wastes such as bottles, crockery and plastic materials.

(*iii*) Ashes.

(*iv*) Large wastes formed due to demolition and construction processes, as for example bricks, plastic, furniture, etc.

(*v*) Dead animals' wastes.

(*vi*) Sludge, settled solid components of sewage wastes.

(*vii*) Industrial solid wastes, as for example, chemicals, paints, sand, etc.

(*viii*) Mining wastes, such as wastes from coal mine.

(*ix*) Agricultural wastes such as farm animal waste, manure, crop residue, pesticides, insecticides and so on.

The problem of solid domestic wastes whether it is garbage, litter or rubbish cannot be underestimated. In advanced countries it is estimated that at an average a city dweller produces more than half a ton of garbage per year. Pollutants are divided into two categories :

(*i*) **Biodegradable pollutants.** These pollutants are natural organic compounds which are degraded by biological or microbial action *e.g.*, sewage.

(*ii*) **Non-biodegradable pollutants.** These are not acted upon by microbes but are oxidised and dissociated automatically. They are further divided into two classes :

(*a*) **Wastes** *e.g.*, glass, plastics, phenolics, aluminium cans, etc.

(*b*) **Poisons** *e.g.*, radioactive substances, pesticides, heavy metals like mercury, lead, cadmium.

2. **Pollution caused by liquid wastes.** Major portion of water on the surface of earth is not in a form that can be used for domestic purposes by man since it is saline. Man obtains fresh water from the well known hydrologic cycle. Surface runoff gathers minerals and organic impurities as it moves down to the sea. Under normal conditions river takes care of many polluting substances that enter its body. Green plants and algae take up CO_2 from water and in presence of sunlight synthesize carbohydrates and O_2 is produced by splitting of water molecules. Animals take up O_2 and give up CO_2 and other compounds which are used by the plants. This is ecological balance in a natural stream. If some organic matters, that can be food materials for bacteria, enter water course then bacteria oxidise these materials and in that process take up O_2 from water. If the process of re-oxygenation is slower than the process of de-oxygenation then river will be devoid of life sustaining dissolved oxygen and aquatic animals and plants will die and under anaerobic condition foul smelling hydrogen sulphide and other products are formed. The river can be termed dead in the sense that it cannot sustain normal aquatic life.

Sewage. The important source of organic pollutants is sewage which contains faecal matter, urine, and kitchen washings and some soil washing. Sewage contains large number of bacteria, both pathogenic and harmless. The strength of organic waste materials of sewage is measured in terms of demand for dissolved oxygen required in oxidation of organic matter by micro-organisms. This value is expressed in terms of mg of O_2 per litre of waste. Since biological reaction is dependent on time and temperature, this O_2 demand (called biochemical O_2 demand or B.O.D.) is given for 5 days at 20°C. If the value of B.O.D. is below 1500 mg per litre, the sewage is termed *weak waste*, if it is below 4000 mg per litre it is *medium* an above this value it is termed *strong waste*.

Domestic sewage in small quantities rarely gives trouble. However, if liquid industrial wastes enter the river along with acid or alkali and poisonous substances like cyanides, etc., the aquatic life in the river is affected and self-purification system of water is impaired. Surface run-off from agricultural fields can carry nitrogen and phosphate fertilizers that increase the aquatic plant life and later undergo decomposition adding to the organic loading of the stream. Pesticides, and herbicides which enter waters may kill some organisms or accumulate in the fishes which when consumed by man, pass on the chemicals giving rise to cumulative poisoning.

3. Pollution from gaseous wastes. The gaseous wastes—most dangerous to people—are the ones that threaten the life of animals and plants. Carbon monoxide, SO_2, NO_2 (nitrogen dioxide), ozone and the so called "smog gases" made up of complex mixtures of hydrocarbons are common gaseous pollutants. These are the gases generally found in the atmosphere of industrial cities.

Carbon monoxide which is a product of incomplete combustion is deadly poisonous at high concentration. It has high affinity for haemoglobin in the blood and prevents that from transporting oxygen from the lungs to the tissue of the body. Fortunately, most of the times the amount of CO in the open air is too low to do much damage to human health.

Hydrogen sulphide is another deadly gas when it occurs in large concentrations, which is rare.

Of the common gaseous pollutants, **sulphur dioxide** (SO_2) is regarded as one of the most dangerous gases to human health. It attacks the respiratory tracts and interferes in the breathing mechanism. Concentrations above 1 ppm (part per million) can begin to affect people.

Nitrogen dioxide gas in sufficient quantities in air may attack lungs and cause eye irritation. Some hydrocarbons and nitrogen dioxide under the influence of sunlight produce complex substances affecting the eyes and mucous membrane.

Smog is the result of fog and the photochemical oxidation products of hydrocarbons and other organic compounds released from automobile exhaust.

4. **Pollution caused by wastes without weight.** The fourth kind of pollution termed as "wastes without weight" can also be called pollution by energy waste. Certain types of pollution cannot be seen and these are included in this group. Wastes without weight include the following :

(*a*) Radioactive substances

(*b*) Heat, and

(*c*) Noise

(*a*) **Radioactive substances.** The amount of radioactivity in this atomic age has increased in the environment many folds as compared to Thirties and Forties. According to one authority, man may be already having radioactive cesium in his muscles, radioactive strontium in his bones and radioactive iodine in his thyroid indicating the extent of radioactive pollution. Although every precaution is taken in the functioning and maintenance of nuclear reactors, it has been shown that minute, yet measurable amount of radioactive waste material escapes out into the environment. From the minining operation of uranium to the use and final disposal of wastes from the reactors, radioactive waste materials continuously escape out. Besides emission from nuclear installations, there is worldwide fallout of radioactive substances from atomic bomb tests. This kind of radioactive pollution caused alarm in the late Fifties and Sixties leading to a moratorium on surface and aerial tests explosions by the super powers. China and France incidentally continue to make occasional tests.

The underground storage of radioactive material in concrete or steel containers still does not ensure complete safety. Radioactivity cannot be destroyed and hence it has cumulative effect. The minute radioactive atoms, molecules or ions in water to which they may have leaked out pass on to

aquatic organisms and since they are part of food chain, the radioactivity goes on accumulating in the higher organisms. In a survey of Columbia river into which cooling water of plutonium producing reactors was dumped, it was estimated that compared to the radioactivity of river water the microscopic plants and animals had one thousand times more radioactivity, fly larvae had 35,000 times more radioactivity, while the eggs of ducks which fed on the larvae etc., had 40,000 times and some birds had almost 75,000 times more radioactivity than that of water.

(*b*) **Heat.** A large quantity of waste heat energy by way of hot liquid streams or hot gases released by industries, automobiles etc., dissipates in atmosphere and water and enhances the temperature.

(*c*) **Noise.** Noise is unwanted sound. It has come to be regarded as an important pollutant of the environment. The sources of noise for the general public are the machine in the industry, traffic noise due to trucks and cars as well as due to the indiscriminate use of transistors, radios and public address systems. Processions, public broadcasting of films, music of high pitch on festive occasions are the noises that pollute the environment. Noise produced from the aircraft, especially the supersonic jets, is harmful.

DIFFERENT TYPES OF POLLUTION

WATER POLLUTION

Water is essential for all forms of life and none can survive on this earth without water. The surface of earth measures 50,000 billion hectare of which about 70% is covered by water and the rest is land. The total volume of water on the earth is 1011 million cubic kilometres of which about 97% *i.e.*, 986 million cubic kilometres is contained in oceans and an additional 3 million cubic kilometres of salty water is buried underground and the remaining 2.5% (22 me kms) accounts for the total fresh water, frozen water of glaciers and polar ice caps. Of the 113 river basins in India, 14 are major, 44 are medium and 55 are minor (major basins are larger than 20,000 square km., minor basins are smaller than 2000 sq km). Three major rivers, namely the Ganga, the Brahmaputra, and the Indus, are snowfed rivers originating from the Himalayas and the other major rivers originate either in the central plains or in peninsular India.

Chemically, water contains two parts hydrogen and one part oxygen. Water for human consumption should be clean, colourless, odourless, well aerated, cool, soft, palatable, free from dissolved toxic substances and suspended particles. But water is rarely found in pure state. Man had polluted the bodies of water to an alarming state . In recent years the pollution of water has become one of the most significant environmental problems in the world. There is a great concern for rapidly deteriorating quality of water. The causes of water pollution are many but urbanisation, industrialization and increasing pollution are more prominent among them. Water is said to be polluted when its quality or composition is changed either naturally or as a result of human activities and it becomes unsuitable for drinking and less suitable for domestic, agricultural, industrial, recreational and other uses.

The dissolved or suspended substances which deteriorate the quality of water and make it unfit for human consumption are called **water pollutants**. In other words, water pollutants are those physical, chemical or biological factors which are harmful to aquatic life and to those who consume water. Water pollutants include several chemicals in dissolved or suspended state, some physical factors such as heat, radiations, and some biopollutants such as aquatic microorganisms particularly pathogens.

Most of the wastes generated by human society are disposed off in the bodies of water such as rivers, lakes and oceans. Some of the wastes which are discharged in air or on land may also ultimately enter the bodies of water. When human population is concentrated too much along the water ways they are unable to handle huge quantities of domestic wastes released into them and consequently they become polluted with unhappy results. Growth of big cities and industrial setup at the banks of rivers have posed serious problems. Huge discharge of industrial wastes and sewage into the rivers, lakes, ponds etc. at times, polluted water to such an extent that dead fishes were seen floating on the surface of water. Today there is growing concern about the pollution of our lakes and rivers. Marine pollution is the matter of international concern from the point of view of conservation of living resources. All coastal nations dispose off millions of gallons of untreated sewage, millions of tomes of garbage, unlimited amount of low level radioactive wastes etc. into the seas. There can be no doubt in it that there has been a serious decline in environmental quality and production in estuarine and shallow coastal waters as a result of pollution. The results of water pollution are quite apparent whether they are measured in terms of living resources, or hazards to human health or reduction of immunities.

Water Pollutants and their Effects

Most of the rivers and fresh water streams in India are badly polluted by industrial wastes or effluents. The major sources of pollution of some Indian rivers are listed in Table 13.1

Table 13.1. Indian rivers and sources of their pollution

Name of river	*Sources of pollution*
1. Kali	Sugar mills: distilleries; paint, soap, rayon, silk, yarn, tin and glycerine industries.
2. Yamuna	D.D.T. factory, sewage, Indraprastha Power Station, Delhi.
3. Ganga	Jute, chemical, metal and surgical industries; tanneries, textile mills and great bulk of domestic sewage of highly organic nature.
4. Gomti	Paper and pulp mills; sewage.
5. Dajora	Synthetic rubber factories. *(Contd.)*

Name of river	*Sources of pollution*
6. Damodar	Fertilizers, fly ash from steel mills, suspended coal particles from washeries, and thermal power station.
7. Hoogly	Power stations; paper pulp, jute textiles, chemical mills, paint, varnishes, metal, steel, hydrogenated vegetable oil, rayon, soap, match, shellac, and polyethene industries and sewage.
8. Sone	Cement pulp and paper mills.
9. Bhadra	Pulp, paper and steel industries.
10. Cooum, Adyar and Buckinghum canal (Chennai)	Domestic sewage, automobile workshops.
11. Kaveri	Sewage, tanneries, distilleries, paper and rayon mills.
12. Godavari	Paper, mills.
13. Siwan	Paper sulphur, cement, and sugar mills.
14. Kulu	Chemical factories, rayon mills and tanneries.
15. Suwao	Sugar industries.

Contamination of the industrial wastes in the water is most dangerous. The sewage of big cities is often drained into rivers. This sewage promoted the growth of phytoplanktons. This excessive growth depletes the oxygen of water. This reduction of oxygen and the presence of poisonous wastes affect the fish population. Besides this, rivers, lakes and ponds are also used directly by people for bathing or washing. This contaminates the water with the germs of various diseases-like cholera, dysentery and hepatitis.

The effluents produce physical, chemical and biological changes in water. Some pollutants produce only temporary effects in water whereas others have long standing effects. There are several types of physical and chemical effects produced by pollutants. These are : (1) addition of poisonous substances; (2) addition of suspended particles; (3) addition of non-toxic salts; (4) water deoxygenation, and (5) Heating of water. Some of the important water pollutants are discussed here as under :

1. **Sewage and other oxygen demanding wastes.** These are largely organic materials that can be oxidised by micro-organisms to CO_2 and water. When the amount of sewage discharged is relatively small, the river will not become badly polluted. So the biological degradation will soon remove most of the wastes. However, medium and strong sewage as well as other O_2 demanding wastes from industry and agriculture can lead to depletion of dissolved O_2 in water. Septic conditions are said to prevail when the dissolved O_2 is very low.

Sewage contains human excreta, dung and urine of animals, some dissolved proteins, carbohydrates, fats and a variety of inorganic wastes

such as nitrites, nitrates, phosphates, chlorides, carbonates, sulphates and mineral elements like sodium, potassium, calcium, magnesium, aluminium, nickle, chromium etc. Through drainage system the sewage is discharged into the rivers, canals, lakes and sea which makes the bodies of water polluted. Pollution of water promotes vigorous growth of algae and other microbes which results in the development of yellow or grey scum on the surface of water. Sometimes water smells stingy and appears to be coloured. This is referred to as water bloom. In natural state, the organic wastes are degraded or decomposed by micro-organisms. Sometimes, the rate of decomposition of pollutants is much slower than their addition leading to depletion of oxygen which makes the pollution problem serious and complicated. In developed countries and in a great majority of developing nations including India, different types of sewage disposal systems are employed for the removal of organic and inorganics wastes and other harmful substances from sewage before that is discharged into the body of water.

Sewage and other O_2 demanding wastes are classified as water pollutants because of the following reasons :

(*i*) their degradation leads to O_2 depletion which affects or even kills fish and other aquatic life ;

(*ii*) They produce foul odour and undesired colours ;

(*iii*) They may lead to scam and sludge that render water unfit for recreational use.

2. **Biopollutants.** Micro-organisms such as algae, fungi-bacteria, viruses, protozoa, etc. often reach to water bodies through surface runoff, domestic wastes and sewage. These microbes produce several undesirable and harmful effects in water. Many of them cause diseases in human beings and equatic animals through contacts. Waste water from municipalities, sanatoria, tanning and slaughtering plants and boats discharged into the rivers, streams, lakes, etc. may be a potential source of infective bacteria and other microbes which cause diseases in man and other animals. Cholera, typhoid and many skin diseases are transmissible though polluted water. Recent Jaundice epidemic in Delhi and Kanpur was considered to be due to the excessive pollution of water of Jamuna and Ganga respectively, which are used for drinking purpose.

3. **Plant nutrients.** Surface runoff from agricultural fields carries nitrogenous and phosphate nutrients that increase the growth of aquatic plants and later undergo decomposition adding to organic loading of the streams. Excess algal growth has been of particular concern since algae lead to depletion of O_2 in water, create problems for municipalities and industries and make water unfit for recreational uses.

4. **Exotic organic chemicals.** These include surfactants, detergents, pesticides, various industrial products, oils and decomposition products of other organic compounds. Good amount of oil along with waste products of industry reaches the sea and rivers. Oil discharged from coastal industries

and from ships is most likely to be responsible for the tainting of fishes and shell fishes. Sea food with oily taints is highly objectionable and the suspected presence of tainted consignment can damage the market generally.

The most important groups of compounds which are both toxic and persistent are the chlorinated hydrocarbons including organochlorine pesticides, such as DDT, Dieldrin, BHC, Polychlorinated biphenyls (PCBs) and benzene products. The pesticides as shown in Fig.13.1 are dispersed in the environment through air and water. They become concentrated in successive transfers from plants to herbivores to carnivores. All these accumulate in marine animals. Agricultural pesticides poison are kill millions of fishes and other aquatic life. DDT may upset behaviour pattern in fish and survival of very young stages of molluscs and crustacea. PCBs compounds seem to be substantially less toxic than DDT but they certainly accumulate in marine animals in the similar manner. There is suggestion that they were responsible for sea birds' deaths at the U.K. coast in 1969 but it could not be substantiated. Some plastic intermediate and the by-products appear to be widespread in the sea. Very insufficient information is available to assess their toxicity which may well accumulate in marine animals and plants.

5. **Inorganic minerals and chemical compounds.** Inorganic chemicals of many types find their way into waters through municipal and industrial wastes and the urban runoff. These pollutants can kill and injure fishes and other aquatic life and they can interfere with the suitability of water for drinking and industrial purposes. Mercury, lead, cadmium and copper are the important metals that cause most concern. Other metals reaching the rivers and sea in substantial quantities are zinc and chromium. Cyanides, thiocyanates, chromates, acids, alkalies, organic solvents and several other industrial wastes are causing serious concern to general public.

Mercury occurs naturally in the sea as the result of weathering of mercury bearing rocks. It is also present in fossil fuels, coal and oils and reaches the sea by serial transport. It is highly persistent and said to be converted into a highly toxic mono methyl mercury (CH_3Hg) and dimethyl mercury $(CH_3)_2$ Hg which produce nervous disorders in marine animals at an ordinarily low level of dietary intake. Normal level of Hg in fish probably ranges between 0.02 and 0.2 ppm. In situations exposed to industrial discharges containing Hg wastes in Japan, Sweden and North America, Hg levels above 1.0 ppm have been found. Consumption of Hg contaminated fishes may be hazardous to man. Human beings feeding on such poisoned animals develop a crippling deformity called *minamuta disease*. Mercury inhibits chromosomal disjunction during gamete formation and brings about genetic changes (Ramel,1974). It is not known that anaerobic bacteria in bottom mud can convert Hg into methyl mercury (CH_3Hg).

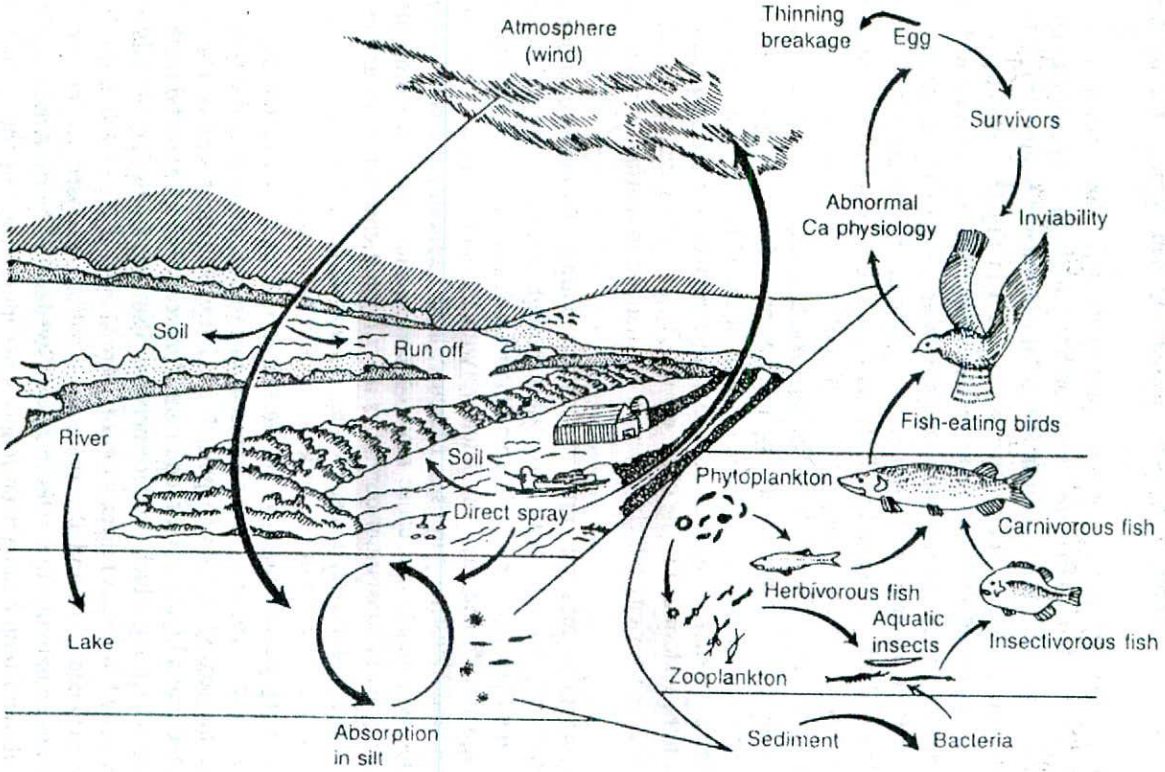


Fig. 13.1 Cyclic distribution of pesticides in nature and their effects on fish eating birds due to biomagnification through aquatic food chain.

Lead is the natural pollutant of water, air and biosphere. Lead is accumulating in the marine environment as a result of drainage from rocks bearing this metal, industrial and domestic sources particularly the use of anti-knock motor fuels containing lead compounds. It has been calculated that motor vehicle exhausts contribute upto 2×10^5 tonnes of lead annually to the ocean through atmopsheric transport. Much of this accumulates in the surface layer of sediments. One study based on geochemical relationships and material balances suggest that modern man absorbs daily 20 mg lead from food, 1 μg from water and upto 10μg from urban air. Natural conditions are estimated to have .01 ppm lead in food, .0005 ppm in water and 5×10^{-4} $\mu g/m^3$ in air. The pollutant is persistent cumulative and may show biological amplification. It has mutagenic effects (Hickey *et al.* 1971) and it may cause congenital deformities. Lead disturbs metabolism through its effect on enzymes. Symptoms of lead poisoning include loss of appetite, appearance of bluish lines round the gums, anaemia, etc. The rapid increase in the lead level in air and aquatic environment in recent years must be viewed with concern

Copper and **zinc** have long been known to accumulate to very high levels in molluscs where they may colour the flesh and render them unmarketable but marine fishes do not exhibit this characteristic to the same degree. No toxic effects on consumers have yet been recorded.

Cadmium is also accumulated by some marine animals and is only slowly excreted. It is highly toxic but there is lack of information as to its biological effects.

The information regarding chromium is also very sparse.

Liquid wastes or effluents from industries. The liquid effluents of industries containing a variety of poisonous chemicals are discharged into the bodies of water. They not only change the pH of water but also adversely affect the aquatic plant and animal life and sometimes cause large scale killing of fishes and other aquatic animals.

Oils. Petroleum extracted from the area of continental shelf is transported from one country to another through sea. After unloading, the tankers are washed in sea. This causes oil slicks or spills in the sea especially near the ports and shore lines. Because of accidents during transportation and extraction process, oil is spread hundreds of kilometres on the water surface which causes serious problems. A line of oil spilled into water can spread and cover an area of four thousand square metres of water surface. Three fourth of the oil spilled into the water is subjected to emulsification and the rest is evaporated. The effects of oil pollution are as follows :

(*i*) oil film on the surface of water prevents oxygenation of water.

(*ii*) it inhibits plankton growth and photosynthetic activity of aquatic plants.

(*iii*) it causes death of aquatic animals due to reduced oxygen availability in water, poisoning of food and toxic effect of oil.

(*iv*) oil spilled over water surface may catch fire and cause damage to aquatic life.

(*v*) detergents used to clean oil spill are equally harmful to aquatic life.

Effects of Water Pollution

The various effects of water pollution are discussed here as follows :

1. Physicochemical Effects

Many pollutants produce undesirable colours, taste and odour in water and make it unpleasant and unfit for drinking and domestic uses. These changes may be in O_2 contents, temperature, and pH which affect the physicochemical nature of water.

The addition of organic substances results in depletion of oxygen and increase in CO_2 due to their decomposition by aerobic bacteria. The addition of nutrients through various sources enhances the algal and other biological growths which help in decompositions and lead to depletion of O_2. The decomposition of organic materials in absence of O_2 produces unpleasant odour and unaesthetic conditions due to release of several obnoxious gases as ammonia, methane, hydrogen sulphide etc. Algal photosynthesis produces increase in pH of water by consuming CO_2. CO_2 dissolved in water produces carbonates.

2. Biological Effects

Excess pollutants affect the aquatic flora and fauna. Most of the fresh water algae are highly sensitive to pollutants and their elimination modifies the pre-predatory relationship by breaking down the food chain which results in change of plant and animal communities, Biodiversity decreases in presence of a few tolerant species in polluted aquatic medium. Excess of nutrients in water promotes algal growth and formation of water blooms by blue-green and green algae. Many of the blue-green algae are not consumed by fishes and other aquatic animals and some of them produce toxic secretions which disturb the aquatic ecosystems.

3. Toxic Effects

Some pollutants for example, heavy metals, biocides, cyanides, and other organic and inorganic compounds are harmful to aquatic organisms. Although these substances have low permissible limits, their presence beyond those limits can make water unfit for aquatic life, human beings and other uses. These chemicals prove to be toxic to aquatic organisms and many of them, especially non-biodegradable ones accumulate in the body of organisms and cause long-term effects.

4. Pathogenic Effects

Few wastes, for example sewage, contain several pathogenic fungi, bacteria and viruses. *Clostridium perfringens, Streptococcus faecalis* cause various types of food poisoning. Besides, several diseases are water-borne which spread by sewage contaminated water. *e.g.*, cholera, typhoid, paratyphoid, dysentery, colitis, jaundice etc.

PROBLEM OF WATER SUPPLY AND SEWAGE DISPOSAL

Supply of Potable Water

The main sources of drinking water supply in the cities are rivers, lakes and streams. Water from such sources is purified or made pollutant-free and germ-free before that is supplied for drinking and other domestic purposes. To make the raw water clean and pollutant-free, the following three steps are followed :

(*i*) Sedimentation
(*ii*) Filtration
(*iii*) Chlorination

(*i*) **Sedimentation.** In this process, alum, aluminium sulphate or iron sulphate are mixed with raw water drawn from lakes or rivers into the mixing tank which form jelly-like floccules with dissolved and suspended substances. Water mixed with flocculants is allowed to flow into the flocculation tank where the floccules along with suspended soil particles, other extraneous materials and microbes settle at the bottom.

(*ii*) **Filtration.** After precipitation of floccules clean water is allowed to pass through special types of filter to remove the micro-organisms from it. For this purpose, water is allowed to percolate down through several alternating superimposed layers of sand and gravels.

(*iii*) **Chlorination.** Water after filteration process is subjected to chlorine treatment. In this process chlorine gas is passed through water which being a strong oxidant causes quick degradation of organic substances and at the same time kills the remaining bacteria. Water so obtained is then supplied to public for drinking and other domestic purposes.

Sewage Disposal

Sewage treatment aims chiefly at the removal of solid wastes and their degradation and conversion into simple inorganic substances through microbial activities.

The following methods are employed for the disposal of sewage :

1. Soaking pits
2. Septic tank
3. Municipal sewage disposal plants

1. **Soaking pits.** In this process a big perforated underground tank made up of concrete and cement is used (Fig 13.2). The sewage is discharged into the tank through a pipe. Sewage water from the tank comes out through the holes and percolates into the soil. The solid wastes are decomposed by micro-organisms inside the tank.

2. **Septic tank.** In this method the sewage from house is discharged into underground septic tanks through pipes. The solid fraction of the sewage settles at the bottom of the septic tank and fraction flows out into the distribution pipes fitted in the upper part of the tank and finally drained into the field (Fig 13.3). The solid fraction of sewage collected at the bottom is decomposed quickly by microbes.

3. Municipal sewage disposal plants. Treatment and disposal of sewage in big cities involve the following three steps :

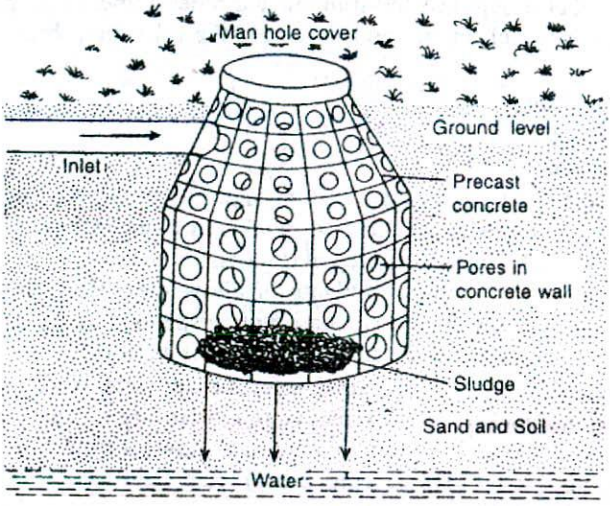


Fig. 13.2. Soaking pit.

(*i*) **Primary treatment.** For primary treatment the sewage is carried into the big open tanks through pipes. The solid fraction of the sewage settles at the bottom of the tanks which is drained through pipe system into the aerobic digester tank is decomposed. The watery fraction of sewage from the primary settling tanks is drained into the secondary settling tank and mixed with aluminium sulphate or iron sulphate which froms jelly-like floccules. The floccules along with micro-organisms and suspended solid particles settle at the bottom of the tank in the form of sludge which is then drained through pipes into the aerobic digester tanks. (Fig 13.4).

(*ii*) **Secondary treatment.** The watery fraction of sewage which contains bacteria and other microbes as well as dissolved organic wastes is collected into the secondary settling tanks and air current under pressure is passed through the fraction to promote microbial decomposition of dissolved organic wastes. After sometime the fraction is passed through sand filters to remove microbes. The clean water is then allowed to flow into the rivers and oceans

The solid wastes and sludge carried to the digester tank are attacked and decomposed by aerobic bacteria. The decomposition of wastes results in the formation of NH_3, methane, hydrogen sulphide gases which are collected for various industry purposes.

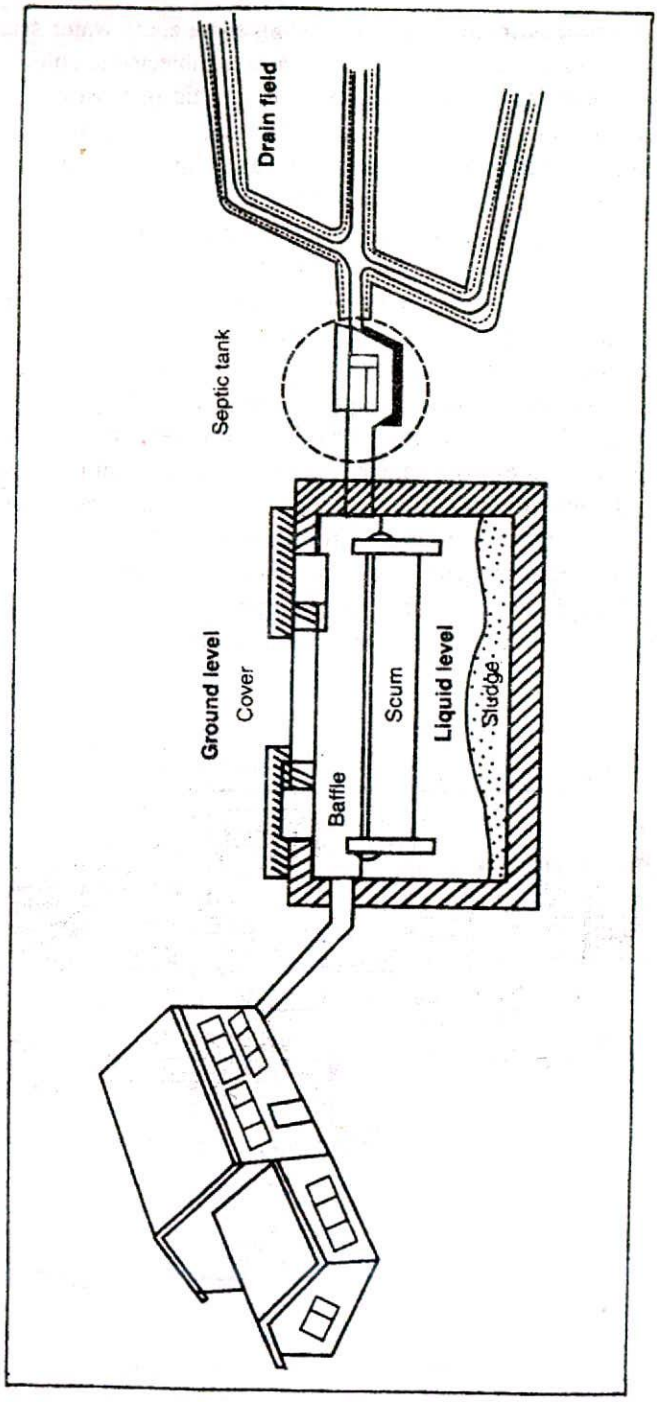


Fig. 13.3. Septic tank for sewage disposal.

(*iii*) **Tertiary treatment.** The cities facing some acute water scarcity, the clear water obtained after secondary treatment is subjected to chlorination and after proper testing that is supplies for domestic purposes.

According to an estimate of Central Pollution Control Board, the total sewage production from urban areas in India was about 30,000 billion litres a day in 1997 and the present total sewage treatment facility is hardly sufficient for 10 per cent of the total waste water generation. Though the drainage and sewerage facilities have now increased in urban areas, the existing facilities are not sufficient for the disposal of total waste water. The waste water treatment programmes are not fully successful because of poor maintenance, improper designs of treatment plants and non-technical and unskilled approach. The sewage treatment plan under Ganga Action Plan between 1980 and 1990 failed completely due to above-mentioned reasons.

Due to poor facilities of sewage and waste water treatment most of the pollutants find their way into groundwater, rivers, and other water bodies. In some pockets of India, the villagers are still dependent for drinking water on natural water reservoirs and face many problems as detailed below :

1. Drinking water is loaded with pollutants.
2. Water contains pathogens of cholera, typhoid, and a number of skin diseases.

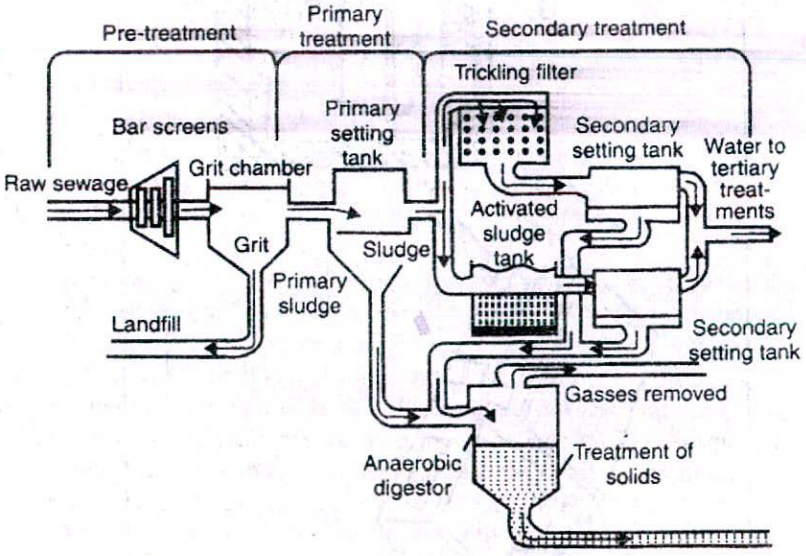


Fig. 13.4. Municipal sewage disposal plant.

3. In some localities water is highly saline and contains fluorides or other toxic elements.

In some urban areas too, the supply of pure drinking water has become a big problem. According to an estimate of World Bank (1998), about 60 per cent deaths in urban areas were due to such water related diseases as cholera, dysentery, gastroentirities hapatites etc.

Water Quality

The evaluation of water quality is done in terms of several parameters such as alkalinity, dissolved oxygen, Biochemical oxygen demand (5 days), number of coliform bacteria, colour, hardness, odour, pH, salinity, temperature, total solids, turbidity, salts–chlorides, fluorides, nitrates, phosphates and sulphates, presence of trace elements like Al, As, Ba, Cd, Cr, Fe, Pb, Mn, Hg, Se, Ag, Sn, Zn and B, pesticides and radioactivity. Among these attributes, the amount of dissolved oxygen, biochemical oxygen demand and total coliform counts are good indicators of the quality of water. These are briefly discussed here as under :

Dissolved oxygen. It is a measure of the ability of water to support a well balanced aquatic life. Sufficient amount of dissolved oxygen in a water body brings about quick microbial degradation of organic wastes. Biochemical oxidation of ammonia to nitrate in natural water requires dissolved oxygen. Insufficient amount of dissolved oxygen in water adversely affects the microbial decomposition and methane is released instead of CO_2, odourous amines result from nitrogen instead of NO_3 and NH_3 and foul smelling H_2S gas is formed from sulphur instead of SO_2.

Biological or Biochemical Oxygen Demand (BOD)

The most common index of water pollution is biochemical oxygen demand (BOD) which refers to the quantity of oxygen required by bacteria to decompose the organic wastes aerobically to CO_2 and water. The BOD test normally measures the amount of oxygen used in the first five days of aerobic microbial decomposition in a certain volume of effluent at 20°C. This is also called BOD_5. Thus 100 ppm BOD means 100 mg of oxygen consumed by one litre of test sample over 5 days at 20°C. Domestic sewage generally has BOD_5 of around 200 milligrams of oxygen per litre and for industrial wastes BOD may be around thousand mg per litre. BOD of 0.17 pound or 77 gm is also called population equivalent, being roughly equal to the requirements for the domestic wastes of one per cent concentration. The capacity of sewage treatment plant is generally measured in terms of population equivalents per day. Contamination of water by sewage is the main cause of water borne diseases *e.g.*, cholera, typhoid, paratyphoid fever, dysentery and infective hepatites.

Total coliform counts. BOD gives a rough measure of the quality of water. It does not accurately indicate the risk of disease. For that purpose more specific parameters are required. One of the most common parameters is the number of coliform intestinal bacteria especially *Escherichia coli* in

feces per unit volume of water. Although coliform bacteria are harmless, their presence in large numbers indicates that pathogenic germs might be present in the sample.

Water quality of river water is monitored at 480 stations under different programmes such as MINARS (Monitoring of Indian National Aquatic Resources), GEMS (Global Environmental Monitoring systems), and G.A.P. (Ganga Action Plan). The number of stations under the MINARS programmes initiated in 1979 increased gradually and at present the number of stations is 260.

A number of physical, chemical, biological and bacteriological parameters are being considered under the programme to determine the quality of water but important ones are DO, BOD and T.C. (Total coliform counts).

The different categories of water in response to quality and their respective uses are as follows :

Class A— Drinking water source without conventional bacteria in water. Dissolved oxygen more than 5 mg/litre, T.C. less than 50/100 ml.

Class B— Water for bathing, swimming and recreational use, D.O. > 4 mg/litre and T.C. < 500/100 ml.

Class C— Drinking water source after conventional treatment.

Class D— Water for wildlife, fisheries etc. D.O. > 4 and T.C. < 500/100 ml.

Class E— Water for irrigation, industrial cooling, no fishing, swimming or drinking. D O. > 3.

AIR POLLUTION

The atmosphere is a mixture of gases, predominantly nitrogen (78.09%), oxygen (20.94%) and some other gases (less than 1%). Table 13.2 gives composition of unpolluted atmosphere. These values remain constant upto 50,000´ altitude.

Table 13.2. Composition of unpolluted atmosphere

Constituents	*Volume*
N_2	78.09%
O_2	20.94%
Argon	0.93%
CO_2	0.032%
Neon	18 ppm
Helium	5.2 ppm
Methane	1.3 ppm
Krypton	1.0 ppm
Hydrogen	0.5 ppm

(*Contd...*)

Constituents	*Volume*
N_2O	0.25 ppm
CO	.1 ppm
O_3	.02 ppm
SO_2	.0002 ppm
NO_2	.0001 ppm

Water vapour which is present in the range of 1-3% is an important constituent of atmosphere. The other minor constituents of atmosphere may be dust particles, smoke, H_2S, hydrocarbons, bacteria, spores of plants. *The atmosphere is said to be polluted if the concentration of any constituent increases or decreases drastically to cause harmful effects on human health or his environment.* The addition of foreign materials into the atmosphere may also cause pollution.

The air pollution may be defined as qualitative and quantitative changes in the atmospheric constituents due to addition or contamination of such substances as may be harmful to man and his environment. Air pollution may be categorised into ***indoor*** and ***outdoor pollutions***. Pollution of atmosphere inside buildings, offices and residences is called indoor air pollution and the atmospheric pollution in the open space is referred to as outdoor air pollution. The different indoor and outdoor air pollutants and their sources are listed in the following Table 13.3.

Table 13.3. Indoor and outdoor air pollutants and their sources

	Pollutants	*Sources*
A.	**Outdoor pollutants :**	
	Lead	Automobiles, industrial emission.
	Ozone	Photochemical reactions in atmosphere.
	Sulphur dioxide	Fuel combustion, smelters.
	Organic substances	Petrochemical solvents, natural sources, vaporisation of unburnt fuels.
	Spores and pollengrains	Bacteria, fungi and higher plants.
B.	**Indoor and outdoor pollutants :**	
	Carbon dioxide	Metabolic activities of living organisms, combustion of fuels.
	Carbon monoxide and Nitrogen oxides	Burning of coal and other fuels, Tobacco smoking.
	Organic substances	Volatilization, combustion of coal, kerosine and other fuels, pesticides, metabolic activities, adhesives,
	Hydrocarbons	cosmetics, solvents etc.
	Particulate matters	Fuel burning, tobacco smoke. condensation of vapours, combustion of coal, kerosine and other fuels.

(*Contd...*)

Pollutants	*Sources*
C. Indoor pollutants :	
Water vapour	Biological activities, combustion, evaporation of water.
Aerosols	Consumer products, varnish and paints.
Allergens	Dust particles, spores and pollengrains.
Ammonia	Metabolic activities, cleaning products.
Asbestos and synthetic fibres	Fire retardants, thermal or electrical insulations.
Formaldehyde	Particle board, insulation, furnishing, tobacco smoke.
Mercury	Spills in dental care facilities, thermometer breakage.

Air forms nearly 80% of man's daily intake by weight. A normal man breaths nearly 2200 times a day inhaling about 16 kg air. The problem of air pollution is not new. Primitive man too introduced foreign substances into the air by way of burning and other activities. Modern man has accelerated the process of pollution to an alarming state. Many of the long known effects of air pollution are reduction of sunshine, morbidity, mortality from respiratory ailments, dust fall, corrosion of metal and so on. Extensive experimental and epidemiological studies carried out in 20th century, especially during the last two decades have verified these scientifically. Although the adverse effects of air pollution are well known, our existence in a pollution free environment is still far beyond our reach. India's main problem of atmospheric pollution is due to unplanned and disproportionate industrialization and unrestricted urbanization. About 80% of the industries are concentrated in 10 or 12 big cities.

In India, air pollution is caused mostly by automobiles, power plants and oil refineries, The vehicles on the road and oil refinery plants emit several types of atmospheric pollutants such as carbon monoxide, nitrogen oxides, smoke, organic vapour and hydrocarbons as is clear from the following Table 13.4.

Table 13.4. Potential sources of specific emissions from oil refineries

Emissions	*Sources*
Aldehyde	Catalytic regenerators
Ammonia	Catalytic regenerators
Carbon monoxides (CO)	Catalytic regenerators, compressor, incinerators.
Hydrocarbons (HC)	Loading facilities, turn around, sampling storage tanks, waste water separators, blow down systems, catalyst regenerators, pumps, valves, cooling towers, vacuum jets, condensors, air blowing, high pressure

(Contd.)

Emissions	Sources
	equipment handling, compressor engines, heaters, process boilers.
Oxides of sulphur (SO_2, SO_3)	Boilers, process heaters, catalyst cracking units, catalyst regenerators, treating units, hydrogen sulphide flares, sludge disposal.
Oxides of nitrogen (NO, NO_2)	Process heaters, boilers, compressor engines, catalyst regenerators.
Suspended Particulate Matter (SPM)	Catalyst regenerators, boilers, process heaters, decoking operations, incinerators.
Odour	Treating units, air blowing streams, drains tank vents, barometric condensors, pumps, waste water separators.

Causes of Air Pollution

Atmospheric pollution is increasing due to the following major factors :

1. Over population and increasing urbanization.
2. Increasing traffic
3. Industrialization and energy consumption.

1. Over population and Urbanization

According to current estimates, the world population is increasing at an average by two per cent annually which means the addition of about one million people every five days or five people every couple of seconds. In India population has already touched one billion (100 crores). Increase in population would demand more food, water and land, the three items that are limited on the earth. The increasing population has led man to exploit the natural resources, especially land and water to support life. This has resulted in disturbance in ecological balance, disruption of natural bio-geochemical cycles and fast depletion of natural resources.

Technological advances in farming practices, use of high yielding cultivars, increased application of chemical fertilizers and pesticides have made it possible to boost agricultural production. Pesticides are being used at the rate of 570 gms/acre/year and are on further increase in India. These pesticides have become contaminants of air, water and food.

Growing population created problems of employment. This leads people to move from villages to urban areas in search of employment, comfort and facilities. As a result, the cities are expanding in area and are being thickly populated. About 40% of the population in India is concentrated in the states of Bihar, Uttar Pradesh, Haryana, Punjab and West Bengal. Thickly populated areas face a variety of problems such as conjestion, large number of vehicles, accumulation of solid and liquid wastes, poor sanitation and management problems.

Particulate matter in city atmosphere comes from cooking fire, industrial activities, automobile exhausts and dirt arising from general transportation.

Accumulation of particulate matter in air may eventually cause some changes in climatic patterns of the city.

The disposal of urban sewage and household wastes into the body of water makes that dirty and contaminated. In India about 50 billion litres of waste water from domestic and municipal sources are released into the body of water daily. This is likely to cause pollution of water.

2. Increasing Traffic

Rapid increase in the number of automobiles is one of the potential factors responsible for air pollution in urban areas. The vehicles on road are mobile sources of air pollution. During the last two decades, there has been a tremendous increase in the number of vehicles. The number of vehicles per 1000 populations was 3 in 1972-73 and 25 in 1990-91. According to a report of Ministry of Surface Transport, 1996 the number of vehicles increased from 0.3 million in 1951 to 30.3 million in 1995. Out of the total vehicles, 32% were confined to 23 metropolitan cities. Data further indicated that Delhi registered highest increase in the number of vehicles which was followed by Chennai, Hyderabad, Bangalore, Mumbai. With the rapid increase in the number of vehicles, the emission of different pollutants has also increased considerably. According to a report of the Ministry of Environment and Forest (1995), the vehicles in major metropolitan cities of India release upto 43% CO, 20% Hydrocarbons (HC), 30-40% NO_x, 5% suspended particulate matter (SPM) and 2% SO_2. The amount of these pollutants is highest in Delhi, followed by Mumbai, Bangalore, Calcutta and Ahmedabad.

The daily pollution load emitted by automobiles in 12 big cities is presented in the following Table 13.5 :

Table 13.5. Daily emission of pollutants from vehicles in 12 metropolitan cities of India (According to a report of Central Pollution Control Board, 1995)

Cities	*Amount of pollutants (tonnes per day)*					
	SPM	SO_2	NO_x	*HC*	CO_2	*Total*
Delhi	10.3	9.0	126.5	249.6	651.0	1046.3
Mumbai	5.6	4.0	70.8	108.2	469.9	651.6
Bangalore	2.6	1.8	26.2	78.5	195.4	304.5
Calcutta	3.3	3.7	54.7	43.9	188.2	293.7
Ahmedabad	3.0	2.9	40.0	67.8	179.1	292.7
Pune	2.4	1.2	16.2	73.2	162.2	255.3
Chennai	2.3	2.0	28.2	50.5	143.2	226.3
Hyderabad	1.9	1.6	16.8	56.3	126.2	202.8
Jaipur	2.0	1.3	15.3	21.0	51.3	89.0
Kanpur	1.1	1.1	13.4	22.2	48.4	86.2

Cities	*Amount of pollutants (tonnes per day)*					
	SPM	SO_2	NO_x	*HC*	CO_2	*Total*
Lucknow	1.1	1.0	9.7	22.5	49.2	83.5
Nagpur	0.6	0.4	5.1	16.3	35.0	57.4
Total	35.3	29.8	422.9	810.0	2299.2	3597.2

The total estimated pollution load from transport sector increased from 0.15 million tonnes in 1947 to 10.3 million tonnes in 1997. In 1997, emission of CO was highest which was 43%. The total emission of NO_x was 30% and those of Hydrocarbons (HC) 20%, SPM 5% and SO_2 2% (Table 13.6). The emission of pollutants depends on the type of vehicle, engine design and type of gasolene diesel used. Leaded petrol is the main source of toxic lead in atmosphere. Keeping this fact in view, recently a worldwide drive has been initiated to supply leadfree gasolene for vehicles.

Table 13.6. Average Emissions from Automobiles.

Type of emissions	*Kgs/1000 litres of gasolene used*	*Kgs/1000 litres of diesel used*
Carbon monoxide	300.00	7.00
Hydrocarbons	25.00	17.00
Oxides of nitrogen	14.00	27.00
Oxides of sulphur	1.00	5.00
Aldehydes	0.50	1.00
Organic acids	0.50	4.00
Benzopyrene	0.06	0.10
Particulate matter	1.50	14.00

Combustion of fuel in aircraft engines produces hydrocarbons, nitrogen oxides, carbon monoxide, small amount of particulate matter, and sulphur oxides. Amounts of pollutants depend upon the fuel used, type of aircraft engine. The various pollutants released into the atmosphere during the take off and landing of aircrafts are listed in the following Table 13.7.

Table 13.7. Emission from aircraft below 1000 metre altitude in kgs per flight (Landing+Take off)

Type of emission	*Jet aircraft four engine conventional*	*Fan jet*	*Piston-engine aircrafts* 2-engine	4-engine
Carbon monoxide	17.5	10.3	67.0	163.0
Oxides of nitrogen	11.5	4.6	3.2	7.8
Hydrocarbons	5.0	9.5	12.5	30.0
Aldehydes	2.0	1.1	0.3	0.3
Particulates	17.0	3.7	0.3	0.7

3. Industrial Growth and Energy Consumption

Industries, thermal power plants and oil refineries are the other important sectors which are major sources for air pollution in the country. Industries are producing a variety of toxic substances. Thermal power plants and oil refineries are releasing tremendous amount of fly ash and many toxic gases into the atmosphere. Domestic burning, agricultural refuse, firewood and dry dung burning are also contributing considerable amounts of pollutants to atmosphere.

According to an estimate of World Bank, the major air pollution is contributed by a few industrial sectors. In India, petroleum refineries, textile mills, pulp and paper industries and chemical industries produce 87% of the atmospheric pollutants.

Common air pollutants and their effects. There are two major factors which contribute to the problem of air pollution : increasing human population and increased productivity each increasing by about 2 to 3% every year. The United States alone discharges roughly 125 million tonnes of junk into the atmosphere each year and a conservative estimate for the whole world would be about 520 million tonnes every year.

The pollutants of atmosphere may be in gaseous or vapour state and in particulate form. Chemical vapours found in atmosphere are derived from those substances which have boiling point less than 200°C. The following are the major air pollutants :

Air pollutants

Gases & Chemical vapour	Particulates (size 20μ = 100mμ in diametre)
	1. Solid particles (dust & smoke)
	2. Liquid droplets (fumes & mists)

1. **Inorganics :**
   Oxides of carbon (CO, CO_2)
   Oxides of nitrogen (NO, NO_2)
   Oxides of sulphur (SO_2, SO_3)
   Other inorganics (NH_3, HF, H_2S, etc.)
2. **Organics**
   (*i*) Simple hydrocarbons
   (*ii*) *Aliphatics :*
   alkenes (ethene, propene)
   alkanes (ethane, methane)
   alkylene (acetylene)
   (*iii*) Aromatics (benzene, toluene, xylene)
   (*iv*) Oxygenated Hydrocarbons
   Aldehydes (Formaldehyde, acetaldehyde)
   Acids (Formic acids & acetic acid)
   Ketones (Acetone)

The sources of atmospheric pollution are many. P.K. Zutshi of Bhabha Atomic Research Centre (BARC) in 1970 classified the sources of pollution as follows (Table 13.8);

Table 13.8. Classification of Air Pollution Sources and Emissions

Type 1	*Category* 2	*Examples* 3	*Important Pollutants* 4
Combustion	Fuel burning	Domestic burning, thermal power plants	Sulphur and nitrogen oxides
	Transportation	Cars, trucks, aeroplanes and trains	Carbon monoxide, nitrogen oxides, lead, smoke, organic vapours, odours, etc.
	Refuse burning	Open burning dumps	Fly ash and particulates.
Manufacturing process	Chemical	Petroleum refineries, fertilizers, cement, paper, ceramics, clay products, and glass manufacture	Hydrogen sulphide, SO_2, flourides, odours, organic vapours and dusts.
	Metallurgical plants	Aluminium refineries, steel plants etc.	Metal fumes (Pb and *Zn*) flourides and particulates.
	Waste recovery	Scrap metals, gards rendering plants.	Metal fumes, organic vapours, odours, smoke, soot, etc.
Agricultural activities	Crop spraying	Weed and pest control	Organic phosphates, chlorinated hydrocarbons, Pb and Hg
	Field burning	Burning of refuse, firewood and dry dung	Smokes, fly ash, soot, Sulphur dioxide, particulates and organic vapours
Solvent usage	Spray painting; Solvent extraction, inks.	Furniture and appliances, finishing, dyeing, printing and chemical separation	Hydrocarbon and other organic vapours.
	Solvent cleaning	Cleaning, degrading etc.	
Nuclear energy	Fuel fabrication	Gaseous diffusion	Fluorides

Type 1	*Category* 2	*Examples* 3	*Important Pollutants* 4
	Ore preparation	Crushing, grinding and screening	Uranium and Berylliu m dust and other particulates, argon-40, iodine-51.
	Nuclear device testing, Spent fuel processing	Bomb explosion, Chemical separation	Radioactive fallout Sr^{-90}, Cs^{-137}. Cs^{-14}, etc.

The main primary air pollutants are oxides of carbon, sulphur and nitrogen, particulate matter and hydrocarbons. Besides these, there are some other pollutants of air. The following table (13.9) highlights the atmospheric pollution levels in four cities of India :

Table 13.9
Atmospheric pollution levels in four cities of India
(based on P.K. Yennawar and others, 1970)

Cities	SO_2 *average (ppm)*	NO_2 *average (ppm)*	H_2S *average (ppm)*	O_3 *average (ppm)*	*Suspended dust average* (mg/m^3)
Delhi	0.0156	0.011	0.0032	0.0088	924
Mumbai	0.0396	0.0108	0.018	0.008	239.4
Calcutta	0.0222	0.0128	0.0048	0.0148	5266
Kanpur	0.0416	0.04	—	0.048	488

The important sources of air pollutants are motor vehicles (gasoline and diesel), aircrafts, rail and road transportation, coal, fuel oil, natural gas, and wood fuel combustion, industrial processes, solid waste disposal, forest fire, agricultural burning, etc. Exhausts and other particulate matters in the presence of sunlight produce the photochemical **smog** which is no less than plague. The December 1952 smog caused 15030 deaths in London within 5 days. Air pollution is clearly a great danger to man and it can lead to disastrous incidence. But not many are however aware of this fact that the air we breath is contaminated with dust and gases in harmful proportions.

Suspended particulate matters. Solid and liquid aerosols suspended in the atmosphere are referred to as suspended particulate matters. (SPM). They arise from grinding, erosion, spraying, etc. Aerosols are the chemicals which are released in the air with force in the from of a mist or vapour. Aerosols have caused serious environmental pollution in the recent years. Jet aeroplane emission is an important source of aerosols in upper atmosphere. Layers of pollution which are largely due to high flying

commercial jets can be found as high as 43000 feet. Although smoke is popularly used to denote mixtures of particulate matter, fumes, gases and mists, 'dust' refers to solid dispersion aerosol and 'mist' to liquid aerosol. Dust particles greater than 10 μ in size are called settleable dust. These are measured as dust fall in tonnes /sq mile/ month. Smaller particles suspended in air are referred to as suspended dust. The aerosols contain flourocarbons. Fluorocarbons deplete the ozone layer in the stratosphere and thus permit more harmful ultraviolet radiations to reach the earth surface ; ozone acts as preventive covering against ultraviolet light. From the emission of supersonic aeroplanes nitrogen and sulphur oxides are released which also cause thinning of the ozone layer. Carbon tetrachloride (CCl_4) is also known to destroy some of the stratospheric ozone. Pilots have discovered pollution high over the middle of the oceans in the north polar region.

The important effects of air pollutants are as follows:

1. Atmospheric particles can scatter and absorb sunlight, thus reduce the visibility. Reduced visibility is aesthetically undesirable and it is also dangerous for aircraft and motors. In general, cities receive above 15 to 20% less solar radiation than rural areas and the reduction of sunlight can become as high as one-third in the summer and two-third in winter. The reduction sunlight is largely due to fuel combustion for industrial and household heating purposes.

2. The effects of particulate matter include corrosion of metals, erosion and soiling of buildings, sculptures and painted surfaces and soiling of clothings and draperies, damage of electric equipments, etc.

3. The toxic effects of particulate matter on animals and human beings can be classified as :

(*i*) **Intrinsic toxicity** due to chemical or physical properties. Carbon monoxide in congested areas removes 5 to 10% of blood from circulation. Although body tissues extract only 25% of oxygen from the blood, the heart needs 75 per cent. So there is little margin for safety.

(*ii*) **Interference** with clearance mechanism in the respiratory tracts. Chronic bronchitis and emphysma have also been found to be caused by SO_2. A 24 hour exposure to about 0.2 ppm of SO_2 may cause serious health problems. Lung cancer has been found to be correlated with air pollution. Polycyclic aromatic hydrocarbons (PAH) are found to be related to the pathogenesis of lung cancer.

(*iii*) **Toxicity** due to absorbed toxic substance.

Many toxic particles including metal dusts, asbestos, aromatic hydrocarbons have been discovered in a polluted urban atmosphere. Lead from vehicle exhausts, resulting from the use of tetraethyl lead as an anti-knock additive to petrol, may build up to dangerous levels in urban areas adjacent to busy road complexes. Lead in high doses kills outrightly. In lower doses (in dense traffic areas) it shortens life span and causes

deterioration of nervous system. Retarded children have a higher lead content in their body than the normal ones.

4. **Benzpyrenes.** Their concentrations are extremely small but they play a role in increasing cancer rate in urban areas as compared to rural areas. Peroxyacetyl nitrates (PAN) or photochemical smog may constitute a serious problem where high levels of vehicular emissions occur in cities experiencing bright sunlight and ambient temperatures above 21°C.

5. The small solid particles can serve as carriers for micro-oganisms and other infective agents and thereby spread diseases. Large dust particles are trapped in nose and throat and very tiny particles which stay in the lungs may start an ugly chain of events leading to serious illness and deaths. Air pollution causes coughing, sneezing, thickening of secretion of mucus and narrowing or complete closure of glottis due to presence of gases, especially SO_2, nitrogen dioxide and oxidants. The silicon particles may cause 'silicosis' and fibrous particles 'fibrosis'. It is suspected that some pollutants can start lung cancer.

Sulphur dioxide (SO_2). The most important air pollutant is SO_2 which is colourless, nonflammable gas with pungent irritating odour. About one-third of SO_2 present in the atmosphere is believed to be produced by man's activity. Robinson and Robbins (1971) have estimated that SO_2 from man's activity introduces 6.6 million tones of sulphur into the atmosphere annually. SO_2 present in atmosphere comes largely from coal and petroleum combustion. Biologically produced H_2S when oxidised produces SO_2. The following table (13.8) gives an idea about the rough estimates of SO_2 and suspended particulates in air in major cities of India :

Table 13.10

City	*Mean value of SO_2 (microgram/m³)*	*Suspended particulate matter (microgram/m³)*
Ahmedabad	10.66	306.6
Mumbai	47.11	240.8
Calcutta	32.88	340.7
Delhi	41.43	601.1
Hyderabad	5.06	146.2
Jaipur	4.15	446.1
Kanpur	15.97	543.5
Chennai	98.38	100.0
Nagpur	7.71	261.6

Source : NEERI, 1970

Effects of SO_2. 1. SO_2 can damage materials and properties mainly through their conversion into the highly reactive H_2SO_4. It causes discolouration and physical deterioration of building materials and

Formation of Acid Rain

1. ***Action of SO_2 leading to acid rain.*** It is formed in two steps:

(*a*) Conversion of SO_2 into SO_3 by absorption of UV radiation

(*b*) Reaction of secondary pollutant SO_3 with moisture to form sulphuric acid. Sulphuric acid dissolved in rain drops falls on the earth surface as acid rains.

$$SO_3 + H_2O \xrightarrow{\text{UV radiation}} H_2SO_4$$

2. ***Action of NO_2 leading acid rain.*** NO_2 acts to produce acid rain in two steps.

(*a*) Formation of NO_2 and N_2O_5 by absorption of UV-radiation from the sun.

(*b*) Reaction of NO_2 and N_2O_5 with atmospheric moisture to form nitric acid which falls down as acid rain

$$N_2O_5 + H_2O \xrightarrow{\text{UV radiation}} 2HNO_3$$

Factors Determining the Acidity

Rain water gets acidified on its way down to the earth. Its acidity depends on the amounts of oxides of sulphur and nitrates available for dissolution in the water.

The acidified rain water is mixed with the already existing water on the earth. The resulting pH after this mixing determines the pH of the aquatic environment. This is influenced by the following factors :

(*i*) The neutralizing ability of the aquatic medium and

(*ii*) The acidity of the rain water

Generally, lakes and rivers show a poor neutralizing capacity because of their low mineral contents. Only the rocky areas having $CaCO_3$ exhibit a buffer action and maintain a pH of about 5 - 6. But continued occurrence of acid rain is bound to lower the pH of the aquatic medium.

Table 13.11. Concentration of SO_2 in different city atmosphere in India

City	*Concentration of SO_2 ($\mu g/m^3$)*	
	1970	*1979*
Calcutta	85	33
Mumbai	83	47
Ahmedabad	71	11
New Delhi	41	39
Hyderabad	26	5
Kanpur	25	12
Jaipur	17	4
Chennai	16	8
Nagpur	12	8

Consequences of Acid Rain

1. Acid rains declourizes the leaf pigments thus causes chlorosis and necrosis of leaves.
2. It inhibits CO_2 fixation and photorespiration and adversely affects the productivity of crops.
3. It inhibits seed germination and growth of seedlings. Alfalfa, barley, cotton, lettuce and spinach are the most susceptible to acid rains.
4. It affects the enzymatic activities.
5. It may cause wilting of plants.
6. Acid rain increases the ability of water bodies and consequently destroys the various aquatic vegetation and animals. Many fishes die in the lakes and their population are affected.
7. Acid rain causes irritation in the eyes and skin of human beings.
8. Since the acid rain water may dissolve some toxic metallic pollutants, it can directly enhance their toxic action and may pose a serious threat to plant and animal life.
9. Acid rains change the pH of soils and affect the plant growth in various ways.
10. Besides above, it may cause corrosion of many buildings, bridges, monuments, railings, fancings etc.

The famous Taj Mahal of Agra is also facing danger from the acid rain because of oil refinery situated at Mathura very close to Agra. This refinery emits smoke and gaseous pollutants including SO_2. If the SO_2 levels in air increases the resulting acidic precipitation may react with marbles and cause pitting in this wonderful monument that attracts people from all over the world.

Hydrocarbons. Many hydrocarbons are known to be present in the atmosphere as pollutants. Natural sources of hydrocarbons are largely biological. Worldwide methane production mainly from anaerobic decay of organic matter probably amounts to 1 billion metric tons annually. Some plants produce volatile terpenes. In urban areas, ethylene is known to inhibit the plant growth. Open chain hydrocarbons affect human beings. Aromatic compounds cause irritation and injury in the mucous membrane at 500 ppm. Hydrocarbons are of particular concern because of their involvement in the production of photochemical oxidants which cause irritation and other effects. Southwick (1976) has listed common chemical air pollutants, their main sources and pathological effects on man (Table 13.10).

Air pollution due to odours. Many chemical compounds, perfumes, whiskeys and wines and many other rotten substances emit undesirable smells which pollute the local atmosphere. Sometimes only by odour the quality of identification of particular chemical is made and many edible things are evaluated only through odours. In dairy industry also smelling and testing of milk and its products may be used to determine the quality

of raw material. Such testing is made only by experts. For food and perfumery industries, correct odour is essential.

Odour is a smell which can be determined by the nose. According of *Karolinska Institute Symposium on Environmental Health*, a product of the activation of the sense of smell, an olfactory experience, is called odour and any chemical compound which can stimulate the olfactory sense is called odour. Odours are described on the basis of both intensity and characters.

Odour is a physiological response of individual person. There are some instruments which can measure the physical or chemical characteristics of odour indirectly but these instruments are not better than human nose to determine the smell.

Other air pollutants. A number of other minor emissions such as vapour resulted from cosmetics, the smoke from tobacco products, aeroallergens (spores and pollengrains) which cause allergy

Table 13.12 : Some Chemical Air Pollutants

Pollutants	*Main sources*	*Pathological effect on man*
1. Aldehydes	Thermal decomposition of fats, oil or glycerol.	Irritate nasal and respiratory tracts.
2. Ammonia	Chemical processes—dye making, explosives, lacquer, fertilizer.	Causes inflamation upper respiratory passages.
3. Arsines	Processes involving metals or acids containing arsenic soldering.	Breakdown of red cells in blood, damage kidneys; cause jaundice.
4. Carbon monoxide	Gasoline motor exhausts; burning of coal.	Reduces oxygen-carrying capacity of blood.
5. Chlorine	Bleaching cotton and floor, many other chemical processes.	Attacks entire respiratory tracts and mucous membranes of eyes, causes pulmonary edema.
6. Hydrogen cyanide	Fumigation, blast furnaces, chemical manufacturing, metal plating.	Interfere with nerve cells, produces dry throat, indistinct vision, headache.
7. Hydrogen fluoride	Petroleum refining, glass etching, aluminium and fertilizer production.	Irritates and corrodes all body passages.
8. Hydrogen sulphide	Refineries and chemical industries, bituminous fuels.	Smells like rotten eggs, causes nausea, irritatery eyes and throat.
9. Nitrogen oxides	Motor vehicle exhausts, burning of soft coal.	Inhibit ciliary action so that soot and dust penetrate far into the lungs.
10. Phosgene (carbonyl (chloride)		Induces coughing, irritation, and sometimes fatal pulmonary edema.

Pollutants	Main sources	Pathological effect on man
11. Sulphur dioxides	Chemical and dye manufacturing.	Induce coughing, irritation, and sometimes fatal pulmonary edema.
12. Suspended particles (ash, soot, smoke).	Coal and oil combustion. incinerators; almost any manufacturing.	Cause emphysema, eye irritations and possibly cancer.

in some persons are also regarded as air pollutants. Industrial processes especially chemical industries produce special air pollutants such as H_2SO_4, HCl, formaldehyde, alcohols and many other chemicals. A particular air pollutant that has attracted special interest in the recent years is asbestos. Its occupational hazards are known since 1943. All the urban dwellers are exposed to asbestos pollution. Pesticides and radiations are other important air pollutants which are very dangerous for human health.

AIR QUALITY AND AIR QUALITY INDEX (AQI)

A number of pollutants are known to occur in air but for the purpose of assessment of the air quality of a particular place, the following five pollutants are considered to be important. These are :

(*i*) Suspended Particulate Matter (SPM)
(*ii*) Nitrogen Oxides (NO and NO_2)
(*iii*) Carbon Monoxide (CO)
(*iv*) Sulphur dioxides (SO_2, SO_3)
(*v*) Hydrocarbons (HC)

Recently lead has also been added to this list in view of its increasing content in the atmosphere and corresponding health effects. The maximum permissible limits or standards of these major air pollutants are presented in the following Table 13.11.

The standards are in two part : (*i*) Primary standards which apply exclusively to human health and (*ii*) secondary standards which apply to property damage and general welfare.

Table 13.13. Standards for different air pollutants

Pollutants	Primary standards		Secondary standards	
	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$
Suspended Particulate Matter (SPM)				
Maximum 24 hrs conc.	—	260	—	150
Sulphur oxides				
Maximum 24 hrs conc.	0.14	365	0.1	26
Carbon monoxide				
Maximum 8 hrs conc.	9	10,000	same as primary	
Maximum 1 hr conc.	35	40,000	" "	"

Pollutants	*Primary standards*		*Secondary standards*	
	ppm	*ug/m³*	*ppm*	*ug/m³*
Nitrogen oxides				
Annual arithmetic mean	0.05	100	,,	,,
Hydrocarbons		160	,,	,,
Maximum 3 hrs conc.	0.24			

The differences observed among the primary permissible limits of these pollutants can be attributed to their toxicities. The combined adverse effects of two or more pollutants should therefore be considered carefully while adopting these standards. A comparison of individual air pollutants against the maximum permissible limits, no doubt, gives some clues on the quality of air, the cumulative combined effects of all the pollutants provides real information on the quality of air, whether good or bad.

Air Quality Index (AQI) is a tool to reduce the vast amount of data to the simplest form rating all the essential information. The Air Quality Index (AQI) is a useful tool as it helps in rating the overall air quality based on the observed values of different air pollutants. Such an index is always associated with specific descriptor category. It may be noted that AQI is a complementary tool and should not replace precise scientific informations.

At present a variety of Air Quality indices are adopted by different organization. Here AQI developed by Thomas and co-workers (1971) at the Oak Ridge National Laboratory, USA is discussed. It is called ORAQI (Oak Ridge Air Quality Index).

This is based on 24 hr average concentrations of five major air pollutants (CO, NO_2, SPM, SO_2, Hydrocarbons). AQI has been modified for three pollutants (SO_2, NO_2 and SPM) for the same 24 hrs standards as follows :

$$\text{ORAQI} : [39.02\ \Sigma^3 (X_i / X_s)\ 0.967$$

where X_i and X_s denote the pollutant concentration and the sum total of respective permissible limits of the major criteria of air pollutants.

For 5 critical Air pollutants ORAQI is represented mathematically by the following equation :

$$\text{ORAQI} = \left\{ 5.7 \sum_{I=1}^{I=5} (C_i / S_i) \right\} 137$$

where C_i = concentration of pollutant

S_i = sum of the standards for 5 criteria of air pollutants. ORAQI system use namograph, a scale representing concentrations for various pollutants and their relation to the established standard value. Thus the pollutants

concentration in a fraction of the appropriate standard (C/S_i) coefficient (5.7) and the exponent 1.37 in the expression are used to scale the ORAQI in a such way that non-polluted background levels obtains Index value of 10 and the polluted air attains an index value between 10 and 100. ORAQI categories are as follows (Table 13.14).

Table 13.14. Index values for different categories of polluted cities

Categories	*Index*
1. Non-polluted	0 —10
2. Excellent	10—20
3. Good	20—39
4. Fair	40—59
5. Poor	60—79
6. Bad	80—99
7. Dangerous	100 and above

Central Pollution Control Board (CPCB) in 1994 used SPM, SO_2, NO_2 as Air Quality data for calculating Air Quality Index for important cities of India. Because there is no clear cut demarcation between industrial and non-industrial areas, the annual average values for residential areas were used in calculation of AQI. In India the following 20 cities have been found to be in dangerous category :

Howrah, Ghaziabad, Delhi, Alwar, Ankleshwar, Jharia, Surat, Rajkot, Calcutta, Patiala, Ludhiana, Agra, Kanpur, Lucknow, Baroda, Jalandhar, Dhanbad, Sindri, Kota and Korba. There are 14 cities which are in bad category. Seven cities are in good category, namely Tuticorin, Coimbatore, Daman, Silvassa, Vasco; Kozhikode and Guwahati. The rest of the cities come in either fair or poor category.

Central Pollution Control Board has published data for the purpose of analysing the Air Quality Index for the period from 1987 to 1996 of the following cities :

1. *Top ten polluted cities.* On the basis of 1991 census data, top ten polluted cities are : Mumbai, Calcutta, Delhi, Chennai, Hyderabad, Bangalore, Ahmedabad, Pune, Kanpur and Nagpur,

2. *Next other smaller cities.* These are Chandigarh, Dehradun, Faridabad, Howrah, Baroda, Mysore, Cochin, Bhopal, Jaipur, Simla, Agra.

The most polluted cities in terms of suspended particulate matter (SPM) are Dehradun, Gajroula, Surat, Kanpur, Delhi and Calcutta. In most of the cities the average value of suspended particulate matter (SPM) in open area may be double or tripple to that of residential areas. Among top 10 polluted cities, the worst in terms of SPM are Kanpur, Delhi, Calcutta, where the average concentrations are nearer to the levels of maximum permissible limit.

In terms of NO_x (nitrogen oxides) some top polluted cities are Howrah, Kota, Dhanbad, Jharia, Gajroula and Mumbai.

The Central Pollution Control Board has suggested the following classification of Indian cities on the basis of Air Quality Index

Table 13.15. Classification of Indian cities on the basis of air quality index

Dangerous	*Bad*	*Poor*	*Fair*	*Good*
Howrah	Faridabad	Vapi	Paonta Sahib	Tuticorin
Calcutta	Satna	Haldia	Chennai	Coimbatore
Delhi	Ahmedabad	Patna	Kottayam	Daman
Kanpur	Mumbai	Chandipur	Aurangabad	Silvassa
Lucknow	Indore	Talcher	Ponda	Vasco
Baroda	Nagda	Yamuna Nagar	Mysore	Kozhikode
Jalandhar	Jabalpur	Bhopal	Nasik	Guwahati
Dhanbad	Rourkela	Chandigarh	Simla	
Ghaziabad	Jaipur	Angul	Hyderabad	
Alwar	Varanasi		Nagpur	
Ankleshwar	Pondicherry		Cochin	
Jharia	Raipur			
Surat	Pune			
Rajkot				
Patiala				
Ludhiana				
Agra				
Sindri				
Kota				
Korba				

AGRICULTURAL POLLUTION

Improved agronomic practices, artificial fertilizers, farm chemicals and improved methods of preserving and transporting food are playing roles in agricultural pollution. Although air and water pollutions have affected agriculture adversely, agricultural methods themselves have contributed to environmental pollution. Some of the important agricultural pollutants are as follows.

Farm animal wastes. Over the century farm animal wastes, such as faecal matter, urine, wastes from slaughter houses, dead animal wastes, have been regarded as important sources of soil fertility. In addition, the presence of farm animal wastes pose serious problems of foul odour and water pollution. Sometimes public health problems arise from their role in transmitting diseases. Animal wastes pose serious problems when they enter the water supplies.

Soil erosion. Eroded materials affect the fertility of the soil. Strong winds carry soil particles into the air and water and thus produce air and water pollution. When they are carried to the streams by storms or by

runoff water they settle at the bottom and destroy irrigation systems. Sediments can clog gills of fishes. It interferes with the industrial uses of water and leads to extra-expenses for purification of water. It can reduce the dissolve O_2 level and thereby it adversely affects aquatic life. It affects the recreational values of lakes, reservoirs and streams. Control of soil erosion consequently can control the environmental pollution.

Plant residues. Plant residues from crop and fields, orchards contribute much to environmental pollution. They carry plant diseases and pests. When they are burnt they emit smoke and hydrocarbons. Since both the situations correspond to an unfavourable alteration of environment, agricultural burning is important pollution problem. Burning of plant residues gives—

8.3% CO,
8.5% particulate matter,
5.3% hydrocarbons,
1.5% nitrogen oxide.

Much of these burnings is for sanitation purposes since plant debris can carry diseases or pests for succeeding crops. Agricultural burnings and the resulting air pollution are likely to continue until better methods of controlling the plant diseases are available.

Agricultural chemicals. In recent years there has been increased use of agricultural chemicals, notably pesticides and fertilizers. Pesticides is a general term applied to the substances that kill the disease pests. These include insecticides, fungicides, nematicides, rodenticides and herbicides or weedicides. Thus, agricultural chemicals have no doubt increased crop yields but they have contributed air and water pollution to a significant level. They have many adverse effects on fish, wild life and sometimes human beings. Excessive application of fertilizers may create problems since fertilizers can be transported to ground water by leaching or to waterways by natural drainage and surface runoff. Nitrates in drinking water can cause methaemoglobinemia in babies (blue bodies), because in infant's stomach the NO_3 is converted into NO_2 which when reaches the blood reacts with haemoglobin to form methaemoglobin. Phosphorus is often implicated in algal blooms in waterways.

A. Insecticides. Farmers and gardeners use pesticides to avoid the damage of crops by pests. Insecticides have come in use from the last two decades. Mitter discovered DDT (Dichlorodiphenyl trichloroethane) which is the first chlorinated hydrocarbon to be used as pesticide. Later on other pesticides were discovered. Insecticides are classified as :

(*i*) stomach poisons (*ii*) contact poison, and (*iii*) fumigants.

(*i*) Important **stomach poisons** are arsenic and fluorine compounds, lead arsenate, inorganic fluorine compounds, such as cryollite, sodium fluoride, mercury compounds (HgCl, $HgCl_2$), boron compounds (borax and boric acid), chlorinated hydrocarbons, Organophosphates, carbamates, and

certain botanical compounds as pyrethrum (powdered flowers of chrysanthemum), nicotine. Arganophosphorus compounds are most toxic insecticides that affect insects and mammals. Many of them (parathion, thimet, phosdrin, paraxon) are supertoxic and are human poisons giving many symptoms as nausea, vomiting, diarrhoea, sweating, salivation and muscular tremors.

(*ii*) **Contact poison insecticides** are chlorinated hydrocarbons and its metabolites, *e.g.*, DDD, TDE , BHC , DDT have primary effects on central nervous system. In the environment DDT is degraded into different forms. Chlorinated hydrocarbons are know to be present in the body of fatty human beings, the main source being food supply. Studies have shown that daily content of DDT in meal is about .04 to .05 mg or more. Chlorinated Hydrocarbons persist in the environment for long time. They not only affect large number of insect species but also they are responsible for undesirable side effects.

(*iii*) **Fumigants.** There are gases which are used to kill pests of stored products or nursery stock, *e.g*, methyl bromide, carbon disulphide, carbon tetrachloride, nicotine, naphthelene, phosphine and other compounds.

B. Fungicides. These are used to prevent fungal pathogens of plants. Sulphur, organic mercuric compounds, formaldehyde, copper sulphate and some others are commonly used.

C. Herbicides. These are chemicals which kill herbs. They are of two types :

(*i*) **Non-selective herbicides** which kill all the plants, examples: sodium arsenite, sodium chlorate, H_2SO_4.

(*ii*) **Selective herbicides** which kill only certain types of plants. Most commonly used herbicides are 2, 4-D and 2, 4, 5-T and their esters and growth regulating substances.

Extensive use of herbicides like 'picloram' and cacodylic acid in South Vietnam by the U.S. army has changed the entire ecology of about one-third land area. They caused defoliation of forest trees and destroyed crops and fauna to a great extent. It is horrible act to play with ecosystem and upset the balance of nature by polluting or poisoning the environment just on political ideology. 2,4,5-T and 2,4-D are potential herbicides. Spraying of these herbicides completely destroyed the vegetation and fauna in estuarian areas of Vietnam. Application of defoliants completely destroyed the forest trees which provided thick cover to Vietnam army. The destruction of climax forest has caused problems of increased erosion, leaching of nutrients and migration of animals from the area.

Herbicides and insecticides are very potent pollutants and they greatly affect the structure and function of ecosystems. Their indiscriminate use may be suicidal for our own race.

D. Rodenticides. They are used to kill rodents, rats and mice. Some have direct immediate action, *e.g.* strychnine, sodium fluoroacetate, P-thallium and ANTV. Others are anti-coagulants.

The demand for pesticides as a plant protection measure has rapidly increased in India since the introduction of high yielding varieties of crops. A large number of pesticides approved for use under the Insecticide Act, 1968 have been found to be effective against various pests either through direct contact or through systemic action. Some are beneficial as fumigants for protection of food grains during storage. According to a report of the International Development Research Centre. Ottawa, Canada, about 10,000 people die of pesticide poisoning every year in the developing countries. The alarming rise in the number to such deaths is attributed to increasing use of toxic pesticides. There are about 40,000 such chemicals. A number of such toxic chemicals banned in Western countries are dumped in the Third World countries.

In India, the use of pesticides has risen from 2,000 tonnes a year in the fifties to over 80,000 tonnes in 1985-86 and the areas of application cover both agriculture and public health. The cropped area under plant protection coverage increased from 6.4 million hectare in 1960-61 to over 80 million hectares. The demand for pesticides in 1989-90 was estimated to be about 1.20 lakh tonnes. BHC, DDT, and malathion which account for more than 50 per cent of total production are the cheapest and most popular with small farmers. DDT is mostly used in public health.

Despite restrictions and regulations on pesticide use, India accounts for one-third of pesticide poisoning cases in Third World. Farm labourers employed for spraying operations are the worst affected as they get exposed for longer period by working continuously during the week. Cases of blindess, cancer, stunted growth of farm workers' children, deformities, diseases of liver and nervous system due to pesticide poisoning have been indentified in the cotton growing districts of two states in India. Studies conducted by the Industrial Toxicological Research Centre (ITRC), Lucknow in collaboration with the Neurology Department of K.G. Medical College, Lucknow revealed that one-fifth of the farm workers have damaged eye-sight following muscular degeneration.

There were 106 deaths in Kerala from consumption of wheat flour and sugar that got contaminated with folidol from leakage during shipment from Mumbai to Cochin, which caused myosis, salivation, pain in abdomen, diarrhoea and unconsciousness. Earlier, Harijans in the Chikmagalur district of Karnataka were affected with severe paralysis and other fatal diseases after eating crabs from pesticides treated paddy fields.

Organic pesticides are more effective and relatively less hazardous than inorganic ones. Chlorinated compounds are quite stable and persist in the environment for long period. Their accumulation in the tissue lipoids causes acute toxicity affecting central nervous system leading to hypersensitivity, convulsions, paralysis and death through respiratory arrest. Some pesticides of this group are DDT, BHC, aldrin, dieldrin, lindane, methoxychlor, endrin, etc.

Ethylene dichloride, ethylene dibromide, methyl bromide (halogenated compounds) and aluminium phosphide (inorganic) are commonly used for fumigating cereals and pulses. There is a risk of bromide residue in stored grains. It accumulates in human and animal tissues ; liver, kidney, heart, spleen and causes degenerative lesions.

RADIATION POLLUTION

P.K. Zutshi of Health Division, Bhabha Atomic Research Central (BARC) has thrown sufficient light on the problems related to radioactive pollution in a paper entitled "Environmental Pollution Studies at BARC" published in *Nuclear India*, Vol. 12.

Fallout of nuclear explosions. Nuclear explosion has both immediate and long-term effects. It can reduce big cities like New York or London to ashes in no time, yet there is no practical method of protecting the population from it. It can char woods and even ignite them within 16 km from the site of explosion. The temperature at the site of explosion is so high that metals and minerals not only melt but are vapourised also. During atomic explosions the radioactive substances are rapidly injected into the upper layer of the atmosphere where they condense due to cooling from gaseous state to liquid and than to fine dust. Radioactive dust particles are suspended in the air at an altitude of about 10 - 15 km and form together with water vapour, a radioactive cloud which moves in the direction of wind. The radioactive cloud settles down slowly to the surface of earth over several years. Most of the radioactive materials produced in explosion are short-lived but some, such as strontium^{90} Cesium1^{137}, Co^{60} , remain radioactive for many years. About 5% of the radioactive matter injected into atmosphere after nuclear explosions consists of radioactive Sr which is easily absorbed by the living organisms. On reaching to the earth, it poisons water, air and soil and is absorbed by grasses and vegetables and thus gets into the milk and finally into human body. There, it accumulates in the bones and other tissues and causes diseases. Low level radioactive liquid wastes, radioactive gases and dusts are released from unclear installations. The liquid wastes are released into the waters and the gases are disposed through high stacks. Besides stack emission from nuclear installations, there is Worldwide fallout of radioactivity from atomic bomb tests. BARC has been assessing exposure of the population in India to radioactivity arising from nuclear tests explosions. It is also studying the atmospheric air circulation pattern by which radioactive pollutants are dispersed on a global scale. Level of radioactivity after test explosions is reported to be insignificant for short period immediately after explosions but it increases appreciably after some time and subsides within a few weeks. Radioactive fallouts have been observed from the upper atmosphere where the debris of tests explosions stays for a long time.

Hoda, M.M. (1977) in his article on *"Nuclear Energy and Environments"* highlighted some of the problems relating to hazards of radioactive materials.

Much has been said about the nuclear weapons, although at least there is great possibility that it may not be used again, the greatest danger to humanity is now posed by the so called peaceful use of atomic energy but not so many of us realise this fact. While man can and does create radioactive elements there is nothing to reduce their activity once he has created them. No physical interference, no chemical reaction but only the passage of time can reduce the intensity of reaction once it has been set going. The fission of Uranium^{235} results in a mixture of a number of long-lived and short-lived isotopes. The disposal of radioactive wastes presents enormous problem. It was thought at one time that radioactive wastes could be safely dumped into the deepest part of the ocean on assumption that no life could subsist at such depth, but within a short time after dumping these materiels in water the great bulk could be found in the living organisms. No international agreement has been reached so far on disposal of nuclear wastes. Nuclear wastes with high level of radioactivity continue to be dumped into the sea while large quantities of so called 'intermediate" and *"low level"* wastes are discharged into the rivers or directly into the ground. An Atomic Energy Commission report observes that liquid wastes find their way slowly into groundwater, leaving all or part of their radioactivity held either chemically or physically in the soil (U.S.A.E.C. Annual Reports to Congress, Washington D.C. 1966, p. 344). The nuclear reactors, after they have become unserviceable, are most massive wastes. The reactors have an average life of 30 years and they cannot be dismantled and shifted but have to be left standing for centuries where they will silently leak radioactivity into air, water and soil.

There is no foolproof method of disposal of radioactive wastes. In many cases the radioactive wastes are sealed in steel drums or concrete blocks and sunk into sea to await their natural decay. The pollution of aquatic environment by radioactive materials forms a serious problems as radioactive isotopes can produce not only immediate effects on living organisms but even more important, can produce mutations in the genetic materials which would have serious consequences for the later generations. Radioactivity can reach the aquatic environment from a variety of sources such as nuclear fallout, nuclear powered ships and submarines, nuclear power plants, laboratory experiments with medical uses of radioisotopes and so on. Desalination and Effluent Engineering Division at BARC has developed high efficiency particulate filters for air pollution control from hazardous contaminants, such as radioactive isotopes from nuclear operations installation and compounds of such toxic elements as berylium and tellurium.

The effects of radioactive elements are difficult to judge unless they are in such concentrations as to give acute effects. Malformation of body at birth, abnormality in organ development are some of the effects observed in the laboratory animals.

THERMAL POLLUTION

Heat or thermal pollution is common to both nuclear and conventional sources of energy production. It can be both an air and water pollutant. Waste heat not only causes widespread climatological changes but also it can cause damage to aquatic and terrestrial life. The thermal discharges are usually favourable to bacteria and pathogens. Rapid temperature changes produce thermal shocks and result in immediate death of fishes. Temperature of the environment controls reproductive cycle, digestion rates, respiration rates and many chemical activities taking place in the body. As the temperature of water increases its viscosity decreases, the vapour pressure increases, and solubility of gases in water decreases. These changes have important effects on aquatic life.

NOISE POLLUTION

In addition to disturbances caused by air pollution, a new kind of disturbance has come into prominence. This is noise pollution. Noise is generally defined as an unwanted or undesirable sound and the release of unwanted sound into the atmosphere is called noise pollution. High pitch sound produced by automobiles, machines, power plants, trains, helicopters, aeroplanes, jets, rockets, public broadcasting systems, T.V., sudden ratting of doors and windows, explosion of bombs, sound of crackers etc. are potent sources of noise pollution. Noise provides alarm system in man's physical environment. It has been regarded as urban pollution. It has become serious in urban areas due to over population and industrialisation. It is associated with almost all human activities. In 1990, Nobel lawreate Robert Koch said, "a day will come when man will have to fight merciless noise as the enemy of health and that day is not far off". The noise should be taken not only as a factor of annoyance but also as a lethal partner of life. According to Dr. Vern O. Knudsen of university of California, noise, like smog, is a slow agent of death. If it continues unabated for the next 30 years it could become lethal to an alarming degree.

The loudness of noise is measured on a logarithmic scale called "decibel". Mathematically the decibel (dB) can be expressed as follows :

$$I\ dB = 20 \log_{10} (P/p\ ref)$$

where, P = measured sound pressure in dynes /cm and, pref = reference sound pressure which is equal to barely audible sound taken as 0.002 dynes /cm.

As the decibel is measured on a log scale, rise of every 10 decibel would cause 10 fold change in sound intensity. For example, a sound level of 100 decibels has an intensity 10 times greater than a sound level of 90 decibels. According to World Health Organization (WHO), a level of 45 dB is considered a safe noise level for city. By internation standard, a noise level up to 65 dB may be taken as tolerable. Noise level above 80 dB causes noise pollution. Noise level above 100 dB becomes uncomfortable and beyond 120 dB it becomes painful. Sudden or intermittent noise is more harmful than continuous noise. According to a report of National

Physical Laboratory, India, the noise level is increasing at the rate of 1 dB per year.

Some important standards developed for noise levels in India are given in Tables 13.16, 13.17, 13.18 and 13.19.

Table 13.16. Noise limits in different areas

Category of Area	*Noise Limits in dB*	
	Day hours	*Night hours*
Industrial area	75	70
Commercial area	65	55
Residential area	55	45
Silence zone	50	40

Table 13.17. Noise limits for different automobiles of 1992

Category	*Standards dB*
1. Motor cycles, scooters, three-wheelers	80
2. Passenger cars	82
3. Passenger or commercial vehicles up to 4 MT	85
4. Passenger or commercial vehicles above 4 MT and up to 12 MT	89
5. Passenger or commercial vehicles exceeding 12 MT	91

Table 13.18. Damage risk criteria for hearing loss
(According to Occupational Safety and Health Administration (OSHA)

Noise level (in dB)	*Maximum Allowable duration (hours per day)*
90	8
92	6
95	4
97	3
100	2

Table 13.19. Different sources of Noise levels (in decibel)

Sources of Noise	*Decibels*
Normal breathing	10
Breeze	20
Whispering	30
Quiet office	40
Homes	45
Quiet restaurant	50
Conversation	60
Light Automobile	70
Food blender	80
Heavy automobiles	100
Jet aircraft taking off	120

Effects of Noise Pollution

Human response to noise varies from man to man according to age and temperament. It may vary even in the same individual from time to time because of change in health, fatigue and other conditions. The effects of noise on human beings can be related to physiological, behavioural and psychological responses.

When we hear a loud noise the blood vessels constrict, the skin pales, the pupil dilates, the eyes close, the voluntary and involuntary muscles tense, gastric secretions reduce and the blood pressure increases. The immediate reactions to noise which starts at noise level of 30 to 70 dB include constriction of peripheral blood vessels with a consequent increase in blood flow to the brain, change in breathing rate, change in muscle tension and gastrointestinal mobility. As these reactions can also be carried out by some other factors, they are called non-auditory reactions. At slightly higher noise level there is "startle effect" produced due to change in pulse rate and blood pressure, release of stored glucose from lever into the blood stream and the excess secretion of adrenalin harmone because of which fear reaction develops in body. Some of the other effects of noise pollution are given below:

1. The short-term auditory effects of noise include some temporary loss in hearing at high noise levels. Explosions or other high intensity sounds may cause immediate deafness by rupturing the ear drums or damaging the cochlea. Continuous exposure at high noise level may cause some permanent damage.
2. Prolonged exposures to noise are known to lead to gradual deterioration of internal year and to subsequent hearing loss or deafness. Hearing loss problems are especially of the opinion that constant occupational exposure at higher frequency is dangerous for human beings
3. Noise also clearly produces annoyance in human beings and can interfere with proper rest and sleep. Annoyance seems to increase with the loudness of the sound.
4. Noise also produces psychological effects in human being.
5. One important effect of noise is the vasoconstriction reflex in which small blood vessels of the body constrict and reduce the flow of blood.
6. Physiological effects of noise include dilation of the pupils, pailing of skin, tensing of voluntary muscles, diminishing of gastric secretions, increase in diastolic blood pressure and the sudden injection of adrenalins into blood stream which increases neuromuscular tension, nervousness, irritability and anxieties. It can adversely affect the development of unborn babies.
7. Impulsive noise and thunders are worse than continuous noise which, if loud enough, may cause sudden hearing loss. Sudden

noises also startle persons and lead to accidents. Surpersonic booms produced by objects travelling faster than the speed of sound produce shock waves which deviate from atmosphere pressures.

8. Recently there has been growing evidence that noise in the range of 90 decibels and above may cause irreversible changes in the autonomous nervous system. Noise may be an important factor in many stress-related diseases, such as peptic ulcer and hypertension.

There is no separate law for noise pollution control in India. It has been suggested that cultivation of thick vegetation along the roadsides railway tracts and industrial establishments may considerably reduce noise pollution.

CONTROL OF ENVIRONMENTAL POLLUTION (ENVIRONMENTAL MANAGEMENT)

The recent growing concern for the quality of our environment has strengthened the concept of environmental monitoring which requires regular periodical measurements of environment followed by timely assessment and interpretation of data obtained. Reliable monitoring data are necessary to know pollution problem.

Environment is deteriorating day by day due to industrial pollution, toxic chemicals, automobile emission and natural resource depletion. Pollution in its various forms is increasing trememdously. Environmental management aims at the study of all these problems and checking pollution so that the environment satisfies basic human needs at the minimum and more, if possible, for an indefinite future. The main aim of environmental management is overall development of environment. Purpose of environmental management is to see whether air is fit for breathing, water is fit for drinking and soil and sea resources are fit to provide all needs. One also expects that people are well fed, well housed, well schooled and enjoying happy and healthy life.

Environmental problems are so diverse and diffused that virtually any activity of civilization interacts with the environment. Many environmental pollution problems are local in character and they can be controlled by creating environmental consciousness in each and every citizen. People should be told about the importance of clean atmosphere as well as about the consequences of different types of environmental pollutions. Besides, action is also needed at national level and guidelines may be established internationally by the United Nations Joint Committee of Experts. Some of the effective and practical control measures for minimising environmental pollution are outlined below :

1. Combustible solid wastes should be burnt in incinerators. This method does not solve the problem in a real sense because in this, solid

waste is being converted into gaseous wastes causing air pollution. Unless it is properly controlled, incineration may cause more nuisance.

2. Solid organic wastes including faecal matter and wastes from tanneries should be converted into compost manure at the places far away from the cities and human dwellings. The composting should be done in pits or in heaps adequately covered with layers of soil at least 8-10 cm thick to pervent fly breeding and rat menace which are important carriers of various diseases.

3. Non-combustible solid waste materials like ash, rubbish, tins, glass pieces if not recoverable for usual purposes should be disposed off by landfill method in low-lying areas.

4. Anaerobic septic tank treatment can be used for individual houses or small communities. Besides, aerobic biological treatment systems including trickling filters, activated sludge treatment and oxidation ponds can also be used for liquid wastes or sewage disposal.

5. Automobiles must be either made to eliminate use of gasoline and diesel oil or complete combustion is obtained in the engine so that noxious compounds are not emitted. The automobiles, trucks and other transport systems must have an antismog device. In some countries factories are using devices like scrubbers, cyclone separators or electrostatic precipitators to minimise pollution.

6. There should be cut back in the use of fertilizers, herbicides and pesticides as far as possible.

7. Excessive and undesirable burning of vegetation should be stopped.

8. Sponges and towels should be used in place of paper towels and also the use of paper cups and plates and similar materials should be stopped.

9. Little use of electric appliances and motor-run appliances will reduce thermal pollution.

10. Washing soda and scouring pad should be used instead of detergents.

11. Used boxes, bags and bottles should be reused whenever possible.

12. Since about 40% of the phosphates in water pollution comes from detergent, it has been suggested that only detergents low in phosphates should be used.

13. Shampoos, lotions and similar products should not be bought in plastic bottles. It has recently been suggested that use of plastic containers and glasses may cause cancer.

14. Smoking should be stopped (there is 5,00,000 tonnes tobacco pollution annually).

15. Proper attention should be given by the government and general to make people realise the implications of environmental problem,

16. Legislation should be passed against pollution.

17. International action is needed to deal with the problems presented by highly toxic pollutants like lead, mercury organochlorine pesticides released in the atmosphere and carried far beyond the country of origin as well as carried down to the sea by rivers. Successful action to improve environmental qualities depends mainly on the acceptance by industry and local authorities of the need to reduce greatly both quantities and toxicity of certain wastes at present being discharged into the sea and the modernization and expansion of sewage disposal systems.

18. Environmental education is the best programme to deal with the environmental problems. It is most fundamental in our efforts to combat and control pollution, over-population and misuse of natural resources. Environmental education includes the following objectives which are based on the major outcome of the 1975 workshop on environmental education.

(*i*) Creation of awareness of the problems.
(*ii*) Providing knowledge to deal with the problems.
(*iii*) Developing new attitudes towards environmental problems.
(*iv*) Developing skills for solving environmental problems.
(*v*) Providing development or evaluation ability in these areas.
(*vi*) Increasing participation and involvement of public.
(*vii*) A broad recognition of the facts that we are all responsible for helping to solve environmental problems.

19. Recycling of wastes and sewage should be done.

The work on pollution control and abatement techniques is being carriedout by Desalination and Effluent Engineering Division of Bhabha Atomic Research Centre (BARC). There is special Directorate of Radiation Protection (DRP), an all-India organization, which keeps watch on exposure of the users or public at large to irradiation and provides proper instructions to users for using radioactive materials. Besides these, a National Environmental Engineering Institute (NEEI) is established at Nagpur to execute studies on different aspects of pollution. This institute has regional offices, one each in Tamil Nadu, Calcutta, Mumbai, Delhi. Hyderabad, Jaipur, Kanpur and Ahmedabad. One more all-India organization, Indian Toxicological Research centre (ITRC), has been established at Lucknow which is concerned mainly with the study of toxicological problems.

Action Committee of 68th session of Indian Science Congress held at Varanasi (1981) recommended the following points on environmental management :

1. Immediate implementation of acts against air pollution, water pollution and noise pollution.

2. There should be specific standards for the use of agricultural chemicals such as insecticides, pesticides and fertilizers.

3. Action is necessary against food adulteration, drug control and

against factories producing effluents.

4. Department of Environment should be empowered for initiating legislative measures by the Parliament. Department should have control of soil, air and water environment and should maintain a strict vigilance over metropolitan and industrial areas. There should be regular monitoring of air and water quality. Penalty on offenders not adhering to set standards against air, water, noise and other sources of pollution should be imposed.

5. Environmental protection should be included in the concurrent list of constitution.

6. Government and voluntary agencies should be provided special incentives for successful anti-pollution researches.

7. Department of Environment should carry out publications on health safety and set directorate criteria for different pollutants.

8. Environmental education should be made compulsory in the curricula of schools, colleges and universities.

9. Mass communication media should be adopted for information related to environmental problems.

10. Scientific societies. Associations and Academies should create a temper of environmental problems in the rural and urban areas.

11. Plantation of trees suited to different climates should be adopted. Deforestation must be legally checked.

12. Wild Life board and Environment Cell should be created in each state.

13. Recycling plants for municipal waste and sewage should be established.

14. Anti-pollution tax should be imposed on industries for discharging the effluents.

15. Reclamation of land to its original state should be the responsibility of the users. There should be legislation against violation for this.

16. Encouragements and incentives should be given to voluntary movements as "Chipko movement" for the protection of plants.

17. In agriculture, biological control of pests should be applied to replace wide use of insecticides, pesticides and fungicides. Biological nitrogen fixation should be adopted.

18. Several Biosphere Reserves containing endangered or rare or commercially important species should be established as early as possible.

19. Gene Pool Reserves and Gene Sanctuaries should be demarcated and protected in their natural environment to preserve wild germ plasm from extinction and conservation.

20. For conservation of flora and fauna the list of endangered species should be continuously renewed.

21. Aero-biological centres should be established in different parts of India.

22. Brick fields should be prohibited by law near agricultural or populated areas.

23. Cleaning of choked lakes and rivers should be done regularly.

24. Different aspects of energy sources should be created as biomass, energy plantation, fuel energy etc. Social forestry should be encouraged.

25. A suitable agency should be established for conservation and monitoring of marine resources and providing protection against pollution hazards.

26. Satellite and space technology may be adopted for weather forecasting, agriculture resources inventories and monitoring of air borne particles.

27. Airport areas should be separated to minimise pollution from noise.

28. Genetic counselling units should be established at different regions of India to monitor genetic disorders.

29. Scientific, administrative and social measures must be adopted to check pollution explosion.

30. At different levels of planning, the involvement of ecologists is essential. All programmes for development should be undertaken without or with the least disturbances to the natural ecosystem.

QUESTIONS

1. What is pollution? What are the various pollutants causing environmental pollution? What are their effects?
2. What is air pollution? In what ways man is affected by air pollution?
3. What is water pollution? Describe various kinds of water pollutions and their ecological effects on the aquatic organisms and man.
4. What is environmental management? What are the various control measures for minimising environmental pollution?
5. Write short notes on:
   Thermal pollution, Noise pollution, Radiation pollution, Hydrocarbons, Pesticides and their effects, Aerosols, Agricultural pollution.
6. Write short notes on :
   (*a*) Air Quality Index (IQI)
   (b) Sewage disposal
   (*c*) Potable water
   (*d*) BOD
7. What is meant by Acid rains? Discuss its causes and impacts on vegetation.

14

GLOBAL WARMING (GREEN HOUSE EFFECT)

The world is facing ecological problems like environmental pollution, increase in population, deforestation, energy crisis, soil erosion and so on. An outcome of the atmospheric pollution is warming of the earth's environment. Warming of the earth atmosphere is a serious problem and in twenty-first century this may be a problem of global concern.

There is a clear indication that the temperature of the earth has increased slightly during the past two decades. This increase in temperature of atmosphere is very dangerous for living organisms. Though there are numerous causes for the global warming, the following two factors are considered to be very significant :

1. Industrialization
2. Deforestation

During the last two decades there has been tremendous growth of industries in the world. These industries release toxic gases, chemicals and effluents in huge quantities in the environment. The industrial wastes produce many harmful effects and ultimately disturb the ecosystems. The toxic gases and effluents released into the environment cause pollution of air, water and soil.

Deforestation is mainly due to increase in population, industrialization, urbanization and increasing agricultural activities. Deforestation has led to soil erosion, wasteland development and extinction of certain species from the flora and fauna. Deforestation is taking place at an alarming rate. For healthy environment one-third area of the earth should be covered by the forest but the total forest cover in India is much less than 33 per cent. Data provided by the Remote sensing Technology reveal that only 14 per cent area of India is covered by the forest. After 1950, about 4.2 million hectares of forest were destroyed and since 1980 every year about 1.5 million hectare forest area is either converted into agricultural land or used for some other purposes. Due to two aforesaid reasons the concentrations of CO_2 gas is increasing in atmosphere. Carbon dioxide at normal concentration (0.03%)

is not considered as a pollutant but its concentration above 0.03% in the atmosphere has an adverse impact on our climate and living organisms. Carbon dioxide gas plays the following important roles in the environment :

1. It produces green house effect causing heating of the earth and its atmosphere.
2. Carbon dioxide is a raw material for photosynthesis in green plants.
3. The gas dissolved in water reacts with lime to form carbonate rock.

Carbon dioxide gas is confined only to lower level of atmosphere (troposphere). The main sources through which the CO_2 is released into the atmosphere are as follows :

(*i*) Burning of fossil fuels
(*ii*) Decay of dead organisms
(*iii*) Respiration of living organisms
(*iv*) Automobile exhausts
(*v*) Thermal power plants
(*vi*) Cultivation of land
(*vii*) Eruption of volcanoes
(*viii*) Domestic cooking
(*ix*) Forest fires.

Carbon dioxide present in the earth's atmosphere not only checks infra-red radiations from being radiated back into the space but also produces heat effects. The average temperature of the earth remains almost constant because of the balance between the amount of solar energy reaching the earth surface and the amount reflected back into the outer space from the earth surface. Sometimes, this balance is disturbed.

In the recent past the average volume of CO_2 in the atmosphere has increased from 290 ppm (part per million) to 350 ppm and in the beginning of 21st century it may reach to about 400 ppm. According to an estimate, by the year 2040 the temperature of CO_2 may reach upto to 500 ppm.

It is a universal truth that the sun is the main source of energy on the earth which is continuously radiating energy in the form of electromagnetic waves into the space. It has been calculated that one part out of two billion parts of total solar energy radiated from the sun reaches earth because of small size of the earth and very long distance from the sun. The solar energy reaches to the earth atmosphere in three forms :

(*i*) Ultra-violet radiation
(*ii*) Visible light (VIBGYOR spectrum)
(*iii*) Infra-red and radio waves

Cosmic radiations do not reach to the atmosphere of earth. When the solar radiations first fall on the top of atmosphere the harmful ultraviolet radiations are absorbed by the ozone layer in the stratosphere and are

prevented from reaching the earth surface. Thus ozone layer acts as a protective layer in the stratosphere. The visible light and infra-red rays then pass through the carbon dioxide layer in the lower region of the atmosphere (troposphere) and ultimately fall on the earth surface. Since infra-red radiation has heating effect, it warms up the earth, its atmosphere and various objects. A part of infra-red rays falling on the earth surface is reflected back into the outer space. Infra-red radiation coming to earth from the sun are of short wavelength but the infra-red rays reflected from the earth and its various objects are of long wave lengths. The infra-red radiation reflected from the earth cannot escape out from the carbon dioxide layer present in the atmosphere. CO_2 gas has the ability to absorb infra-red radiation reflected from the earth surface. Therefore, the blanket of CO_2 in the atmosphere traps all the infrared rays in the atmosphere and these traped infra-red rays produce heat on the earth surface. The heating up of earth's atmosphere due to trapping in infrared rays reflected from the earth surface by the CO_2 layer in the atmosphere is called *Green-House Effect* which causes global warming.

The rise in temperature of earth's atmosphere caused due to green house effect depends on the amount of carbon dioxide present in the atmosphere. At normal CO_2 concentration (0.03%) in the atmosphere the surface temperature of the earth remains constant due to energy balance of the sun rays which strike on the earth, heat it and then radiate back into the space. This is called *Energy Budget.* But when there is increase in CO_2 concentration in the atmosphere, the thick layer of CO_2 prevents the heat from being radiated out into space. This layer of CO_2 thus functions as a glass panel of green house or glass window of a motor car which allows the sunlight to filter through it but prevents heat from being radiated back into the outer space. Thus most of the heat energy absorbed by CO_2 layer of the atmosphere warms up the air in the troposphere. It is also now known that in addition to CO_2, some common pollutants like methane, CFCs (Chloro-Fluro carbons), CCl_4 (carbon tetrachloride) etc. also help in global warming. It has been observed that carbon dioxide alone increases the temperature by 50 per cent, CFCs by 20 per cent and other air pollutants by 10 per cent. More recently, the role of methane in global atmospheric changes received much attention. Methane has a global warming potential about 63 times that of CO_2 and accounts for about 15 per cent of the global warming (Brown, 1994). Annual global emission of methane in 1997 was estimated to be 7.1 tonnes from land fill sites. Data further indicate that if CO_2 concentration becomes double the average temperature of earth will rise by 2°C.

Impacts of Global warming : The following may be the consequences of global warming :

1. Melting of glaciers, snow mountains and polar ice caps.
2. Flooding of low lying coastal areas.

3. Increase in sea level.
4. Increase in the flow of rivers and change in rainfall pattern.
5. Chances of submersion of islands.
6. Occurrence of more cyclones and hurricanes.
7. This will cause damage of agricultural crops.
8. Fresh water will be contaminated with the salty water of sea.
9. Human population will be displaced.
10. The forest vegetation will not be able to adapt with the changing temperature and may face destruction.
11. As a result of global warming, the temperature of southern Europe and central America will rise and affect the rainfall in these areas.
12. The effect of global warming on the Tropics and Southern hemisphere will be uncertain.

Ozone Depletion and Ozone Hole

Ozone gas is found on the upper surface of stratosphere at the height of about 50 km in the form of a layer called ozonosphere. The main functions of ozone layer are as follows :

1. It regulates the weather and climate of the earth.
2. It filters away the ultraviolet radiation and protects the earth from its harmful effects. Thus it acts as a protective layer.

Earth receives ultraviolet radiation in three forms :

(*i*) UV–A in the wavelength range of 315-400 NM
(*ii*) UV–B with wavelength from 289-315 NM and
(*iii*) UV-C with wavelength from 100–280 NM

Out of these, UV-B in the wavelength range from 250-315 NM is most dangerous. It affects the living organisms in many ways. Sunburn, ageing, wrinkling of skin, cataract of eye, destruction of protein, mutation of genes leading to skin cancer or melanoma, etc. are some of the common effects of UV radiation in human population.

Ozone is an unstable gas and for its formation and destruction both UV rays are essential which come from the sun. The following reactions are involved :

$$O + O_2 \xrightarrow[\text{UV rays}]{} O_3$$

$$O_3 \xrightarrow[\text{UV rays}]{} O + O_2$$

This is continuous process. Thus ozone is in dynamic equilibrium. In the processes of forming and breakdown of the ozone molecule a part of the harmful ultraviolet rays is converted into infra-red rays which is not lethal to man. In addition, ozone prevents the escape of UV-rays into earth's atmosphere. Thus a balanced chemical reaction is set in. The retarded rate of formation and increase in destruction of ozone molecules allow UV-rays to escape in to the atmosphere. This leads to less ozone formation

which is commonly known as **ozone depletion**. CFCs (chlorofluorocarbon), CCl_4, CH_4 etc. are main chemicals which check the ozone formation. The main damaging among there are CFC-12 and CFC-13. These carbon compounds produce the chlorine in nascent state which breaks the ozone molecules and reduces ozone content in the atmosphere. One atom of chlorine is sufficient to destroy a lac of ozone molecules and since this process is cyclic, the damage being caused is tremendous.

The reaction is given below :

(*i*) $Cl + O_3 \rightarrow ClO + O_2$

$ClO \rightarrow Cl + O$

Chlorine atom liberated at the end of reaction breaks another ozone molecule.

Ozone hole. Ozone hole means complete disappearance of ozone layer over a part of the atmosphere. Ozone hole was first detected in 1975 but its worst effect was noticed in 1985 by some British scientists. They saw ozone hole over Antarctica. Later on, the presence of ozone hole was confirmed over the North Pole also. It starts appearing at the end of winter, shows maximum display in spring and disappears in summer. This is because in winter the air is heavy and industrial gases like CFCs get concentrated over an area in Antarctica where the maximum damage of ozone layer has been noticed. In Antarctica CFC bearing winds in winter become frozen to form ice crystals. During spring when ice melts the trapped CFCs and ClO are freed at once which, in turn, release nascent chlorine to attack ozone. Consequently, the hole becomes large in the spring.

Global Concern

Global warming is the Global concern. In this context, many countries assembled and held a conference at a global level at Montreal in 1987 called *Montreal Protocol.* It was decided in the conference to cut level of CFCs to 50 per cent by 1999. But India and China opposed and refused to sinn this protocol. This was supported by many developing countries on the ground that their per capita consumption of CFCs was only 1/100th as compared to developed and industrialized countries. Later on, in London Protocol (1990) India, China and several other countries demanded more time to reduce CFCs consumption. The developed countries agreed to stop CFCs consumption completely by 2000 AD and for developing nations the time limit was extended to 2010 AD. Developed countries have also agreed to establish a multilateral fund under Montreal Protocol to provide financial support to developing countries for that purpose.

In recent years, few substitute of CFCs have been explored. Two viable substances in the form of HCFC and HFC-34 are considered to be harmless for ozone. Out of these two, HFC-34 is less harmful because of absence of chlorine in it, although it is expensive, inflamable and toxic in nature. There are some other substitutes such as, Butane and Propane which are less expensive, less harmful and freely available. The ozone depletion and its

impact was discussed in detail in London agreement at global level. In 1988, the world conference on the changing atmosphere was held in Toronto (Canada). There it was decided to reduce 20% carbon dioxide emissions by the year 2005. Then in 1990 the second world conference on climate was held in Geneva. In 1992, the Earth Summit was held in Rio de Janeiro but with no concrete results because of interference of the industrialised countries. The United States and Japan have not been able to decide so far to reduce CO_2 emissions although they verbally declare their commitment to the Toronto agreement every now and then. The European countries, however, have set the goal of stabilizing CO_2 emissions at the level of 1990 by the year 2000.

At present on the basis of Montreal Protocol India has established a *ozone cell* under the Ministry of forests and Environment with the help of UNDP (United Nations Development Programme). The ozone cell has prepared a document under National Programme for the phasing out of ozone depleting substances "ODS". This document has recommended two billion dollars for India to phase out "ODS" completely. This includes the cost of new technologies and expenses for creating public awareness and coordinating the activities at National level.

During the 6th meeting of Executive Committee of the Multilateral Fund held in Nairobi in October 1994, the committee decided to create a fund of 4 million dollars as a contingency grant for India to undertake the programme and extension of technical assistance necessary for the purpose. On this ground, India has developed "R—22" and "R–134" as CFC's substitutes which are presently at trial stage. Accordingly India and some other developing countries have been allowed to phase out CFCs completely by 2010 AD.

Check on Global Warming

Global warming can be checked by reducing CO_2 concentration in the atmosphere by adopting following measures :

1. Plantation of trees at large scale.
2. Increasing diffusing capacity of oceans for CO_2.

In the photosynthetic process green plants use CO_2 to prepare the food material and release O_2 as a by-product. Therefore planting trees on waste- land and replanting of new trees in place of destroyed trees is most important. If one-third part of the world is covered by the forest then CO_2 will be stabilized. Thus green plants cause decrease of CO_2 concentration through photosynthesis.

Ocean plays a significant role in reduction of CO_2. Carbon dioxide is continuously dissolving in the oceans which is stabilized in the form of carbonate rocks at the bottom of sea. According to an estimation half of the CO_2 evolved is absorbed by the sea and Phytoplankton (free-floating plants) found in them. There is a new method to reduce the CO_2 concentration in environment. According to J.H. Martin the growth of phytoplankton can

be enhanced by spraying iron supplement in the ocean. Phytoplankton take CO_2 from sea water in greater amount, due to which CO_2 will decrease in the oceans. Therefore, more CO_2 will dissolve in the oceans resulting in the decrease of CO_2 concentration in the atmosphere. In 1955, 454 kg ferrous sulphate was sprayed in 1600 square km area of pacific ocean. After few days there was plenty of growth of phytoplankton in sea water of that area. Due to which the colour of water became green in place of blue. About 6-21 per cent CO_2 can be reduced by this method.

United Nations Conference on Environment and Development (UNCED) on Earth Summit at Rio de Janeiro held from 3-14 June, 1992 in which more than hundred countries participated. In that Earth Summit, Global Warming was one of the important topics. In the Earth Summit, USA and other developed countries including EEC signed convention on climate change, but they refused to make a specific time bound commitments to bring down the levels of emission of carbon dioxide and other gases.

QUESTIONS

1. What is green house effect? Discuss the causes of global warming and various remedial measures to check it.
2. Write brief notes on the following :
   (*i*) Ozone depletion and ozone hole
   (*ii*) Causes of ozone depletion
   (*iii*) Impacts of CFC (Chloroflourocarbons) in global warming.

15

CONSERVATION OF NATURAL RESOURCES

Man lives in nature and depends on the resources of nature. The progress of mankind depends upon the exploitation of different natural resources. The utilization of soil, water, coal, electricity, oil, gas and nuclear energy is very important for the development of nation. These resources have changed the level of living standard of man.

Of the world's total population of six billion, one million in U.S.A. and Europe alone use 84% of world's total energy. Three billion people of India, China, Brazil and few other countries use only 15%. India contains the world's largest resource of coal and third and fourth largest resource of manganese and iron. Fossil fuels (coal, petrol, and natural gas) on which modern industrial centres are based, are limited. At present rate of consumption, fossil fuel may be drastically depleted leading to severe energy crisis. Coal reserves of the world are higher than petroleum and natural gas and they may last longer. The leading coal producing countries are China, U.S.A., U.S.S.R., Germany, U.K., Japan, India, Poland, France and Czechoslovakia. The major oil producing countries are U.S.A., U.S.S.R., Kuwait, Saudi Arabia, Iran, Iraq, Nigeria, Libya, Arab Republic and Indonesia. New discovery of oil has been made recently in the sea beds of Mumbai.

India is facing an ecological crisis and is degrading her natural resources day by day. Now the shortage of natural resources is a matter of international concern. There is increasing deficiency of energy, metals, coal, non-fuel and non-metallic materials. With regards to fuels there is great concern over the huge outflow of foreign exchange and every year enough oil is purchased from the Middle-East countries which are major sources of petroleum. The developed nations of the world have created abundant resources but the developing nations are importing many of these from foreign countries.

We are aware of the fact that earlier the human being was essential part of the nature and human society had impact on the other components of the biosphere. However, with the advancement of social and cultural revolution

which came in the twentieth century there has been a growing conflict between man and nature. Due to its unending greed, man has destroyed the nature to the maximum for his little gain and made himself the master of nature. However, all human efforts to have mastery over the nature have only resulted his further dependence on nature. On account of such unthoughtful and ruthless exploitation the human society has vastly modified the ecosystems found in different parts of the world and has brought undesirable changes in the natural habitats. Consequently, some natural stocks of plants and animals have disappeared. About 1000 species are currently threatened with extinction or are dangerously rare. The human encroachment in nature has deprived the world civilization of 130 mammal species and has endangered more than 250 species. Out of the total of approximately 0.3 million species of plants in the world, over 20,000 are in the category of either endangered or threatened with extinction by the year 2001 A.D.

Food, shelter and clothing are the primary requirements of man. Early human society has used natural resources relatively in much less quantity to cover his wants. Among them, most essential requirement is a well cooked food. We know that cooking requires energy. The simplest source of energy available for cooking since the early human history is fuel wood. According to an estimate, about 60.5 per cent of Indian people's consumption is fire wood and other agricultural wastes. According to Government of India's "Fuel Wood Policy Committee", the annual demand for fuel is roughly 133 million tonnes which is expected to increase to about 270 million tonnes by 2001 A.D.

There is a great controversy over the sufficiency of the mineral resources to retain domestic and economic development all over the world. According to "Resources and Man" (1969), "true shortages exist or threaten for many substances that are considered essential for current industrial society." Mercury, tin, tungsten and helium, are known examples and the prospective resources of these substances will be nearly exhausted by the end of this century or early in the next, and new sources or substitutes to satisfy even the relatively short-term needs will have to be found.

One of the most serious aspects of the problem arises from the impact of economic efforts of mankind especially for the purpose of maintaining its existence, protection, survival and betterment of the standard of living. The basic needs which induced the human beings to spoil the natural resources for their welfare have finally led to a situation which threatens to be disastrous. Now in almost every advanced country, the overpopulation has been a vital concern along with the atmospheric pollution. Every effort is being made to save mankind from self-destruction. The situation has become so serious that it is necessary to take some precautionary steps so that the complications may not become worse further. There are various problems which have arisen due to industrial and agricultural developmental

activities. Many of these problems are due to mismanagement of natural resources and their impacts are not localized but are universal in nature. It has been estimated that the quantity of CO_2 will be doubled in 23 years and all the oil and natural gas resources will be no more available after 50 years and coal will be almost consumed within 150 years.

There are four basic reasons for the depletion of natural resources :

1. Rapid population increase,
2. Pollution,
3. High consumption of resources, and
4. Deterioration of land.

1. **Rapid population increase.** There has been a tremendous increase in India's population and it has now reached 100 crores. An increase in population will decrease all types of natural resources and result in environmental pollution. Ultimately, there will be short supply, as well as deterioration in quality of natural resources. This is because increase in population will increase the demand of natural resources and environment.

At present, the world population is increasing by two per cent every year. The industrialized countries have annual growth rate of 0.5 to 1 per cent and on the other hand the developing countries have the growth rate of 2 to 3 per cent. The per capita use of energy and mineral resources shows a difference between the developing and developed countries of the world. The developed countries consume less but their resources are enough. The population and per capita consumption have a considerable impact on the environment. The world cannot meet the continuously increasing demand for natural resources.

2. **Pollution.** We are deteriorating our environment due to increasing population. We are polluting atmosphere, lakes, streams, rivers by sewage, industrial wastes, heat, radioactive materials, detergents, fertilizers and pesticides. Besides these, we are releasing a number of toxic materials into our surroundings. The uncontrolled and indiscriminate use of pesticides has disturbed the entire food chains by which animals including man are affected. It has been estimated that average individual has about 7 parts per million (ppm) DDT in his body which affects in long-term. Recent researches have revealed that this proportion of DDT in our body has deleterious effects on heart and liver and higher concentration may cause several other diseases including cancer. Many gases, *e.g.*, carbon monoxide, sulphur dioxide, carbon dioxide and nitrous oxide are known to cause respiratory troubles. The unplanned and uncontrolled industrial growth may adversely affect or destroy the health of the society.

3. **Consumption of materials.** Due to tremendous increase of population, most of the natural resources are being rapidly consumed. This high rate of consumption has disturbed our ecosystems. But, on the other

hand, many of the natural resources are essential basic human needs. Many industries require raw materials which are essential for the advancement of the country. However, their rapid consumption will affect adversely the quality of our environment either by unwise use of natural resources or by increasing pollution.

4. **Deterioration of land.** Due to excessive consumption of minerals of the soil by cropping or soil erosion or other natural events, fertility of soil is lost and the land deteriorates gradually. Sometimes drought also results in deterioration of land and many nutrients of the top soil are destroyed and soil fertility is lost. As a result of cropping, the cycling of soil mineral nutrients is greatly reduced.

Erosion has also depleted soil fertility because most of the minerals remain in the upper part of the soil and they are easily removed by wind or washed away by water. Sometimes water erosion takes its toll of fertile soils.

Man has also deteriorated agricultural land and ultimately caused the loss of national economy. It is commonly seen that man cannot degrade one part of his environment without simultaneously affecting other parts. For proper economic development lands for cropping, forest, recreation, transportation and wild life are needed but their availability is reduced day by day. Therefore, integrated policy of resource management should be practised, otherwise unexpected future shortage might upset the national economy.

Different Types of Natural Resources and their Conservation

Basically the natural resources may be of two types.

1. **Renewable natural resources.** These resources can be replenished and do not change the ecological balance. The cut trees can be grown again, soil forms again and animals reproduce themselves.

2. **Non-renewable natural resources.** Resources which once used up, will be exhausted for ever.

It is clear if the man wants to survive on this planet he must conserve the natural resources rather than merely exploit them. It does not mean mere preservation of the resources without using them. We should use the resources wisely and judiciously without wasting them.

Different types of these natural resources and their conservation are given under the following heads :

Mineral resources. Now it is known that the world's resources of minerals, oils, coal and natural gases are limited. Mineral resources are of several types : metallic minerals and non-metallic minerals. Nonmetallic or industrial minerals include a wide variety of substances which comprise the building materials such as rock, sand, gravels, cement and clay. The non-metallic minerals are fertilizers which are essential to increase agricultural yield. Large amount of nitrogen in the form of nitrates is available in the natural deposits but now it is possible to fix nitrogen synthetically from air.

Thus, the deficiency of nitrogen resources is compensated. Phosphorus is obtained from phosphate rocks. Although the phosphorus resources are abundant, yet not evenly distributed. Potassium is also quite abundant in the world.

Among metals, iron, nonferrous metals, silver and gold are important. Among these, iron is the most important element because it is the main component of steel alloys. Chromium, cobalt, magnesium, molybdenum, nickel, tungsten and vanadium are included under ferro-alloy elements.

So far as the causes of mineral loss from the soil are concerned, soil erosion and cropping are considered to be the most significant. Most of the soil nutrients remain in the upper part of soil and many minerals of upper soil are carried away by rapid winds or running water and thus the soil becomes deficient in fertile minerals. Soil is the most important resource of nature, it is essential for human existence and provides the basic requirements to man.

At present, there is a great loss of minerals all over the world which should be considered seriously. Further demands for mineral resources must be thought of seriously. Although it is difficult to make exact estimate, yet there should be proper relation between demand and supply. Sudden shortage of mineral resources results in poor economy. It has been estimated that for a number of important minerals the resources are limited. So the new resources must be supplied immediately otherwise the minerals will be exhausted within a few years. Due to excessive consumption new minerals should be added rapidly. Now it has become essential for resource-producing undeveloped countries to make some Act to maintain control over their own natural resources. Even oil rich countries have formed an International Organisation of Petrol Exporting Countries (OPEC) which produces more than 50% oil of the world. It has been calculated that out of 19 important minerals 9 would be exhausted in 10 years and coal, iron and aluminium will be consumed by 2100. Therefore, entire quantity of world's mineral reserves should be replaced time to time.

There are three important conservation approaches which should be taken into consideration :

(*i*) to reduce wastes and to minimise demand.

(*ii*) to change the way of life, and

(*iii*) to increase reclamation and recycling of materials.

Solid wastes should be reutilized for their energy content and it is possible to recycle the materials. The total demand can be met with a decrease in the consumption of new materials and increasing the amount of reclamation,.

Forest Resources

Forest is an important natural resource. It is the most important natural habitat for wild life. It is also utilized by farmers for commercial and recreational purposes. Many herbivores find shelter and carnivores search

their prey in the forest. Many wild-life store food supplies and breed in the forest. Besides this, forest plays most important role from commercial point of view. It is the source for a large number of products useful to man. It provides raw materials for many products of daily use. It feeds several industries which depend on wood products. Turpentine oil, paints, resins and printing paper industries get raw material from the forest. Man not only benefits from forest, but also gets recreation. Forest also provides sanctuary for the modern city. Large number of people visit the forest for peace, beauty and recreation. Forest based cottage industries, such as bee-keeping, bamboo mat and basket making provides means of livelihood to the tribal people. Sal is a most important source for timber industries. Forest also provides raw materials for pulp and plywood industry.

Green plants of the forest are food-producing organisms and are primary producers of the "food chain". They trap energy from the sun and use it to transform CO_2 from the air, together with water and nutrients from the soil into food substances like starch, sugars, through the process of photosynthesis. These foods are stored in the fruits, nuts, seeds, nectar and wood. Therefore, forest serves as an energy reservoir, trapping energy from sunlight and storing it in the from of a biochemical product.

Forest plays a most important role in keeping the atmospheric balanced by consuming CO_2 and releasing O_2, the latter is essential for animal life. So removal of plants and trees would disturb the composition of natural air. An acre of forest absorbs 4 tonnes of carbondioxide gas and recycles 8 tonnes of oxygen into environment.

If a forest is cut down, energy stored in the wood is lost and also most of the nutrients of the system are lost. Such deforestation leaves a poor soil which can support agriculture for only a short time, because the harvesting of the first few crops removes the remaining nutrients and renders the soil useless. Deforestation shows other disastrous results also. Removal of trees exposes the surface of the land resulting into erosion. Soil is then washed away. In many places soil erosion occurs ten times more rapidly than usual, once the trees are removed. Soil erosion is particularly more on hill slopes where heavy rain sweeps soil downhill to choke rivers. The reduction of forests later affects rainfall and thereby restricts the availability of a most important natural resource, the rain water.

In natural forests, the tree roots bind the soil and about 90 per cent of the water falling on the forests is retained either in humus or in the plants tissue. The forest thus acts as a soaking device and plays a vital role in the hydrological cycle. The rain water thus soaked up is gradually released over the days and weeks which supply to streams and rivers even during dry seasons. Hence, it is important to retain forest cover in upland catchment areas as an alternative to flooding the whole barren and uncultivable area. The washed away top soil silts river beds, and reservoirs reduce the holding capacity and flood in the surrounding area is a natural calamity. It has been

estimated that in India 60,000 million tonnes of top soil is carried away annually by rain water from deforestated area.

Nowadays the tendency of deforestation is increasing. Man is cutting forest to get temporary benefits but there will be a tremendous loss in due course of time. Now, due to gradual destruction of forest, wild life is disappearing and their number is becoming reduced for which government should consider various aspects of forest management. Forest management programme should be motivated by forest employees and general public to increase yield, to avoid forest cutting and to prevent forest fires. Whenever plant or timber is cut, that area must be reforested. Similarly, any forest which has been destroyed by insects, diseases, hurricanes that area should be reforested. The primary aim of the forest service is to make the greatest number of forest resources available to the maximum number of people.

Shifting cultivation is another practice which destroys the forest. Many farmers destroy the forest for agricultural purpose and soil is exhausted. Therefore, farmers should use the same land for cultivation and they should apply better farming methods so that soil fertility remains restored and the soil can be used again.

Most severe damage of the forest is due to attack of insects, pests and fungi. Many destructive forest diseases are due to parasitic fungi, rusts, viruses and nematodes. Young seedlings are destroyed due to attack of nematodes. Many diseases such as heart rot, blister rust, oak wilt, phloem necrosis and Dutch elm diseases are common in the forest. The forest diseases can be controlled upto some extent by the following methods :

1. By eradication of alternative hosts
2. By using suitable antibiotics,
3. By DDT spray,
4. Sterilization, and
5. By using resistant varieties.

Besides above, the following measures of forest management have been recommended :

1. Reforestation.
2. By improving the quality of timber.
3. By converting wasteful cutting into quality yield harvesting.
4. By increasing forest protection.
5. By increasing forest area.
6. By developing fast growing trees.
7. By controlling harmful forest agents.
8. By developing the better varieties.
9. By using disease resistant varieties.

In India about 75 million hectares area is occupied by forest alone which is about 23 per cent of the total land. In India forests have not so far

played a significant role in improvement of economic condition of the country. Proper scientific management, conservation and utilization of forest wealth are likely to increase their resource value and utility in the future. At present there is an urgent need to conserve the existing forest resources and to expand the forest area. The most important task is to restore the vegetation cover which is destroyed through our false policies. New forests and wood lots should be created to meet the daily demand of fuel and fodder and to provide more habitat for the wild life.

The National Commission on Agriculture is giving serious thought to the problem of deforestation and has recommended introduction of "Social Forestry", *i.e.*, to create multipurpose village wood lots in rural India. Social forestry may be defined as an additional aid to wild life conservation. According to K.M. Tewari (President, Forest Research Institute, Dehradun), *"Social forestry is a concept, a programme and a mission which aims at ensuring ecological, economic and social security to the people, particularly to the rural masses especially by involving the beneficiaries right from the planning stage to the harvesting stage. It aims at mixed production system of wood, fibre, fodder, grasses, fruits and other raw materials for self-consumption and cottage industry".*

Different components of social forestry programme are :

1. Protection and afforestation of degraded forests in the vicinity of human habitations.
2. Creation of village wood lots on community lands and government waste lands.
3. Block plantation.
4. Agro-forestry (trees along with agricultural crops) on marginal and sub-marginal farm lands.
5. Tree planting around habitation area, field boundaries and pasture development.
6. Tree planting in Urban and Industrial areas for aesthetic purposes, purification of polluted air, absorption of CO_2, release of O_2 and control of noise pollution.
7. Control of soil erosion by planting trees or shrubs.
8. Strip plantation along road sides, canals and rail lines.

If above programmes are carried out effectively the basic needs of rural people such as fuel, fodder, fibre and timber could be met easily and it will ensure ecological security like protection against wind, erosion, polluted water and air and availability of desired habitat for the wild life. Social forestry can play a significant role to check flood and drought which affect 34—68 million hectares of land respectively in India (Dr. K.K. Mahajan, Deptt. of Environment, Govt. of India).

Wild Life Resources

Wild life is defined as "the uncultivated flora and the undomesticated fauna amongst the plants and animals."

In the modern sense, according to Dr. Mahajan (1961), wild life means, life in any form (plant/animal) existing in natural surrounding. Wild life provides recreational and economic benefits to man. Recreational and economic benefits are closely related to each other. For instance, fishing and hunting provide entertainment and economic benefit to man.

Wild life includes 350 species of mammals, 1200 species and 2,100 sub-species of birds and more than 20,000 species of insects. In its diversity of life forms India is the second largest country in the world.

It is absolutely necessary to protect and conserve all forms of life on this earth as they are all interdependent and form a chain. Nature has created them in such a balanced manner that if one form of life is disturbed it affects all the other lives also. The very existence of man depends upon the survival of other forms of life both plants and animals. So the destiny of humanity depends upon the survival of other forms of life.

The causes of decline of wild life in India are many. Wild elephants were captured and trained for use in war. Rhinos were killed for making shield. Rulers of princely states indulged in killing of wild animals as their hobby. Forests were cleared for development of agriculture, industry and other developmental projects. Wild animals were mercilessly killed which resulted in decline in their number and they are facing extinction now.

Today wild life species are gradually disappearing and their number is becoming reduced. Many species of wild life have become extinct or are on the way to extinction. Uptill now 106 species of animals and 139 species of birds have become extinct due to climatic and geographical changes or hunting by man and about 600 species of animals and birds are going to be extinct if they are not protected. Today the lion is limited in number. The number is around 200 in the Gir forest of Gujarat. The rhino existed in Indus valley in the vicinity of Mohenjo-Daro some 5000 years ago. The rhinos are now found in certain parts of Nepal, West Bengal and Assam.

The number of tigers are also very limited. According to 1972 census the tigers were 1827 in India.

The protection of wild life from unwanted destruction is called conservation. Conservation is an intelligent and judicious management of resources towards their optimum utilization without depleting the basic stock.

Well planned projects for conservation of forests and wild life are executed with the aid from W.L.F. (World Wild Life Fund), the International Union for Conservation of Natural Resources. Through the Convention on International Trade in threatened and endangered species of wild Fauna and Flora, a number of species such as hispid hare, pigmy hog, lion, tiger, rhino, thamin and great Indian bustards have been saved. In 1973, a project for saving tiger was started which yielded very satisfactory results. The number of tigers increased considerably and it has become difficult to

material for photosynthesis and numerous products. Man needs water for survival, drinking and many other commercial purposes.

Man can live few days without food but cannot live without water. Our body contains 100 pounds of water. There are many functions of water in the body. It serves as a solvent. It promotes chemical activity. It serves as transportation medium for nutrients, hormones, enzymes. Man will die if he loses more than 12 per cent water content from his body. Most organisms regardless of body size, food habits or habitat have a high water content. The water content in corn is 70 per cent.

Sometimes due to severe dry condition drought is produced. It is due to lack of rainfall for sufficient duration and causes widespread damage to crops. The more severe droughts result in reduction in groundwater levels, heavy mortality of aquatic wild life, extensive destruction of grasses, pasture and crops. Top soil is desiccated and this leads to erosion. It also results in high incidence of forest fires.

Flood is the result of excess rain and uneven distribution of water and man has suffered a heavy loss from the damage caused by flood. In some parts survival becomes difficult. Fertile soil of upper surface is carried away and lost, thus agricultural economy is reduced. It is difficult to control the flood but it can be prevented upto a limited extent. Flood can be controlled by protecting the watershed, construction of dams and prevention of human encroachment on forest land.

It has been estimated that the annual production of water through rain is about 3,70,000 cubic kilometre and total water which is used annually is about 10,000 cubic kilometre. Still there is shortage of water and there are two main reasons of its shortage. Firstly, there is no proper utilization and distribution of water and secondly water quality is deteriorated.

This problem can be solved by recycling of water at local level.

Today there is a great problem of water pollution. Many of the wastes of human society are disposed of in the river, lake and ocean and water becomes polluted which is not fit for drinking and other purposes. The sewage of big cities is often drained into rivers which is most dangerous. Reduction of oxygen and presence of wastes in water affect the fishes and other aquatic populations. Such water is also consumed by man for various purposes. This causes diseases like cholera, dysentery and hepatitis etc. Other effects are :

1. Addition of poisonous substances
2. Addition of suspended particles
3. Reduction of oxygen
4. Heating of water

Waste water from municipalities, sanitaria and tannings discharged into the rivers, canals and lakes etc. carries many species of bacteria and other microbes which cause diseases in man and animals like cholera, typhoids and many skin diseases. These are transmitted through polluted water.

The water conservation is very important for agriculture, industries and for urban population. This can be done by following methods :

1. Proper distribution and utilization of water
2. Proper drainage
3. Proper storage
4. Storage by dams
5. Pumping of groundwater
6. Flood control

Soil Resources

The top layer of the earth is called soil which is very fertile because it contains minerals and humus. Soil is natural habitat for plants and animals. It provides water and nutrients to the living organisms. Knowledge of soil is helpful in agricultural practices, such as cultivation, irrigation, artificial drainage and use of fertilizers. It is also important from geological, petrological, minerological and paleobotanical points of view.

Soil is much damaged through tree cutting, running water and wind. It has been estimated that from 1959 to 1969 there was a loss of 16.9 lac hectares of land. The soil is subjected to a continuous and simultaneous depletion and addition of soil resources. The important factors which make the soil less fertile are leaching, cropping and soil erosion. The damage of soil can be prevented by plants in the following ways :

1. Trees check the force of strong winds which causes the fertile soil to move from its original place. Thus, trees act as windbreakers.

2. Roots of plants bind the soil firmly. This prevents the soil erosion by rain and flood and fertile soil is checked from damage.

3. Plants and animals when die are decomposed by bacteria and fungi, which increase the fertility of soil.

4. Soil fertility can be restored by supplementing with manures and fertilizers.

The details of soil conservation are described in the chapters on soil erosion and soil conservation and soil fertility.

Now man is cutting trees for habitation, cultivation and timber use and indirectly soil is spoiled. Destruction of forest has caused soil erosion and climate is also affected. Oxygen supply in the atmosphere becomes reduced and many other problems are resulted. It has been estimated that one inch spoiled soil takes about 900 years to restore the fertility.

Marine Resources

The ocean covers nearly three-fourth of earth's surface. Ocean has been the source of many needs of man from the time immemorial. The rapid growth of human population and the advancement of industrialization have exerted great pressure on the resources and the environment of oceans.

According to recent data, about 35 km^3 of sewage and 3.5 km^3 of industrial wastes are released annually into the coastal waters of India. In addition, the offshore oil installations have added another stress on the ocean environment. The recent exploration of the oil well in the "Bombay high" invoked a great concern about growing dangers of pollution of the ocean water. The increasing exploitation of certain economically important red and brown algae without any proper conservation and indiscriminate mining of coral stones for industrial purpose eliminating the substratum for the sea algae to grow are the serious problems which need our immediate attention.

Land resources are depleting at tremendous rate and in view of this, man has started thinking to exploit the oceanic resources. Navigation and shipping are important uses of ocean. Besides, seabeds and ocean floors are now known to contain larger reserve of fuel and minerals, such as coal, petroleum and metallic minerals. The edible fishes and marine animals are in abundance. Certain areas of west coast of India are rich in petroleum and oil. Efforts are being made to modernise marine fishing technology in India.

Sea weeds which are generally considered a nuisance could offer a solution as an alternative source for food because of their high nutrition value. Sea weeds can be used as a food, pharmaceuticals, textile and agar. Algin and carragenin are the important substances extracted from sea weeds and are used in ice cream, malted milk, cheese, chocolates, puddings etc. Besides these, sea weeds are also used as food, fodder, fertilizer and biomass. It has been estimated that the total annual yield of sea weeds in the country is 50,000 tons and it may reach to one lakh tons if all the precautions are taken in utilizing the resources. Planktons (phyto-planktons and zooplanktons) provide rich nutrition. Scientists are now interested in evolving methods of directly converting the plankton into food so that the world's food supply may be considerably enhanced and utilized for overpopulated world.

Mangrove forests are more common in the sea coasts. These act as guard. The reclamation of saline soil by enriching the coastal soils with organic matter thereby facilitating other plants to grow and the control of soil erosion in coasts are the main contribution of mangrove forests. It is a matter of great concern that these forests are being damaged at an alarming rate which expose sea coasts to the tides and cyclones. An important step in this direction is to replace the slow growing mangroves by fast growing trees along the coasts and thus provide an alternate supply of fuel to the people.

It is a well established fact that the ocean surface of 1 cm thickness known as surface micro-layer plays a crucial role in air-sea interaction. Detailed study of this layer is important in meteorology, agriculture and pollution. This micro-layer transfers not only energy and water vapour but also rich nutrients like N.P.K. into the atmosphere. Oil spills and other

pollutants over the ocean concentrate in this micro-layer and finally enter the food chain through marine organisms.

Other uses of sea in the future are :

(1) Manufacture of sea planes.

(2) Floating cities on the surface of the ocean.

(3) Cultivation of sea weeds as an alternative source of food and energy.

(4) Production of power from sea tides.

(5) Fresh drinking water by modern methods of desalination.

(6) Study of origin of monsoons and avoid recurrent droughts.

(7) Rich potential of off-shore oil.

(8) Mineral deposits of oceans.

The task of harnessing the potential of ocean resources for development purposes is of great importance. We should pay our attention to the development of necessary resources of ocean when our land resources are in short supply. Now much awareness is needed by the National government and International agencies including United Nations about conservation of ocean's wealth. While studying the ocean environment, it is necessary to know about the physics, chemistry, biology and geology of the ocean. It is essential that in ocean-oriented programme, lawyers, economists, businessmen, scientists and social workers should be involved in the decision-making policies.

Food and Agriculture Resources

Man needs energy for his various activities as movement, growth, respiration, reproduction and many others. For physical and metabolic activities energy is essential. In our body many biological activities are going on which are collectively called metabolism. These activities need energy which is obtained from food. A food is a substance which is mixture of nutritive and non-nutritive substances. The main components of food are carbohydrates, fats, proteins, minerals, vitamins and water. These are supplied through cereals, pulses, oils, eggs, sweets, milk, meat, cheese and fruits.

Food is classified mainly on the two bases :

1. On the basis of work.

2. On the basis of nutrients.

On the basis of work food has been classified into three groups :

(*i*) **Energy-giving food.** This includes fat and carbohydrates. This food provides high energy which can be obtained from cereals, sugars, animal fats, vegetable oils etc.

(*ii*) **Body-building food.** This includes protein and minerals. These are found in pulses, milk products such as cheese, fish, meat, eggs etc. These provide energy which is essential for body-building, growth and repairs of tissues.

(*iii*) **Protective food.** This food protects the body from different diseases and regulates different functions of body. This food is rich in minerals, salts and vitamins. This type of food is available from green vegetables, fruits, milk and eggs.

On the basis of nutrients food may be in the form of carbohydrates, protein, fat, vitamin and minerals.

Our food contains different nutrients and each nutrient performs its own function but we need protein, carbohydrate, fat, minerals, vitamins and water in proper proportion. Deficiency or excess of any of these causes disorder in the body. Thus a balanced diet is that which provides proper amount and proper proportion of nutrients. Balanced diet of an average adult man is given below in Table 15.1.

Table 15.1. Balanced diet for adult man

Food	*Weight*	*Food*	*Weight*
Cereals	400 gm	Milk and milk products	284 gm
Pulses	85 gm	Flesh (meat)	125 gm
Other vegetables	85 gm	Sugar	57 gm
Root vegetables	85 gm	Fat (Ghee, oil)	57 gm
Fruits	85 gm		

A healthy youngman who does physical work needs 3,000 calories daily. Such diet should contain 90 gm protein, 90 gm fat, 450 gm carbohydrate and sufficient amount of vitamins, minerals and water. Nutrient value of different foods is given below (Table 15.2).

Table 15.2. Nutrient value in different sources of food

	Food	*Protein*	*Fat*	*Carbohydrate*	*Salt*	*Water*
1.	Milk	3.5	3.7	4.9	0.7	87.0
2.	Meat	15.1	14.7	—	0.8	69.4
3.	Fish	16.0	5.0	—	1.0	78.0
4.	Wheat	11.4	1.0	75.0	0.5	12.0
5.	Rice	1.7	0.4	76.0	0.4	15.5
6.	Maize	8.4	4.7	72.0	1.3	13.6
7.	Potato	2.0	0.1	21.0	1.0	75.9
8.	Sugar	—	—	100	—	—
9.	Egg	13.2	10.3	—	0.9	75.6

Today food demand is increasing rapidly due to overpopulation and increased consumption of food. Effort is being made to increase food production all over the world. In many parts of the world a number of ecologically unsound practices are being applied that have resulted in short-term production gains at the expense of long-term food output. Overgrazing,

burning of vegetation, deforestation, and expansion of agriculture are some known examples.

Most of us get food mainly through agriculture. Cultivation of crop plants is done through two methods :

1. **Shifting cultivation.** This is very old agricultural practice. In this case natural ecosystem is manipulated and cultivation is done in the limited area for short period. In this system cultivated area is temporarily covered by wild vegetation. This type of cultivation is generally practised in the mountain area where the rainfall is heavy. Most of the tribal populations depend primarily upon shifting cultivation.

There are many defects of shifting cultivation. Natural ecosystem is disturbed, yield is poor due to uncared cultivation and crops are infected by many diseases.

The following control measures have been taken regarding shifting cultivation :

(*i*) Proper management of settlement of tribal population should be made because migration of tribal people needs shifting cultivation and facilities of farming should be provided to them.

(*ii*) Now agriculture should be altered with silviculture scheme so that land use involves an integrated programme of agriculture, horticulture and forestry.

(*iii*) Annual crops should be replaced with perennial crops.

(*iv*) Rotation of crops with forest and field crops has given better results in the sloppy area of hills.

2. **Sedentary cultivation.** In this case natural ecosystem is permanently changed. In this system previous plants are removed and then domesticated plants are grown. In dry places soil is gradually depleted with minerals and nutrients which may be restored by adding fertilizers or green manures.

Deforestation, overgrazing, fire and deserts are the results of mismanagement of agriculture. Soil erosion and lowering of water table are also the results of climatic and geological factors.

Extension and intensification of agriculture are the important steps to increase the yield which have solved the problem of shortage of food and malnutrition. For extension we need better irrigation, improved varieties of seeds, agricultural instruments and better roads. Flood control, proper drainage, erosion control, mechanisation, fertilizers, pesticides and improved varieties of seeds are the important steps to increase yield.

Besides these methods, we should select some alternative sources of food. Deficiency of protein should be compensated from animal source rather than plants. Fishes and eggs are the important sources of protein. Now-a-days everywhere fisheries departments have been established to meet the high demand of fishes. It also gives enough foreign exchange. Poultry

breeding programme is very significant now-a-days because the consumption of eggs is increasing tremendously day by day. Under poultry, chickens and ducks are included. Some algae, mushrooms, grasses and some aquatics are also rich in protein contents which are consumed by man.

There is a tremendous loss in yield due to plant diseases which are caused by bacteria, viruses, mycoplasma and pests. It has been estimated that there is 15—20 per cent loss in yield due to plant diseases alone. Sometimes sudden outbreak of a disease can cause severe loss in the production. Plant diseases are the main problems and barriers to crop production. The damage caused by pests is tremendous and sometimes it is irreparable.

Energy Resources

The energy crisis is a global problem today. The survival of the man will be difficult if the energy problem is not solved on the priority basis. Many scientific organisations as Department of Science and Technology, Department of forestry and environment, Department of Non-conventional energy, Department of Oceanography, Fuel Research Institute and several other regional, National and International Institutes are engaged in researches on this current problem.

There are several energy sources in the world such as coal, oil (Petroleum and its products), natural gas, electricity, nuclear energy, solar energy, thermal and wind energy. Nuclear energy is supposed to be the latest source of energy. Now efforts are being made to harness energy from solar radiations, nuclear fission, wind, thermal power, tides of the ocean and biogas etc. Fossil fuel reserves are limited and it is estimated that the stock of the mineral oil will lost in 21st century if it continues to be used at present rate. Thus, there is a need to exploit sources of energy.

The energy consumption is maximum in developed countries as compared to developing nations. The per capita daily consumption is highest in America and then come Canada, U.K., Germany, Soviet Russia, Japan, Mexico, Brazil and India in decreasing order. United States of America alone consumes about 35 per cent of the world total energy. Soviet Russia consumes about 16 per cent and India consumes only two per cent of the total available energy of the world. The following Table 15.3 presents a comparative idea of energy consumption by some countries:

Table 15.3. Energy consumption in some countries

(Data based on scientific American, 1971 and UN Demographic yearbook, 1974)

Name of country	*World energy consumption in per cent*	*Per capita daily consumption*
USA	35	230
Canada	20	165

Name of country	World energy consumption in per cent	Per capita daily consumption
UK	26	145
Soviet Russia	16	85
Japan	3	40
India	2	6

In the world coal reserves are much bigger and will lost longer than the petroleum reserves. The main coal producing countries are China, Russia, USA, UK, India, Germany, Japan, Polland Czechoslovakia and France. The oil producing countries are Saudi Arabia, Iran, Iraq, Nigeria, Libya, Arab Republic, Indonesia, USA and Russia. In India new resources of oil have been explored recently in the sea bed of Mumbai high and Gujarat.

According to latest information India has coal reserve of about 1,31,000 million tons which is sufficient for coming 1000 years if the current rate of production and consumption continues. The annual crude oil production of India is 8 million tons as against its requirement of 20 million tons which is much less than its total requirement. The annual oil consumption which was 33 million tons by 1980-1981 is increasing at fast rate and has now become more than double. The oil and Natural Gas Commission in India is exploring new oil and gas fields.

Agriculture, industry and automobiles are the main sectors where the consumption of oil is maximum. The tremendous increase in population would need more food and that need can be fulfilled by increased oil production. The cost of petroleum is continuously increasing in the world due to which India is greatly affected. Therefore, some suitable alternative sources of energy will have to be developed to replace petroleum. Now efforts are being made to find out new sources of fertilizers which are not petroleum based. Among them, biofertilizers, genetic engineering techniques, sewage and some nitrogen fixing blue-green algae have been found successful. Nitrogen fixing Blue-green algae are used as biofertilizers in the paddy fields without any harmful effects on our biosphere. Serious efforts are being made now to produce natural gas for fuel purpose. The object of the process is to produce synthetic methane from coal. Burning of coal releases CO_2 gas into the atmosphere and causes environmental pollution.

DIFFERENT SOURCES OF ENERGY

Energy from Plants

Green plants by virtue of possessing special pigments are able to absorb and use a portion of solar energy for the synthesis of food. The process is called photosynthesis. By this, organic substances are synthesized from carbon dioxide and water using the light energy absorbed by the special pigment chlorophyll. In this process solar energy is converted into chemical energy or food energy and molecular oxygen is produced as a by-product.

All other organisms including man directly or indirectly depend upon the energy accumulated in green plants in the form of organic food.

The total solar energy reaching the earth is 3×10^{24} J per year. Out of this, green plants utilize about 0.1 per cent resulting to net annual production of 2×10^{11} tonnes of organic matter utilizing 3×10^{12} J energy. The total solar energy received in India is 6×10^{13} MWH, with 300 days of average Sunshine per year. Thus, there is a vast scope for harvesting solar energy through improved photosynthetic efficiency. The increase in photosynthetic efficiency will lead to an increase in food, biomass and energy. The fossil fuels (coal, oil and natural gases) that we use today resulted when ancient wide spread dense forests were fossilized and converted into major coal beds during the carboniferous period about 300-350 million years ago. Thus photosynthesis is a vital process in the living world of this planet. A detailed study of the biophysical, biochemical aspects of this process is urgently needed for improving the photosynthetic efficiency and productivity to meet the future food and energy requirements. Photosynthetic efficiency is much greater in algae and bacteria. It is 16% in algae and bacteria as compared to 1-2% in land plants.

Energy Plantations

Fuel wood has been the primary energy source for mankind from the beginning of civilization and still continues to be the main source of energy in the developing countries. Plant based energy is obtained by energy plantations which can produce biomass from selected trees in the shortest possible time at a low cost. These plants give rise to heat and yield solid, liquid or gaseous fuel through burning, gasification, digestion etc. Such plantations can be raised in both hills and plains particularly on marginal land. It has been calculated that about 4 tonnes of dry matter can be obtained in 0.25 hectare land which is sufficient for an average family. According to Khoshoo, 1983 around 1.86 million square km of marginal or stripland is available in India for such plantation which would yield around 1,400 million trees. Water hyacinth (Jalkumbhi) when grown in water enriched with sewage, may produce 8—10 tons of plant material/acre which may yield 3500—7000 cubic of methane.

Now-a-days extensive cultivation of alga *Spirulina platensis* is being undertaken in India. This alga is composed of proteins, carbohydrates and lipids in varying amounts and is a rich source of hydrocarbons. It has been calculated that a 200 square miles of algal form could provide enough petroleum substitute (30,000 barrels/day) (Khoshoo, 1983). *Spirulina platensis* contains 60% crude protein rich in Tryptophan, Lysine and Vitamin B-12. Recently, the NBRI, Lucknow has started its culture on mass scale in sewage. Dabur Research Foundation and some other pharmaceutical companies in India prepared *SPIRULINA* health capsule which is said to be richest source of iron, Beta-carotin, Vit. B12, glutamic acid and variety of other essential aminoacids. It cures heart ailments, stress and builds fitness.

The use of blue-green alga as a self-generating source of nitrogen in rice field is well known.

Now-a-days much emphasis is being laid on the cultivation of sea weeds. Many varieties of sea weeds are used for various purposes such as food, pharmaceuticals, textiles, fodder, fertilizer and biogas. It is estimated that the total annual yield of sea-weed is about 50,000 tonnes and if all resources are explored it can produce tremendous energy.

Some of the important plants for energy plantation which are extensively grown in India are *Leucaena laucocephala, Casuarina,* Poplar tree and *Eucalyptus.* Recently an exotic plant Palonia has been introduced from China for agroforestry purpose. This tree species has good adaptability for soils and is fast growing one. *Leucaena leucocephala* possesses all the qualities as wide adaptability, high genetic variability, hardyness, resistance to diseases and pests, adaptability to different edaphic conditions, requiring only marginal inputs of fertilizers, high regeneration potential and easy propagation, wood with high caloric value and ability of wood to burn without sparks and smoke, nitrogen fixing ability by virtue of root nodules, fast growth and high yield of biomass per unit area. It is used as a source of fuel, fodder and fibre.

Rice bran oil is a rich source of edible oil. In Japan bran oil is used in cooking. Paddy contains about 25 kg of oil/tonnes. In India the annual production of rice bran oil is about 80,000 tonnes.

The plantation of energy plants would result in an inexhaustible source of renewable energy. The agro-industrial products, their by-products and their residues can play a very important role in the production of energy. Biomass from corn, sorghum, sugar cane, cassava also provide base material for production of alcohol and gases. The biomass available from oil seeds, fruits and vegetable wastes, cowdung, waste from the sea weeds, rice husk and a variety of other waste organic matter can serve as a suitable medium for the production of gases.

Some aquatic weeds as *Eichhornia crasspes* (water hyacinth), *Lemna* (duck weeds), *Wolffia, Pistia, Salvinia, Hydrilla,* etc. growing abundantly in water can be utilised as rich source of energy.

Biogas obtained from biotic sources is an important source of energy. Biomass collected in the form of wood, roots, foliage, algae etc. from agricultural land or forest can be converted into energy source either in gaseous, liquid or solid forms through diverse ways. Biomass from natural forests and energy plantations will serve as dependable and renewable energy sources in future. For increasing forest biomass fast growing tree species are planted, harvested and regenerated on short-term rotation of 2-4 years.

The fast growing trees as for example, *Eucalyptus, Zizyphus, Prosopis, Popler, Albizzia, Acacia* etc. are not only important from silviculture point of view but are known to reclaim the waste land and check soil erosion as

well. The reclamation of waste land or usar land can coupled with biomass production. *Acacia, Terminalia, Prosopis, Ficus* etc. can be raised on saline and alkaline soils.

Among the various non-conventional sources of energy, forest biomass plays a significant role in solving the fuel wood crisis. Recent data reveal that one seventh of world's fuel need is met by forest biomass. This figure is equivalent to 20 million barrels of oil per day.

Many countries, for example Bangladesh, China, France, Germany, India, Indonesia, Japan, Pakistan, Sweden, UK, USA are actively engaged in research in the field of bioenergy. Several International agencies as Food and Agricultural Organization (FAO), International Development Research Centre (IDRC), United Nations Educational, Scientific and Cultural Organizations (UNESCO), United Nations Environmental Programmes (UNEP), United Nations Industrial Development Organization (UNIDO) and World Health Organization (WHO) are also engaged in Bioenergy research and development programmes.

Importance of Fuel Wood Plantations

Plants absorb and convert solar energy into chemical or food energy through photosynthesis which is stored in their body. When the parts of the plants are burnt that stored energy is released in the form of heat. Whether plants are grown for producing fuels for cooking and various other purposes, the process is called fuel wood plantation. For fuel wood plantation such tree species are selected as are fast growing. The advantages of fuel wood plantations are as follows :

1. The fuel wood would save enormous quantity of cow dung which is applied as natural manure or farmyard manure (FYM) or compost.
2. Fuel wood plantation would provide an inexhaustible and renewable source of energy.
3. Use of fuel wood produces non-hazardous mineral-rich ash which can be used as fertilizer.
4. It causes little or no pollution.
5. Plants create pleasant and beautiful surrounding and provide safe habitat for wild life.
6. There is little or no energy input in fuel wood plantation.
7. Fuel plants also provide us fruits, seeds, edible leaves, forage, tannins, gums, dyes and several other useful substances.
8. Soil erosion is checked through plantation.
9. Three is no problem of waste disposal.

Petroplants (Hydrocarbon Plants)

Several plants are known to yield liquid hydrocarbons, the substitute for liquid fuels. Such plants are called Petroplants. The hydrocarbons present in such plants can be converted into petroleum hydrocarbons of high molecular weight (10,000). More than 385 plant species belonging to

Euphorbiaceae, Asclepiadaceae, Apocyanaceae, Convolvulaceae, Sapotaceae and some other families have been screened for hydrocarbon contents. Now, the efforts are being made to increase the biomass of such plants and convert their hydrocarbons into petroleum products. Indian Institute of Petroleum, Dehradun and National Botanical Research Institute Lucknow have undertaken research programme in this area.

A large number of species belonging to Euphorbiaceae secrete latex containing 30% hydrocarbon. *Hevea brasiliensis* (rubber tree) is important source of hyrdocarbon. These plants may be utilized either to get diesel fuel or high quality liquid fuel. *Euphorbia abyssinica, E. resinifera, E. lathyris* produce good amount of biomass. *E. hirta, E. splendens, E. pulcherima* also have enough fuel potential. There are few trees such as, *Eucalyptus, Agathis dammara, Canarium ovatum* produce cheaper fuel. *Jatropha curcus* tree yields 2 kg of seed oil per plant/year. The oil obtained from this plant is expected to replace the conventional diesel fuel (Khoshoo, 1983).

Besides higher plants, some algae also yield hydrocarbons. *Botryococcus braunii,* an unicellular green alga contains about 70% hydrocarbons. The algal hydrocarbons is very similar to crude oil. This alga can thus be exploited for production of hydrocarbons. For large scale production of hydrocarbons it is therefore necessary to increase the algal biomass. Hydrocarbons are recovered from the algal cells by centrifugation. *Chlorella pyrenoidosa* is another fresh water alga which can yield hydrocarbons. When this alga is subjected to hydrogenation for about an hour at high temperature 50 per cent of algal biomass is converted into oil with a little amount of ammonium carbonate.

Other resources of Energy

Energy consumption and its qualitative trends characterise the life style of a country. The highly industrialised countries depend upon different sources of energy such as coal, oil, natural gas, hydroelectric power and fission fuels for their developmental activities. In developing countries, on the other hand, there is more dependance on non-commercial sources of energy like fire wood, animal wastes and agricultural wastes rather than the fossil and fission fuels. Energy is consumed in different sectors as industry, transport and agriculture. The following table 15.4 gives the details of total energy consumption in different sectors in India :

Table 15.4. Energy consumption in different sectors in India
(According to Fuel Policy Committee Report, 1974)

Sector	*Energy consumption in India (Kilo calories × 10^{12})*	*Percentage of energy used*
Industry	345	22.4
Transportation	160	10.4
Govt. Commercial	35	2.3
Agriculture	30	2.0

Sector	*Energy consumption in India (Kilo calories × 10^{12})*	*Percentage of energy used*
Urban domestic	83	5.3
Rural domestic	890	57.4

Various other sources of energy include coal, hydroelectric, thermal power, nuclear energy, wind energy, biogases etc.

Coal. India has vast coal reserves which may be sufficient for coming 1000 years. Coal is used as a fuel in railways, thermal power plants, domestic cooking and many industries. Nevertheless, the use of coal often causes environmental pollution. The emission of smoke, ash and other particulate matter (fly ash) from coal burning poses a serious threat to human health.

Nuclear energy. The generation of electricity from radioactive uranium and plutonium fuels by nuclear power plants has solved energy problem to some extent but at the same time it is creating several problems. Many harmful gases are released by atomic power plants and radioactive wastes are posing a serious threat to the environment. In spite of development of nuclear waste management technology the atomic power plants are not as safe as claimed by atomic scientists. Even slight leakage of radioactivity in the coolant water will tend to accumulate and amplify in plants, animals and human beings and cause mutations, body deformity, many physiological disorders and even death. It will be fatal to human beings if misused. Proper use of x-rays, γ-rays may be beneficial to human and agriculture, but their misuse proved to be deleterious. Recent Pokhran nuclear explosion in 1998 is well known. A small quantity of radioactive material can produce an enormous amount of energy. For example, one ton of Uranium^{235} (U^{235}) produces energy equal to that produced by three million ton of coal or 12 million barrels of oil. Presently there are 300 atomic power plants in the world. The principal atomic power producing countries are USA, Soviet Russia, UK, France, Japan, Germany, China and India. India ranks 7th among the atomic power producing country of the world.

Hydroelectric power and Thermal power. Hydroelectric and thermal power are the most important and widely used energy. These are renewable and can be generated again. In thermal power plants fossil fuels or mineral fuels like coal, petroleum and natural gases are used to produce energy. Hydroelectric power, on the other hand is generated from water. The energy obtained from power plants is widely used in agriculture, industry, transport, domestic sectors etc. India has very big potential for hydroelectric and thermal power generation.

Wind energy. The wind can also be exploited as a source of energy in different ways. National Aeronautics Limited, Bangalore is engaged in research and development of power generation through wind mills. In many states wind mills have been set up for irrigation purposes. Wind energy may be converted into mechanical and electrical energy. Now a days wind energy is being used for pumping water in rural areas. According to

an estimate, about 20,000 mw electricity can be generated in India from wind alone.

Biogas. Biogas production technology offers a low cost alternative source of energy. Lacs of gobar gas plants installed in rural areas are the important and cheapest source of energy without any kind of pollution. The enormous quantity of animal dung (gobar) available in India may produce about 22,425 million m^3 gobar gas. Gobar gas is used mainly in cooking and lighting. Besides gas, waste (slurry) of gobar gas plants can yield about 206 million tonnes of organic fertilizer every year. Biogas is a mixture of several gases such as methane, CO_2, N_2, O_2 as given in Table 15.5.

Table 15.5. Composition of biogas

Name of gas	*Percentage*
CH_4	50 — 68
CO_2	25 — 36
N_2	2 — 7
H_2	1 — 5
O_2	0 — 0.1
H_2S	rare

Efforts for Conservation of Natural Resources at National and International Levels

Life of man, his development and development of nation depend on the natural resources. Shortage of these resources will lead to poverty of nation. Man is exploiting the various natural resources at fast rate without thinking on its serious consequences. Man is using tremendous amount of coal, petrol and natural gas. Considerable amount of this non-renewable energy reserve can be saved or reduced and air pollution resulting from burning of petroleum products can be minimises. Increasing use of nitrogenous fertilizers and pesticides in agriculture has created the problem of water pollution. Deforestation has produced the soil erosion, loss of soil fertility and floods. Industrialization and urbanization have created the problems of waste disposal, sanitation and healthy air.

Now man has started thinking about the natural resources. He wants to minimize the indiscriminate use of environment for best possible use of land and sea reserves. Praiseworthy Chipko movement started by Mr. Sundarlal Bahuguna can be cited as an example in this direction. The details about the objectives and suggestions are given at the end of this chapter. The success can be achieved on above objects at global level by national and international efforts. For this, national and international legislations are needed. The International Union for Conservation of Nature and Natural Resources (IUCNNR) was established in 1948. The head office of this organization is in Switzerland. Similarly, another sister organization has been set up in the name of World Wild-Life Fund (WWLF). The World Wild Life Fund deals with the following objectives :

(*i*) To raise the funds for conservation.

(*ii*) To make the people aware of various conservation methods.

(*iii*) To protect the wild animals from hunting.

(*iv*) To develop sanctuaries and national parks for their protection.

There are 24 branches of WWLF including one in India. Besides these, Indian Board for Wild Life was created in 1952. Under this, from 1st to 8th October a wild life week is celebrated throughout the country. WWLF has spent about Rs. 160 million on different conservation projects in different countries. These projects include the breeding of rare species. The construction of national parks and pressurising governments to pass legislation necessary for conservation are also objectives of these organizations. The branches in India were established in 1969 to support many valuable projects. Among these projects "Great Indian Bustard" and "Nilgiri Tahr" are significant which have established a. "Madras Snake Park", 'Tiger project' have been undertaken by the Government of India.

Government of India is very careful and making serious efforts to preserve our natural resources. Now government has enacted some legislation against hunting of certain wild animals and cutting of trees. Hunting of tiger, lion, deer and elephant has now been banned. The export of tiger and panther skins, crocodile skin and rhino horn has been restricted.

Reforestation, replanting and construction of National parks are being seriously undertaken all over the country. In India there are several national parks and wild life sanctuaries. The "Corbett National Park" and "Dudhwa National Park" in U.P., "Kanha National Park" in M.P. are important where wild animals plants are protected. Similarly "Gir Sanctuary of Gujarat" is an important harbour for lions. "Bharatpur Water Bird Sanctuary" in Rajasthan is one of the most beautiful sanctuaries of the world.

Environment management is another solution of depletion of resources. We know that the environment is deteriorating due to industrial pollution, toxic chemicals, depletion of natural resources and air pollution. Many of us probably do not understand the environment management due to our ignorance or deliberate negligence. According to a project "The Limits to Growth" which was summarised by Jolly, 1977 in a symposium organized by Government of India at New Delhi, the current trends are as follows :

1. If the present growth trends in the world population, industrialization, food production and natural resource depletion continue unchanged the limits to growth on this planet will be reached within the next hundred years.

2. It is possible to alter these growth trends to establish a condition of ecological economic stability that is sustainable far into the future. The state of global equilibrium could be designed so that the basic material needs of each person on earth are satisfied.

3. If the world's people decide to strive for this second outcome rather than the first, the sooner they begin working to attain it the greater will be their chances of success.

If above programmes are carried out effectively, it would meet the basic needs of the common people in respect of fuel, fodder, fibre, timber on one hand and ensure ecological security on the other hand.

CHIPKO MOVEMENT

The Chipko movement was started by Mr. Sundarlal Bahuguna in Tehri-Garhwal district of UP against ruthless felling of trees and destruction of forests by contractors. The movement gathered momentum in 1978 when the women faced police firings and other tortures. Though the objectives of the movement were broad based, the main objective was to protect the trees on the Himalayan slopes from the axes of contractors of forest. The movement was organized to oppose the ruthless destruction of nature to achieve short term gains. Mr Bahuguna emphasised the importance of trees in environment which check the erosion of soil, cause rains and provide pure air. The women of Advani village of Tehri-Garhwal tied the sacred thread around trunks of trees and they hugged the tree, hence it was called *Chipko Movement*. When any body tried to cut trees villages faced police firing and later courted arrested in February 1978. This in support of Chipko Movement under the leadership of Sri SundarLal Bahuguna spread in other villages of Tehri-Garhwal. Mr Bahuguna presented a plan for protection of soil and water through ban on tree-felling in the Himalayas at the meeting of United Nations Environmental Protection (UNEP) held in London in June 1982. He emphasised that every standing green tree in the forest protects us from avalanches and land slides, purifies our atmosphere, saves our soil, water and other components of environment.

Chipko Movement is now a movement for planting food, fuel, fibre, fodder and fertilizer yielding trees to make the people self-sufficient in all their basic needs. It would generate a decentralized and long term policy which will conserve the environment and bring everlasting peace, prosperity and happiness to mankind. Mr Bahuguna took this mission along with his dedicated workers and marched 3,000 km from Srinagar (Garhwal) to Siliguri. Mr. Bahuguna has focussed public attention for protection and conservation of forests which were being destroyed due to construction of Tehri Dam.

Tehri Dam on the Bhagirathi Ganga in UP at the foot hills of Himalayas is big project of more than Rs. 3,000 crores. The dam will displace 85,000 people and will totally immerse the Tehri town and 100 villages. The site is prone to intense seismic activity. The 3,200 million tonnes of water could cause a major earth tremor. In the event of a disaster, Deoprayag, Haridwar and Rishikesh would be devasted and thousands of acres of agricultural land will be submerged. The efforts are still being made to pressurise Government of India to stop further construction of this dam because this

dam will destroy the forests, wild life, tribal habitation and disturb the ecosystem of that area.

People from France, Sweden, Germany, Switzerland and several other countries have approached Mr. Bahuguna to get experience of this movement. In an International meeting held on June 5, in Stockholm to celebrate "World Environment Day" following statement was given about *Chipko Movement.*

"A powerful environmental movement has grown up on the slopes of mountains of Himalayas. Villagers have created an effective non-violent way to stop the devastation by forest industries. When the axemen come, the people form circle around the trees—they embrace the trees. This has given the movement its name *Chipko Andolan* the tree hugging movement."

The following suggestions are being made by the organisers of Chipko movement :

1. All commercial green tree fellings should be stopped forth with.
2. No new contracts should be entered by forest departments with the industrialists to supply raw materials and old contracts should be revised, especially those made for long-term supply of raw materials at cheap rates.
3. Pine trees damaged due to extraction of resin should be given rest for a period of 10 years.
4. A massive programme for setting up biogas plants, especially in the lower region be taken up. Night soil and other refuge of the cities be utilized by bio-gas industries.
5. Every water source should be trapped to generate hydroelectric power. People should be encouraged to set up their community power houses.
6. Plantation of the trees of food, fodder, fuel, fertilizer and fire trees should be encouraged.
7. All branches of forest department should be integrated into one. At a later stage integration of Agriculture, Horticulture and forest department should be considered into one "Land Use Deptt".
8. There should be strong people's participation in protection of environment. Government alone cannot achieve success. Foot-marches should be organized in all districts to create general awareness in public regarding protection of environment.

In Chipko Movement there is greater people participation for soil conservation and plant protection. The rural people have preferred their own priorities. Conservation work first began in the Chipko villages not for protecting trees but walls were built around agricultural fields to protect from wild animals. The grasses grew rapidly in the protected areas in the fields. This benefit became clear to village women, they began to organise themselves for protecting and afforesting other patches of common lands. While trees take many years to bear fruit, grasses grow faster in a protected

area and can provide fodder in few months. The Chipko women have devised a simple way for sharing this produce. The head of the *Village Mahila Mangal Dal* announces once a month a particular day on which one member from each family can take away as much grass as she can. Thus the role of women in ecological regeneration is very significant.

Today there are many voluntary organizations in the country involved in environmental issues, although their objects are different. Some have aim in preventing deforestation, while others are interested in afforestation. Some are interested to prevent the construction of dams. Some prevent water and air pollution. Among all these organizations Chipko movement in the UP Himalayas, probably is the oldest and most famous of all the organisations which has played a major role in deforestation. There is another parallel movement in the South the *'Apiko Movement'* in the western Ghats of Karnataka started by Medha Patekar. Dams like silent valley and Bethi have already been stopped because of strong people's protests through this movement. *Kerala Sastra Sahitya Parishad* is another important organization which made efforts about the water pollution of the Chaliyar river in Kerala by a Rayon mill. There are many others who are doing excellent work in mobilising people, both to prevent further ecological destruction and to bring about ecological regeneration.

QUESTIONS

1. What do you know about conservation? What are the main reasons of depletion of natural resources?
2. What are different kinds of natural resources? How can their misuse be checked?
3. Write brief notes on :
   (*i*) Mineral resources,
   (*ii*) wild life,
   (*iii*) social forestry,
   (*iv*) food resources,
   (*v*) Chipko movement.
4. What are various steps for conservation of natural resources at national and international levels?
5. Give an account of various energy resources.
6. Give brief notes on :
   (*i*) Importance of fuel wood plantation;
   (*ii*) Petroplants;
   (*iii*) Energy plantation;
   (*iv*) Bio-energy.
7. What is Chipko Movement? What are main objectives of this movement?

16

FORESTS AND FOREST MANAGEMENT

The word forest is derived from the Latin word 'foris' meaning "out of door". It is large uncultivated tract of land covered with trees and underwoods. In other words, forest is an ecosystem of tree-dominated vegetational association. In developing countries like India forests play important role in providing economic wealth, maintaining ecological balance and improving the productivity of agriculture. With the rapid increase in human population more and more areas of forests are converted into agricultural land. The consequences of this are that there are increased soil erosion, frequent floods, drought and land slides. The role of forests in sustaining agriculture must, therefore, be realised and the conversion of forest areas into agricultural land must be checked.

Significance of forest. Forest is an important natural resource which plays several important roles in nature. It is a store house of biological diversity. It is most important natural habitat for wild life. Forest is composed of a large flora and fauna. It maintains ecological balance and biological diversity, acts as catchment for soil and water, prevents floods and provides food, fuel, fodder, fibre, shelter and timber to man. It supports industrial and commercial activities and provides job opportunity to a large number of people. It maintains life support systems essential for food production, health and allround human development. Forest is best site of recreation, meditation, peace and it provides aesthetic sense. It conserves water and soil moisture. Development and conservation of forest will improve the living standard of local people and tribals. Forests control air and noise pollution to a great extent. Forest prevents land slides in the hills and flood havoc in plains. It is harbour of genetic resources.

Ecological Significance of Forest

Green plants of the forest are primary producers of the food chains in forest ecosystem which trap solar energy and transform carbon dioxide from the air along with water and nutrients from the soil into food substances as starch, sugar and protein through the process of photosynthesis. Food materials are stored in the different parts of the plants such as fruits, nuts,

legumes, seeds and wood in various forms. Thus forest acts as energy house by taking energy from the sunlight and converting that in potential or biochemical forms. Forest plays a significant role in keeping the balance of atmospheric gases by consuming CO_2 and releasing O_2. Oxygen is essential for living organisms. Thus the removal of forest will disturb the composition of natural air. In forests, the roots of the trees bind the soil and increase the priority and water absorbing capacity of soil. About 90 per cent of the water falling on the forests is retained in the form of humus or in plant tissue. Thus forest plays a major role in the water cycle or hydrologic cycle.

Forest ecosystem is dominated by trees which plays important role in environment by influencing the life supporting system. Thus forests help in balancing $CO_2 - O_2$ gaseous cycle of atmosphere, tend to increase local rainfall and water holding capacity of the soil. It maintains soil fertility, regulates earth's temperature and water cycle, checks soil erosion, land slides, shifting of sand and flood. Thus it helps in the improvement of environment.

Deforestation

Destruction of forest is called deforestation. Deforestation has serious effect on human life and environment. According to survey of forest department, India has about 75 million hectares of forest area. Recently collected satellite imagery data have revealed that only about 17 per cent area is covered by forest. India is loosing 1.3 million hectare of forest a year. In the hilly region deforestation is so acute that economy and ecology of the area is severely affected. The original vegetation of Himalaya has been greatly destroyed which has resulted in gradual loss of the natural habitat and is posing a threat to natural resources. Due to overpopulation, industrialization, urbanization, road construction, mining and other developmental activities the natural habitats of the flora and fauna are disturbed and have caused tremendous pressure on the living resources. Many plant and animal species are on the verge of extinction or endangered. Forest destruction may also be caused by several adverse factors as land slides, drought, flood, storm, earthquakes, diseases, water and air pollution and human interferences. Other adverse factors such as lack of stable soil, aridity, swampiness, biotic agencies, commercial exploitation etc. may also be responsible for depletion of forest vegetation. Natural diversity of India is one of the richest in the world which is disappearing gradually due to aforesaid factors.

According to FAO report, the annual deforestation rate in India was 0.6 per cent (0.34 million hectares during the period 1981 to 1990). According to Ravindra Nath and Hall (1994) 1.44 million hectares was afforested every year. In 1990, the total forested area in India was 70.6 million hectares of which 27 per cent was under commercial plantations consisting mainly of *Eucalyptus*, teak and pine. According to Khoshoo

(1986), the total area under forest in the world was about 7000 million ha. in 1900. By 1975 it was reduced to 2890 million ha. By the end of 2000 AD, total area under forest in the world will be reduced to about 2370 million ha if the present trend of deforestation continues. The destruction of forest cover in the ecologically sensitive Himalaya region has already started showing adverse impact in the form of increasing shortage of water, recurrent land slides, increasing flood, high sedimentation in the rivers, shortage of fuel and fodder and decrease in grazing land. Due to deforestation the life supporting systems are disturbed. Underground water table is progressively going deeper and deeper. Large area of the land becomes affected by drought and wells, tube-wells, lakes, ponds etc. dry up sooner than expected during summer months.

In Kumaon and Garhwal Himalaya the oak forests are maintaining general environment and villagers depend to a great extent for fodder, fuel and some other necessities on these forests. But now oak forests are being destroyed to meet the ever increasing demands of the people. This has resulted marked changes in the environmental conditions. Consequently the herbal vegetation and microbial community associated with oak are destroyed. This may lead to the loss of medicinal herbs and shrubs associated with oak. The availability of fodder will be reduced and the age-old animal link in the hill ecosystem would be broken.

At the Earth Summit in Rio de Jeneiro (1992), issue related to deforestation was a major concern. The Agenda 21 of the UNCED (United Nation Conference on Environment and Development) stated: "Deforestation is a result of many causes; some natural, but others mainly due to human development, such as inappropriate land tenure systems and incentives, expansion of agricultural areas, increasing forest product demand and lack of information about and understanding of the value of forests." A review of available literature has revealed the following facts about India's forest :

1. The sustainably extractable quantity of fuel wood from India's forests is far below the requirement of the population.
2. Livestock population in India is greater than can be sustainably supported by the available land and forest resources.
3. The demand for industrial wood and other wood, part of which is currently being met by imports, will continue to rise with industrial and economic growth.
4. Unregulated and increased harvesting and non-wood forest produce will result in loss of biodiversity.
5. Expansion of protected area network will result in increasing pressures on the existing productive forests.

Causes of Deforestation

The different causes of deforestation are as follows :

1. **Overgrazing.** Overgrazing in forests destroys newly regenerated growth. It also makes soil more compact and impervious. Soil becomes less

fertile due to destruction of organic matter. Seeds of certain species do not germinate in excessively grazed soils which results in reduction of species. Overgrazing also leads to desertification. Domesticated animals are thus deprived of their natural grazing and forage support. Overgrazing also accelerates the soil erosion. Soil erosion results in the removal of minerals and nutrients from the top soil and adversely affects the soil structure which ultimately lowers the productivity. Satellite imagery data indicate that the area under pasture land is severely degraded. The uncontrolled and indiscriminate grazing in the forests leads to degradation of forest soil and affects natural regeneration of forests.

2. **Shifting cultivation.** This is most common in North-Eastern India due to heavy water erosion, Shifting cultivation is locally called *Jhum*. Many farmers destroy the forest for agricultural and commercial purposes and when fertility of soil is exhausted due to repeated cropping, a new forest area is destroyed. Therefore, farmers should be advised to use the same land for cultivation and apply improved farming methods. It is estimated that every year about one million hectare land is degraded by shifting cultivation.

3. **Fuel wood.** Maximum destruction of forest vegetation is done for fuel wood. Of the total fuel wood nearly 85 per cent is used in rural areas and 15 per cent in urban areas. The annual fire wood consumption was 134 million tonnes in rural areas and 23 million tonnes in cities in 1987. According to an estimate of Forest Survey of India (1987), the annual demand for fire wood in the country was 235 million cubic metres. Thus fuel wood is a major factor for deforestation.

4. **Forest fires.** Frequent fires are the major cause of destruction of forests in India. Some fires are incidental while the majority of them are deliberate. According to study conducted by the Forest Survey of India (1996), on an average, 53.1% forest vegetation is affected by fire. Data further indicate that fire destroys about 0.5 million hectares of forests annually.

5. **Timber.** Timber and plywood industries are mainly responsible for the destruction of forest trees. Thus the increased demand for timber led to a rapid depletion of forest. According to Forest Survey of India 1987, against an annual demand for more than 27 million cubic metres the permissible cut of timber from forests was only 12 million cubic metres.

6. **Industry establishment.** Sometimes factories are established after destruction of forest. Thus for a small gain there is an irreplacable loss. In this process precious plants, wild animals and rare birds are destroyed and the quality of environment is adversely affected. A factory should be established on a waste land away from the urban population. Supply of raw materials to the forest based industries is another major cause of forest destruction in the hills. The forest based industries such as Resin and Turpentine industry are also responsible for destruction of trees in the hills.

7. **Encroachment of forest.** Another cause of deforestation in India is encroachment by tribals on forest land for agriculture and other purposes. According to Forest Survey of India about 7 million ha of forest land has been encroached upon for agriculture. Although such land makes a good contribution for agriculture production yet produces environmental hazards. So it is not desirable to convert forest land into agriculture land.

8. **Forest diseases.** Many diseases caused by parasitic fungi, rusts, viruses and nematodes cause death and decay of forest plants. Young seedlings are destroyed due to attack of nematodes. Many diseases such as heart rot, blister rust, oak wilt, Phloem necrosis and Dutch elm disease etc. damage the forest trees in large numbers.

9. **Land slide.** Deforestation due to land slide in the hills is of great concern. It has been observed that, the land slide occurred mainly in the areas where developmental activities were in progress for past few decades. The construction of roads, and railways particularly in hilly terrains, setting up of big irrigation projects have caused enough destruction to forest and accelerated the natural process of denudation.

10. **Ravine formation.** The forests and cultivated lands along the sides of ravines of big rivers (Yamuna and Chambal) are facing a serious danger of soil erosion. Once the ravines are formed, they continue to destroy the vegetational cover.

11. **Increase in population.** The population of India which was 36 crores in 1951 is expected to touch 1000 million (100 crores) by 2000 A.D. The number of persons dependent on one hectare of agricultural land increased from 3 in 1960-61 to 5 in 1990-91. Such an increase has resulted in acute shortage of land. Besides agriculture, forest land has also been diverted into other sectors. Table 16.1 gives an idea about diversion of forest land into different sectors.

Table 16.1. Diversion of forest lands to other uses

(According to a report of Forest Survey of India, 1988 and Indian Council of Forestry Research and Education, 1995)

Land use	*Total Area (in million ha) diverted into different sectors from 1951 to 1995*
Agriculture	2.764
Ravines Valley Projects	0.518
Industry and townships	0.141
Miscellaneous	1.036
Total	4.696

FOREST MANAGEMENT

Forest management has been defined as the practical application of the scientific, technical and economic principles of forestry. Forest management or forest maintenance is essential to achieve the following two objectives :

1. For climatic or protective purposes which are sometimes referred to as indirect objectives.
2. For productive purposes or economic objectives which are sometimes referred to as direct objectives.

The forest protection is essential due to following physical reasons :

1. Protection of mountain, slopes and catchment areas,
2. Protection against wind,
3. Protection against erosion and ravine formation,
4. Protection for soil aesthetic value or recreation,
5. Protection for pasture, and
6. Protection for wild life.

For all these, the forest management must be such as to conserve moisture, preserve climatic factors and prevent soil erosion. The forests have significant role in the improvement of economic condition of the country. Therefore, scientific management, conservation and utilization of forest wealth needs special attention of the scientists. At the first step the existing forests should be protected and the forest area should be expanded. The National Commission for agriculture has taken the problem of deforestation seriously and recommended plantation through social forestry and other programmes. Thus plantation is the best method of conservation of forest. The forest plays vital role in the amelioration of environment and improve the quality of life. Therefore, considerable attention must be paid for its proper management. There is an urgent need to restore the ecological loss through afforestation in all areas including arid and semi-arid zones. This is essential fore conservation of biological diversity, catchment for water conservation, reducing the sediment load of rivers thus preventing flood. National Forestry Policy of 1952 recommended that at least 33 per cent of the land area should be covered by forest.

The forest cover of India specially of Uttar Pradesh is much less than recommended by the National Forest Policy (1952). In view of this fact, vigorous afforestation and social forestry programmes have been launched to increase the tree cover. One of the important aspects of these programmes is the selection of suitable land for afforestation. The best location for afforestation programme in the first instance would be degraded and waste lands which are not suitable for agriculture. This would increase the productivity of the wastelands and lead to qualitative improvement of such degraded lands. Under afforestation programme indigenous and exotic fast growing tree species are being planted on selected land. Social forestry programme will also fulfil the demands of local people. Every year plenty of seedlings are distributed for plantation. Besides this, many plans and programmes for conserving forests are being implemented by government and voluntary organizations. Now government of India has brought legislation to preserve forests, wild life and biosphere reserves. Current National Forest Policy has recommended the following categories of forest to reduce

environmental degradation caused by deforestation which are presented in the Table 16.2.

Table 16.2. Categories of forest to reduce environmental degradation
(Forest Survey of India, 1996)

Categories of forest	*Area*	
	Million hectares	*Percentage of total forest area*
Reserve	41.65	54.4
Protected	22.33	29.2
Unclassed	12.54	16.4
Total	76.52	100.0

The various aspects of forest management are as follows :

1. Conservation or Protection forestry or Reserve forestry
2. Production or commercial forestry
3. Social forestry including afforestation of waste land

Conservation or Protection or Reserve Forestry

Reserve forests are the most important conservation and scientific management. Conservation forests are also called reserve forests where water reservoirs are present. The major aims of conservation forestry are protection or conservation of existing forests and restoration of the degraded forests in ecologically sensitive areas as Himalayan region, western and eastern Ghats, catchment areas, National parks, sanctuaries and biosphere reserves etc. These areas are restricted from commercial exploitation.

Commercial Forestry

When the afforestation is undertaken and managed intensively for much higher productivity on limited area of forest land it is called commercial forestry. The main aim of commercial forestry is to provide and fulfil the requirements of the people and industries.

Social Forestry

Social forestry means afforestation or developing of forests with the participation and cooperation of public to meet the requirements for self-consumption and cottage industries. The main objects of social forestry are to provide adequate fuel wood for cooking, green fodder to domestic animals, edible fruits for improved nutrition and timber for house construction.

Forest management programme includes the following activities :

1. Reforestation.
2. Forest protection from encroachment and shifting cultivation.
3. Control of forest fires.
4. Restriction on grazing.
5. Extension of forest areas.

6. Control of excessive cutting.
7. Cultivation of useful plants on wastelands.
8. Plantation of fast growing trees.
9. Control of harmful agents.
10. Improvement of timber quality through improved varieties.
11. Converting wasteful cutting into quality yield harvesting.
12. Legislation to check deforestation.
13. Control of forest diseases.

The forest diseases can be controlled up to some extent by :

(*i*) Eradication of diseased host plants.
(*ii*) Spraying of suitable antibiotics, fungicides, nematocides.
(*iii*) Spraying of effective insecticides.
(*iv*) Sterilization.
(*v*) Planting of resistant varieties.

14. By undertaking afforestation with particular emphasis on fuel and fodder plants.
15. More attention for forestry research, personnel management and data base in the field of forestry.

The Present Programmes for the Development of Forestry and Wild Life

The Ministry of Environment and Forest is implementing the following Projects :

1. Biosphere Reserves.
2. Development of National Parks and Sanctuaries.
3. Project tiger.
4. Project elephant.
5. Modern forest fire control methods.
6. Ecodevelopment around National Parks.
7. National Afforestation and Ecodevelopment Board (NAEB).
8. Integrated action oriented research demonstration and projects for Himalayan regions.
9. Association and involvement of Scheduled Tribes and Rural poors in the programmes of region of degraded forests.

State Governments have also many schemes to implement which are :

1. Afforestation and regeneration of degraded forests.
2. Greening of rural and urban areas.
3. Development and conservation of minor forest produce.
4. Development of National Parks and Sanctuaries.
5. Regeneration of Sal and Oak forests.

Afforestation in Denuded Hill Slopes

Denuded hill slopes are found throughout the country. In most of the humid regions vegetational cover establishes naturally, but in drier parts of

the country, the afforestation assumes special importance not only for productive reasons but also for conservation of soil and water. The incidence of grazing is one of the important causes of denudation and the protection of plants raised under afforestation is a tidius problem.

Soil preparation for afforestation work is done either in the form of (*a*) contour trenches (*b*) patches and pits. The selection of species for plantation is made taking into consideration the various factors prevailing in the region. The surviving indigenous or local species give a clear indication of the species which may be most suited for the area under afforestation. Thus fast growing species can survive under the adverse condition of the locality. Examples of few plant species suitable for denuded hill slopes are given below :

Chir or pine trees _____ in moist subtropical area
Acacia modesta _____ Dry subtropical area
A. Catechu, Olia ,,
Dedonea, Prosopis julifloro ,,
Robinia ,,
Pinus wallichiana and Deodar _____ Temperate zone

Afforestation in Ravine Lands

The ravines of Yamuna and Chambal have not only rendered vast areas of land barren but are causing serious danger to the cultivated lands.

Continuous development of ravines results in the formation of hillocks and ridges in between two adjoining ravines. These hillocks and ridges have practically no contact with the permanent water table and their own moisture retaining capacity is low, their soil becomes extremely dry during summer. Uncontrolled cutting of trees, grazing and fire which are said to be generally responsible for the formation of the ravines continue to pose a serious threat to afforestation. The following species have been successfully raised in ravine areas :

In sandy soils : *Acacia catechu, Dalbergia sissoo, Albizzia* spp, *Azardirachta indica, Pongamia pinnata, Prosopis juliflora* etc.

In clayey soils : *Acacia leucophloea, Acacia arabica, Albizzia, Syzygium, Terminalia arjuna, Holoptalia, Haplophragma, Pongamia, Prosopis spicigera* etc.

Afforestation in Shifting Sands

Shifting sands are found along sea coasts as well as in the interior. The inland sands are found along rivers and deserts.

Coastal sand. All along sea coast large quantities of sand get accumulated as a result of tides. Such sand deposits are found in the estuaries of big rivers. Coastal sand keeps on shifting under the pressure of strong wind. It is not capable of retaining moisture, water table is found a few meters below the surface. The winds are strong and carry salt particles with

them. For most of the sea coast, *Casuarina equisetifolia* has been found to be the best species. It is quick growing and hardy. Other species which have been successfully raised are *Eucalyptus, Pongamia pinnata, casuarina* etc.

Inland river sand. The inland sand generally occurs along the rivers and deserts. The soil is sandy, unstable and deficient in nutrients, water table is not deep and so irrigation is possible. Soil preparation is made by digging trenches and pits. The plant species which have been successfully grown in inland sands are *Dalbergia sissoo, Acacia catechu, Acacia arabica, Albizzia procera* and *Pongamia pinnata.*

In desert areas climate is characterised by extreme temperature, dry condition and scanty rainfall. Soil varies from place to place. In order to reduce the velocity of wind and prevent sand movement, mulching is done in April and May. For this purpose. *Crotolana bruhia, Aerua tomentosa, Leptadenia pyrotechnica* plants are used. Before the onset of rains seeds of the following species are sown along the windward side of the mulch lines :

Tree spp – Prosopis spicigera, Prosopis juliflora, Acacia arabica, Acacia sengal, etc.

Shrubs – Calligonum polygonoides, Ziziphus spp, *Cassia auriculata* etc.

Grasses – Panicum antidotate, Lasiurnum spp.

Indian Forest Policy 1947-1997

Scientific management of forests in India was initiated in 1864. India's first forest policy was framed in 1894 by British administration which gave priority to commercial exploitation of forest and focussed more attention on crop cultivation than on forestry, permitting forest areas to be converted into agriculture lands. The National Forest Policy formulated in 1952 laid emphasis on increasing the forest area to one-third of the total land area. It has not been possible, however, to implement this policy. On the contrary, forest land had to be used for river valley project, minor irrigation projects, industries, residential settlements, rehabitation of landless people and construction of roads etc. and in the late fiftys and early sixtys forest lands were allotted to people for farming under the *"Grow more Food Programme"* which was later postponed.

The National Forest Policy provided a functional classification of forests and brought under its purview the conservation of wild life. Forest legislation was brought on the concurrent list in 1977. The enactment of the Forest Act, 1980 put a check on the uncontrolled diversion of forest land for other purposes.

The Forest Act, 1980 was revised in 1988. The main objectives of policy are :

1. Maintenance of environmental stability through preservation and restoration of ecological balance.

2. Conservation of biological diversity and genetic resources.
3. Control of soil erosion and desertification.
4. Increase in the forest cover through afforestation and social forestry.
5. Maximum utilization of forest produce and maximum substitution of wood.
6. People's participation and active involvement of women in achieving the above objectives and in minimising pressures on forest.
7. A maximum of 33% of the total land area of the country and 60% of the hill area to be brought under forest or tree cover.
8. Total protection of tropical rain forests.
9. Control on introduction of exotic species.
10. Involvement of tribal population in protection, regeneration and development of forests.
11. Discontinuation of the practice of supplying forest produce to industry at concessional rates.
12. The use of forests for grazing and extraction to be determined with regard to carrying capacity.

Laws for Conservation of Forests

Article 51-A(g) has made it the fundamental duty of every citizen "to protect and improve the natural environment including forests, lakes, rivers and wild life". Government of India enacted the forest (conservation) Acts in 1980 which impose restriction on destruction of reserved forests, use of forest land for non-forest purposes by the states. These restrictions are contained in section 2 of the Act.

The section 2 of the Act states that—Notwithstanding any thing contained in any other law for time being in force in a state, no state government or other authority shall make, except with the prior approval of the Central Government, any order directing :

(*i*) that any reserved forest or any portion thereof, shall cease to be reserved.

(*ii*) that any forest land or any portion thereof may be used for any non-forest purpose ("Non-forest purpose" means the breaking up or clearing of forest land or portion).

(*iii*) that any forest land or any portion thereof may be assigned by way of lease or otherwise to any private person or to any authority, corporation, agency or any other organization not owned, managed or controlled by Government.

(*iv*) that any forest land or any portion there of may be cleared of trees which have grown naturally in that land or portion, for the purpose of using it for reafforestation.

The Act does not permit any mining in the forest areas. Therefore, the mining activity in the forest areas must be stopped.

SOCIAL FORESTRY

The National Commission on Agriculture has given serious thought to the problem of deforestation and recommended introduction of *"Social Forestry"* to create multipurpose wood lots in rural India. Social forestry may be defined as additional aid to wild life conservation. Social forestry is a new revolutionary concept, a multipurpose programme and a mission which aims at ensuring ecological, economic and social security to the people particularly to the rural masses especially by involving the beneficiary's right from the planting stage to the harvesting stage. It aims at a mixed production of fire wood, timbers, fibres, fruits, fodder and other raw materials for self-consumption and cottage industry. These objectives are achieved through public participation and cooperation.

In view of increasing population and deforestation, social forestry will not only serve to meet the ever increasing demand of fire wood, fodder, timber and a variety of tree-based produce for rural cottage industries but also to maintain the ecological balance.

To meet the basic needs of villagers Social Forestry Programme was initiated in 1979 with the help of world bank. Now the social forestry is adopted in almost all the states. Under social forestry programme different species of fast growing trees are planted which will provide fuel, fodder, raw materials for cottage industry.

Under social forestry programme plantation is done in the following types of lands :

1. Government land which includes roadsides, side land along railway lines and degraded forest land.

2. Semi-government and institutional land–which includes wasteland under Panchayat, school and college land and land around other buildings in cooperative sector.

3. Private land.

Forest department manages for cultivation in the wasteland of village according to requirement of villagers. Care and protection of plants is done by village committee. There is agreement between village committee and forest department through which 20 per cent profit is given to village Panchayat and the rest goes to forest department. Seedlings or nursery plants are supplied free of cost to villagers and the cost of plantation is met by the village Panchayat.

The social forestry which is done on private land is called *agriculture-forestry* or *agroforestry*. Agroforestry is one of the important components of social forestry. In this forestry, nursery of economically important plants is prepared at Block and Panchayat levels and supplied at nominal costs to villages for agricultural and timber purpose. Such plantation is done around agricultural field, wasteland of houses and schools. *Eucalyptus*, sessame, babool, Neem, mango, Mahua, Peepal, Gular, Ber trees etc. are grown

preferally in rural areas. In the rural areas now-a-days Arjun tree are being planted on large scale for culturing tassar insects. This gives income of about Rs. 5000 – 7000 per hectare.

The preparation of planned scheme to ensure rapid economic emancipation of large number of poor people without any capital in rural areas needs a different approach. The trees like mango (*Mangifera indica*), Guava, Mahua (*Madhuca longifolia, M. indica,* Neem (*Azadiracta indica*), Kanji (*Pongamia pinnata*), Imli (*Tamarindus indica*), Saijana (*Moringa obifera*), Lisora (*Cordia*) spp, Ber (*Ziziphus*), Bel (Aegle marmelos), Babul (*Acacia nilotica*), August (*Sesbania grandiflora*), Bamboos etc. will provide necessary wood, timber, fruits, fodder and raw materials for a variety of cottage industries.

Future Planning of Social Forestry

Today a new consciousness is developing in our country about the importance of forests and social forestry. Social forestry is a new catch word which aims at meeting the fuel, fodder, fruit and timber needs of the people. The programmes aims at covering a total of Rs 2.15 million hectares (ha) of land of which 1.52 million ha land will be covered under social forestry programme and the rest under production forestry. The afforestation in general and social forestry programme in particular have increased substantially in recent years.

Several state governments, particularly Tamil Nadu, Karnataka, Gujarat, Haryana and West Bengal have already started new social forestry projects with the financial support of International agencies like World Bank, Swedish International Development Authority (SIDA), Canadian International Development Authority (CIDA) and the US Agency for International Development (USAID).

The Government of India has already sponsored programmes like a *"tree for every child", ecodevelopment camps* involving college students in tree planting and free distribution of seedlings to farmers. State sponsored Agroforestry schemes in Gujarat and Karnataka have resulted in plantation of trees of commercial values. The World Bank funded extension of the existing social forestry programme to bring under tree cover some 110,000 ha private land holdings currently being used for growing crops. Despite these developments, many environmentalists are critical of government's social forestry schemes. They often question the choice of tree species, monoculture plantations and the actual beneficiaries of these schemes. Critics of these schemes like Sundarlal Bahuguna from the Garhwal district of U.P. have charged that paper Mill owners and synthetic fibres manufacturers are using social forestry programme to meet their selfish end rather than helping the poor man facing energy famine.

In the hills of U.P. recent afforestation pattern has changed and in place of naturally growing broad leafed deciduous tree species such as oak, Ash,

Pangar etc., timber trees like Pines, Deodar and conifers are being planted now which have industrial and commercial values. While the old stands of broad leafed trees produce a rich humus and hold the rain water well, the new trees don't play an adequate ecological role. The survival rate of new tree species is also poor because local people don't care for commercial value of those trees as they do not gain any thing from them.

There is enough scope for social forestry in the hills to cover lands with timber and other useful trees in order to check rapid run off rain water and to avoid sudden floods in the plains. Soil conservation measures should be adopted to check washing off of the top fertile soils and to increase moisture retaining capacity of soil which promote the growth of trees and crops. These two programmes, social forestry and soil conservation if launched together will prove to be beneficial for the poor masses and ensure the better standards.

Table 16.3. Some Important Plant species for social forestry

Botanical names	*Common name*	*Habitat Suitability*	*Remarks*
Acacia catechu	Khair or Katha	River beds up to 1000 m altitude	Suitable for denuded areas
Aegle marmelos	Bel	up to 1000 m altitude	Medicinal, Hardy, edible
Bauhinia purpurea	Lal kachnar	up to 1000 m	Fast growing
B. variegata	Kachnar	up to 1000 m	Fast growing, Flower buds edible, nutritious
Boehmeria regulosa	Genthi	up to 1300 m	Fast growing
Bombax ceiba	Semal	up to 1000 m	Fast growing
Betula alnoides	Kathbhuj	up to 2000 m	Plywood, suitable for ravine areas
Alnus nepalensis	Utis	up to 2000 m	Suitable for soil conservation
Dalbergia sisso	Shisham	up to 1000 m	Soil conservation
Emblica officinalis	Amla	up to 1000 m	Rich in vitamin C
Eucalyptus hybrid	Mysore gum	up to 1000 m	Pulp
Ficus palmata	Pheru	up to 100 m	
Castanea sativa	Chestnut	up to 2000 m	Soup delicacy
Grewia oppositifolia	Bhimal	up to 1700 m	Fodder and fibres
Morus alba	Shahtut	up to 1000 m	Sericulture, fast growing
Moringa spp	Saijana	up to 900 m	Fast growing, used in vegetables
Populus alba	Safeda	1000–1700 m	Match wood, Packing
Madhuca indica	Mahua	Plain	Medicinal

(*Contd.*)

Botanical names	*Common name*	*Habitat Suitability*	*Remarks*
Tamarindus indica	Imli	Plain	Fruit edible
Cordia spp.	Lisora	Plain	Used in sauce
Sesbania grandiflora	August	Plain	Flowers used in vegetables

QUESTIONS

1. "Afforestation plays an important role in the improvement of Environment." Discuss
2. Write brief notes on :
   (*i*) Afforestation
   (*ii*) Forest management
   (*iii*) Deforestation
3. What are the main objectives of social forestry? Discuss the role of forest department in social forestry programme.

17

IMPACT OF POLLUTION ON VEGETATION

Many chemicals, fertilizers, pesticides combustion of coal, waste treatments release toxic substances into the environment that are taken up by the plants from air, water and soil. Atmospheric pollutants particularly SO_2, halides (HF, HCl), ozone, carbon monoxide and peroxi-acetyl nitrate (PAN) produced from automobiles, industrial fumes and strong radiations are dangerous to plants. Harmful substances that reach to plants through the air are SO_2, nitrogen oxides, hydrocarbons, dusts and smokes. Plants growing in water are severely affected by toxic chemicals like cyanides, chlorine, hypochlorate, phenols, benzyl derivatives and heavy metal compounds of sewage.

Effects of different kinds of pollution can be determined by the nature of pollutants, their concentration and the period of exposure. Under exposure to high concentration, plants suffer acute injury with externally visible symptoms, such as chlorosis, discolouration, necrosis and death of entire plant. Besides morphological changes, chemical, biochemical, physiological and fine structural changes also occur in plants.

The damaging effects of air pollutants, on vegetation have been recognised by many workers. In general, air pollution decreases the yield of all crops by affecting their photosynthetic activity and growth. Pollution damage can also be recognised by the accumulation of toxic material in the plant, changes in pH, reduced or increased activity of certain enzymes, increase in compounds with SH groups and phenols, lowered ascorbic acid level in the leaves, depression of photosynthesis, stimulation of respiration, low dry matter production, changes in permeability, disturbances in water balance and reduced fertility under prolonged exposure. The disturbances in metabolism are due to chronic injury with irreversible consequences. Plants show reduced productivity and yield and quality is lowered and ultimately they die. The symptoms of pollution affected plants are varied and unspecific. A particular pollutant affects different plants in very different ways and a particular symptom can be produced by a variety of substances. The influence of external factors (pollutants) on plants depends upon the

species, stage of development and the organ and tissue involved. Morphological alteration of a plant and floristic composition of a plant community are commonly used to indicate changes in the environment. According to Van Haut and Stratmann (1970), visible plant symptoms are most commonly used to indicate the responses of plants to pollutants. Jacobson and Hill (1970) have studied the effects of common pollutants on plants. It is possible that any part of a plant body, if it responds specifically or characterstically to any pollutant, can be used for its indication. M.U. Beg (1980) from Industrial Toxilogy Research Centre, Lucknow has reported the responses to air pollutants as a biological indicator, taking several parameters into consideration such as, seed germination, growth of plant, development of lateral branches, expansion and colour changes in leaf, flower and fruit formation, decolouration of flower, loss of physiological control, mineral composition, chemical constituents of cells, enzymatic activity and pollen germination.

Germination and General Growth

Seed germination has been used by many workers to monitor pollution responses. Several growth parameters such as percentage of germination, seedling survival, seedling height, cotyledonary expansion and fresh and dry weight have been taken as criteria to assess plant response to a specific pollutant. *Phaseolus vulgaris* has been grown in smoke free and smoke affected region by Sorauer (1899). The toxic effect of thiosulphate has been indicated as germination inhibition in many plants. Houstan and Dochinger (1977) have evaluated germination inhibition in relation to pollution by sulphur dioxide and ozone. The effects of lead, cadmium, NO and CO have been studied on many plants.

Some plant species are sensitive to pollution *e.g., Polygonum, Rheum, Vicia, Phaseolus* and *Capsella.* Generally, the plants response to pollutants is characteristic rather than specific. Stunting of corn, sweet potato and rye has been reported due to high toxicity. Reduction in root length, shoot length, numbers of tillers, leaves, ears and grains in wheat have been reported under conditions of cement dust pollution. Similarly plant height, number of leaves and bolls per plant are reduced in cotton exposed to particulate pollution. Inhibition of lateral growth of forest trees is caused by lime stone dust. Pine trees do not flourish in SO_2 polluted areas. It has been noticed that leaf is the most sensitive organ to pollution. The pollution indicator value of leaf has been exploited by many workers in response to a variety of conditions. Leaf injuries are a characteristic symptom to various pollutants. The characteristic symptoms on leaf include pigmentation, chlorosis, yellowing, necrosis etc. The leaves of dicotyledons generally exhibit spotted markings between the veins while monocotyledons usually show necrotic streaks between parallel veins. Injury may also occur along the margin and tips. Reduced expansion of cotyledonary leaves in response to pollution has been observed in several cases. Decrease in dry weight

of leaf, decrease in leaf thickness, cell size, loss of leaves and early senescence may be due to smoke and SO_2 pollution. Yunus and Ahmad (1980) have observed that leaves in the polluted area of cement factory showed higher stomatal and trichome densities, smaller epidermal cells and trichomes as compared to leaves obtained from unpolluted atmosphere.

Biochemical and Physiological Changes

Among the biochemical aspects, the most important parameter is pigment analysis. Chlorophyll a and b have been measured as index of response to different types of pollution. In *Cassia* and *Cynodon*, 50 per cent reduction of chlorophyll has been observed while in *Saccharum* the pigment is least affected. Chemical estimation like proteins, aminoacids, soluble sugars, sucrose, starch, reducing sugars, vitamin C, riboflavin, thiamine and carbohydrate are used to indicate foliar sensitivity to air pollution.

Physiological activities as opening of stomata and rate of photosynthesis can also be used as indicator of pollution. Photosynthesis can also be used as indicator of pollution. Photosynthesis as a parameter has been used for mixed exposure of SO_2, NO_2 and dust.

Enzymatic parameters are also used to indicate the presence of particular pollutant. Peroxidase was found to be most sensitive indicator of pollutant in the absence of visible injury. Thus on the basis of enzyme activity, the susceptible species of plants can be identified. Many workers have reported that enzymatic activity is retarded due to air pollution. Other common enzymatic parameters used are ribulose diphosphate carboxylase, glutamate-pyruvate, transminase, glutamate-oxaloacetate transminase etc.

Effects of Different Pollutants on Vegetation

Air pollutants are absorbed by the plants in appreciable amount. The absorption is affected by the nature, concentration of pollutant, exposure time, plant species, age of the plant, nutrient supply and other environmental factors. The effects of common air pollutants on plants are described below :

Sulphur dioxide. SO_2 is a major air pollutant in the areas where large quantities of fuel are burnt. Leaves of green plants are able to absorb SO_2 through their stomata. The absorbed sulphur is incorporated into various organic compounds.

SO_2 is one of the most phytotoxic pollutants. Foliar injury is prominent symptom recognised in the leaves. Its effect on plants varies from species to species depending on genotype and physiological stages of the plants, their age, climatic condition, concentration of pollutant and duration of exposures. The most recognised symptoms are interveinal chlorosis, necrosis in plants, brownish colouration in the tip of pine needle. Lower concentration over long period leads to chronic leaf injury such as gradual chlorosis. Trees are injured followed by shrubs and herbs. Some of the plant species,

especially the sensitive ones are unable to regenerate in the area and gradually get eliminated from the soil. SO_2 also reacts with cell through stomata causing injury or death of tissues. Flower buds of *Gladiolus* are very sensitive and they exhibit necrosis at the tips and margins. SO_2 also affects photosynthesis, water relations and enzymatic system of plants. Beg and his team (1982, 1985) at ITRC, Lucknow have tried to investigate the mechanism of phytotoxicity of SO_2 and suggested certain morphological and physiological traits in plants as monitors of air pollution. Scientists of ITRC, Lucknow have evolved a simple and quick technique of screening the forest species according to their reactivity. On the basis of their experiment they concluded that the plant spp. like *Eucalyptus, Ficus infectoria* (Paker), *Dalbergia sissoo* (Shisham) and *Syzygium cuminii* (Jamun) are resistant where as *Ficus bengalensis,* (Bargad), *Ficus religiosa* (Peepal), *Bombax melabaricum* (samel) and *Terminalia arjuna* (Arjun) are susceptible to SO_2. Characteristic symptoms were noticed on *Aegle marmelos* (Bel) and *Holoptelea integrifolia* (Chilbil) when these are exposed with 6.5 PPM SO_2 for four hours. Interveinal necrosis, marginal necrosis and leaf curling were common visible symptoms. These symptoms appeared after 48 hrs of exposure.

At low concentrations of SO_2 no significant reduction in chlorophyll and carotenoid contents were noticed in forest trees. But at higher concentration of SO_2 the reduction in total chlorophyll and carotenoid contents was noticed. Thus, it can be inferred that forest species can be proved as an effective measure for purifying the environment.

Oxides of nitrogen. Oxides of nitrogen are produced in internal engines where oxygen and nitrogen are subjected to heat and pressure and also by incineration of organic wastes and in petroleum refining. These pollutants produce marked injury to affected plants. Sometimes there is a combined effect of SO_2 and oxides of nitrogen which produce more injury than either of them alone. Besides leaf injury, reduction of growth occurs in sensitive plants. NO_2 causes leaf injury and reduction of growth in several sensitive plants.

Fluorides. Fluorides are emitted largely from aluminium and phosphate plants. It is widely spread in the earth's crust as a natural component of soil, rocks and minerals. When these substances are heated or treated with acid, toxic fluoride are released into the atmosphere. This becomes phytotoxic above the critical levels. In recent years, the losses to agriculture from fluoride have greatly increased with the vast expansion of industries. This pollutant damages plants if deposited on the leaf surfaces. Thus reduces the photosynthesis. It also blocks stomatal pore, thereby reducing respiration, photosynthesis and transpiration and finally plants become weak and ultimately die. On account of fluoride pollution, leaves show

marginal necrosis as well as interveinal chlorosis. The fluoride accumulated in plants enters the food chain through herbivorous animals and passes into the soil through animal wastes.

Ozone. Ozone is a natural component of atmosphere where it filters out dangerous ultraviolet radiation. In urban localities where there is high population density, hydrocarbons and oxides of nitrogen are emitted into the atmosphere from automobile exhaust which in presence of sunlight interact to form large amounts of ozone which causes serious injury to vegetation.

Ozone injury on plants range from collapse of extensive areas of the leaf blade to discrete necrotic spots on upper surface, chlorosis, abscission of leaves, fruits and suppression of growth without visible symptoms of injury. Extent of injury and characteristics symptoms vary widely with type of plant, concentration of toxicant, duration of exposure and environmental conditions. Visible injury may occur on the most sensitive plants.

Ammonia. It has been observed that fumigating trees with ammonia gas increases the ammonium content. Leaves of soybean, sunflower, cotton and maize are able to absorb ammonia from the atmosphere. In maize, a part of absorbed ammonia is metabolised into aminoacids. It is experimentally demonstrated in rye grass and several other crops. Some hydrophytes *e.g., Ceratophyllum demersum, Potamogeton pectinalis* and *Elodea* spp. also absorb NH_3 through their roots because ammonia is highly soluble in water. The absorbed ammonia is translocated to the leaves for assimilation.

Carbon monoxide. Carbon monoxide is a product of incomplete combustion. It is deadly poisonous at high concentration and is one of the important gaseous air pollutants. Main activities result in the production of nearly 250 million metric tons of CO annually. It is taken up by plants including algae.

Particulates. Particulates or dusts come under major pollutants which remain suspended in the air for a short time. Particulates are produced from many sources as cement factory, lime processing plant, refuse disposal and agricultural practices. Heavy metals arise from foundry affluents and combustion. Rao and his associates (1980, 1981, 1985) have studied the responses of certain crops to particulates and developed certain methods, to mitigate pollutant including its injury to plants. These particles become deposited on the plants especially on the leaf surfaces thus leaves become coated with dust which block the stomata causing the reduction of photosynthesis followed by reduction in food production. Transpiration and respiration processes are also regulated.

In the coal dust polluted areas mango and lemon trees show morphological changes leading to loss in productivity. It has been seen that the fallout of fine coal particles especially at the time of flowering

significantly hampers the process of pollen germination and fertilization which are essential for fruit setting. Trees in such areas show decortication of bark, defoliation of branches and stunting of growth. Similarly, cement dust released from cement factories leads to irreparable degradation of soil characteristics and plants' structure and function. It is likely that cement dust affects plants through leaf encrustation, stomatal plugging, and changes in leaf reaction.

Control of Pollution through Vegetation (Plants as Ameliorator of Environmental pollution)

Plants, being the most important component of the ecosystem must be given top priority in the environmental planning and management. Trees have ability to reduce the amount of pollution in air. Plantation is extremely important in polluted and water catchment areas including urban and industrial areas. Many instances are known which indicate that the trees are capable of making our environment more pleasing and livable. Trees also provide an aesthetic link between man and his environment. Trees play an important role in enhancing the quality of environment by influencing the life supporting systems. They restore ecological balance of all ecosystems, maintain biological diversity, act as catchment for soil and water, prevent floods and check or reduce the noise pollution. The capacity of plants to absorb aerosol (very small particles of solid or liquid that remain suspended in the air) or gaseous pollutants from the air has not been thoroughly investigated but few studies have shown that trees can effectively filter certain aerosols. Researches based on the foliar accumulation of chloride and fluoride have also stressed the ability of plant leaves to retain atmospheric aerosols. Plants also improve the quality of air by absorbing or altering gaseous pollutants from the atmosphere. For example, leaves exposed to low level of SO_2 may transform the gas to SO_4. SO_4 is less injurious to plants. Thus plants, in general, act as mitigators of air pollution.

The surface of vegetation provides a major filteration and functions as sink to mitigate pollutants from air. At present there is great crisis of CO_2–oxygen balance in atmosphere. Only green plants have capacity to utilize CO_2 in the process of photosynthesis and release free oxygen in the atmosphere. Green plants not only take up CO_2 and release O_2 but their leaves retain some pollutants. Dense and tall trees also filterout dust. Data collected from Lucknow showed high dust trapping potential of different plants. In this regard peepal (*Ficus religiosa*), mango (*Mangifera indica*) and ashok (*Polyalthia longifolia*) trees were found to be better dust collector than amaltas (*Cassia fistula*), Kachanar (*Bauhinia variegata*) and gulmohar (*Delonix regia*).

Enough evidences are now there which show the role of plants as sinks for gaseous pollutants. For example, an oak (*Quercus suber*) tree has

been found to reduce about 20 per cent ozone concentration. It has been shown that alfalfa canopy removed 1/4 ton of nitrogen oxide or SO_2 per square mile per day. Tree plantation is economically important for protection against environmental pollution. According to an estimate a peepal (*Ficus religiosa*) tree is reported to replace 2,252 kg polluted air with 1,713 kg of O_2 during its life time which is sufficient for 60,000 people. Hence real value of medium size tree comes to about Rs. 15.7 lac in 50 years of life time.

The use of vegetation in filtering out the dust, soot and particulates from the atmosphere has been widely accepted. Ahmad etal (1988) at National Botanical Research Institute, Lucknow have initiated studies on the impact of air pollution on vegetation with following objectives :

1. To study the nature and extent of damage caused to vegetation by common air pollutants.
2. To determine the role of plants in indicating the level of pollution in a particular area.
3. To identify pollution tolerant/resistant plant species to be used as green belts around industrial areas to mitigate air pollution.
4. To determine the dust trapping/filtering potential of common trees and shrubs.

Thus pollution is a problem which is going to increase with the increase of population in the coming years but vegetation can reduce it upto some extent if it may not altogether eliminate. Pollution can be checked through vegetation by adapting the following measures :

1. Green belts should be planted around urban and industrial areas with plants that are pollution resistant to help in purifying the atmosphere by regulating temperature, humidity and air movement and also to reduce damage caused by air pollutants. Green belt around the cities will also increase the aesthetic sense.
2. Screening of Indian plants should be done in order to replace pollution tolerant species.
3. Research laboratories and organisations should carry out regular monitoring of environmental pollution through proper vegetation in metropolitan cities and industrial towns.
4. Many forest species have been proved as an effective measure for purifying the environment.

Based on vegetational survey in response to pollution some tolerant species have been enlisted as suggested by Ahmad etal 1988 :

Herbs

Achyranthes aspera (Latjira)
Amaranthus graecizans (A variety of Chaulai)
Argemone mexicana (Sialkanta)
Solanum xanthocarpum (Bhatkataiya)

Shrubs

Bougainvillea (Baganvilas)
Calotropis procera (Madar)
Cassia sophera (Kasunda)
Clerodendron infortunatum (Bhant)
Croton sparsiflorus
Ipomoea fistulosa (Behaya)
Lantana camara (Ghaneri)
Murraya exotica (Kamini)
Nerium odorum (Kaner)
Ricinus communis (Arand)
Tabernaemontana coronaria (Wild Chandni)

Trees

Acacia arabica (Kateria Babul)
Aegle marmelos (Bel)
Albizzia lebbeck (Siris)
Syzygium cuminii (Jamun)
Tamarindus indica (Imli)
Zizyphus mauritiana (Ber)
Alstonia macrophylla (Chatian)
A. scholaris (Chitaman)
Anthocephalus cadamba (Kadamb)
Artocarpous heterophylla (Kathal)
Azadirachta indica (Neem)
Butea frondosa (Palas)
Casuarina equisetifolia (Jhau)
Citrus medica (Lemon)
Dalbergia sissoo (Shisham)
Delonix regia (Gulmohar)
Diospyros melanoxylon (Tendu)
Eucalyptus citriodora
Ficus bengalensis (Bargad)
F. infectoria (Pakar)
F. religiosa (Peepal)
Holoptelea integrifolia (Papri)
Lagerstroemia sp. (Sawani)
Madhuca indica (Mahua)
Mimusops elengi (Maulsri)
Moringa oleifera (Sahjan)
Phyllanthus distichus (Harfarwari)

P. emblica (Amla)
Pithecobium dulce (Jangal Jalebi)
Polyalthia longifolia (Ashok)
Psidium guajava (Guava)

QUESTIONS

1. What is impact of Pollution on vegetation?
2. What are morphological and biochemical changes in response to various Pollutants.
3. In what ways Pollution can be controlled through vegetation?
4. "Plants act as ameliorator of Environmental Quality". Discuss.
5. Suggest important plants which are pollution tolerant.

18

NATURAL DEPLETION OF VEGETATION AND ENDANGERED ECONOMIC PLANTS OF INDIA

Indian flora is very rich in diversity due to varied topography ranging from sea level to highest mountain, the long coastal line in peninsular India, desert in the west, cold desert in the north and humid tropical conditions in the eastern part of the Indian subcontinent. In the recent past the forest wealth of India is known to have depleted to a large extent both in terms of quality and quantity ultimately leading to various kinds of environmental hazards which not only deplete the biomass reserve but also degrade the land, affect the climate thus disturb ecosystem of the area. Frequent occurrence of floods and droughts are the resultant effects of deforestation which ultimately influences the human and animal populations to a great extent. Scenic beauty of mountains is fading due to destruction of forest. According to Ministry of Agriculture (1980) about 175 mha area is suffering from environmental degradation due to deforestation alone. About 90 million hectare area is badly degraded and has become completely unproductive. According to S.K. Jain (1987) out of about 15,000 species of Indian flowering plants, nearly 2,500 species are under various degrees of threat. The National Remote Sensing Agency (NRSA, 1983) has reported 16.52 per cent loss of total forest area in India during 1972 to 1982. In U.P. alone vegetation cover was 17.41 per cent in 1982 of the total geographical area.

Causes of Threat

The depletion of forest wealth is mainly due to heavy and uncontrolled biotic interference which has greatly affected natural forest environment thereby adversely influencing the wild life. Many species of tropical flora and fauna have reached near extinction and some are known to have even become extinct. For better survival of wild animals in future, it is necessary that they must be allowed to live in their own habitat.

The causes of threats to plant species may be of two types :

1. Natural
2. Artificial (Man-Made)

The natural causes responsible for endangering plants are land slides, droughts, floods, storm, earthquakes, diseases, avalanches etc. Other threats include invasion of exotic and other aggressive weeds, air, water pollution and lack of pollinators.

Man-made threats include grazing, commercial exploitation, industrialization, forestry, urbanisation, scientific and educational research, roads, dams, increasing townships, internal tourism, mining and pressure of introduced plants. Introduction and growth of weeds and pests result into reduction in vegetation of natural flora. Over exploitation of plants for commercial purpose leads to destruction of their habitat. Supply of raw material to the forest based industries is also a major cause of forest destruction in the hills. The other cause of forest destruction is due to increase in cattle population.

Conservation or Protection of Endangered Plants

Throughout the world, there is growing awareness for conservation and protection of endangered flora and fauna. *Red Data Books* on endangered animals, birds and flowering plants have been prepared by the survival service commission of the International Union for conservation of Nature and Natural Resources (IUCN). It has been estimated that out of 18,000 to 20,000 species of flowering plants in India, about 1,000 species fall into the conservation category (rare, endangered, vulnerable or depleted) and need adequate conservation. In fact, the 10th General Assembly of the IUCN held in New Delhi in 1969 had focussed attention on the urgent need to protect endangered species in Indian flora and urged to the government to bring these endangered plants into effective cultivation. Thus some of our notable plants like *Rauvolfia serpentina* (Sarpgandha), *Dioscorea deltoides, Cypripedium cordigerum* (Lady slipper orchid), *Nepenthes khasiana* (Pitcher plant) and *Rheum nobile* have been decimated and are being threatened with extinction in their original habitat. Of many valuable use of botanic gardens and their ancillary research establishment, the conservational ones are the most important, at least for the future, as human population pressures and resultant degradation of the biosphere increase. Therefore, it is proposed to set up a conservation unit to cater the needs of endemic and vanishing plant taxa in Indian flora and to prepare a baseline upon which future action plans can be prepared.

There has been some consciousness about the depletion of forests mainly due to alarming situation. The forest cover of the country especially that of U.P. is comparatively much less than recommended by the National Forest Policy Govt. of India (1952). Accordingly, vigorous afforestation and social forestry programmes have been launched to increase the tree cover. One of the important aspects of these programmes is the selection of

suitable land which can be acquired with care without changing their present land use which may otherwise lead to socio-economic problems. Therefore, the best location for afforestation programme would be the degraded or waste lands. This would not only increase the productivity of such land but would also lead to qualitative improvement of such degraded lands.

During the last decade, however, various efforts have been made to rehabilitate the forest cover through launching of afforestation programme. These can be implemented well only when the problems related to these are fully understood. It is possible to identify and map such lands where social forestry and afforestation programme can be undertaken more effectively. This would not only increase the forest area to meet ever increasing demand of timber, fuel, wood etc. but would simultaneously improve their lands. The more important aspect of these programmes is the continuous monitoring of the afforested area.

Botanical gardens and sanctuaries play a major role in the conservation and protection of endangered flora and fauna. Exchange of information of plant material would serve in preserving germplasm. Cultivation of endangered plants in botanical gardens would serve as a germplasm collection for better genetic resources for future generation. Popularization of rare and endangered plants in the agricultural field may be used to protect them from extinction. Detailed data on the Morphology and Autecology of endangered species are of immense importance for monitoring populations for successful reintroduction. Studies on germination, growth, flowering, fruiting and acclimatization of a species are also of great importance for successful cultivation. In various centres of India plant tissue culture techniques are now being adopted to preserve highly endangered plants. For reintroduction of plants, knowledge of seed germination, survival, transplanting, plantation, transportation and documentation is essential. In order to get better results of reintroduced plants for the establishment in the future, help from forest department and voluntary organizations should be taken. These steps will create and preserve endangered plants and help in the evolution of new and more useful cultivars suitable for present ecological conditions.

Recently Sunderlal Bahuguna (1981) the leader of "Chipko Andolan" has suggested following measures to protect forest :

1. All commercial green fellings should be stopped henceforth. This will serve at least 4 lac cubic metres of timber.
2. Pine trees damaged due to excessive resin collection should be given rest for ten years.
3. A massive programme for setting up biogas plants should be popularised. Night soil and other refuse of cities be utilized to produce biogas for industries.

4. Plantation of trees for food, fodder, fuel, fertilizer and fibre should be given top priority.
5. For the success of mass plantation programme, it is essential to involve people and voluntary organisations.
6. There should be coordination between all branches of forest and agriculture department and an independent "Land Use Department" should be created.
7. Adequate facilities for moisture conservation should be provided.

Other points of conservation have been suggested by various workers :

1. Preservation of regional flora should be encouraged which would highlight the rare and endangered species.
2. Conservation of natural areas and gene centres for wild plants for scientific research and teaching and for preservation of rare plants.
3. Intensive botanical survey of national parks, wild life sanctuaries and reserve forest should be undertaken.
4. Preservation for living species and other taxa found in their original habitat should be maintained.
5. Living collection of endangered, economic and rare plants should be maintained.

ENDANGERED PLANTS

In India, amongst the commercially exploited plants are many species of medicinal and economic importance in the various genera such as *Aconites, Nardostachys, Podophyllum, Commiphora, Coptis, Coscinium, Vanilla* etc., and plants of horticultural importance such as *Cycads*, tree-ferns, *Orchids* (*Vanda, Dendrobium*). Over exploitation even of some very widely growing species can also result in their rarity; examples of which are species of *Dioscorea, Rauvolfia* and *Colchicum*. Over exploitation of biologically important species such as primitive and insectivorous species also results in their rarity or loss. Examples of this category are *Gnetum, Ephedra, Psilotum, Ophioglossum* and *Pinus*.

A list of some economically and medicinally important endangered plants from Indian subcontinent is given below along with their outline information :

Rare, Endangered and Threatened Economic Plants of India

1. *Aconitum deinorrhizum* Stapf. (Ranunculaceae)
   Herb. Important aconite of medicinal value. Rare in occurrence, exploited for trade.
2. *Acorus calamus* Linn. (Araceae)
   Rhizome carminative, emetic, antispasmodic used in Dyspepsia and in chronic diarrhoea.
3. *Allium strachevi* Baker (Liliaccae)
   Leaves are medicinal and used for flavouring also.
4. *Angelica glauca* Edgew (Apiaceae)

Roots used for confusions and as blistering agent, seeds purgative.

5. *Arundina gramnifolia* (D. Don) Hochr. (Orchidaceae)
   Flowers are ornamental. Rare in occurrence.
6. *Atropa acuminate* Royle (Solanaceae)
   Used in reducing hypertension.
7. *Betula utilis,* D. Don (Betulaceae)
   Timber used for commercial purposes. Bark of the tree is sacred.
8. *Balanophora involucrata* Hk. f. (Balanophoraceae)
   Used as illumination in java.
9. *Castanopsis tribuloides* A. Dc. (Fagaceae)
   Used for timber and fodder.
10. *Colchicum luteum* Baker (Liliaceae)
    Carminative, luxative and used in Rheumatism. Rare occurrence, exploited in trade for its valuable alkaloid colchicine.
11. *Commiphora wightii* (Arn.) Bhandari (Burperacae)
    Small tree, exploited for its gum, resin from the bark. Scarce.
12. *Coptis teeta* Wall. (Ranunculaceae)
    Rhizomes are medicinal, rare occurrence, exploited in trade for its high medicinal value.
13. *Carduns nutana* Linn. (Asteraceae)
    Used as a blood purifier.
14. *Cyperipedium cordigerum* D. Don. (Orchidaceae)
    Highly ornamental, rare, threatened due to trade.
15. *C. elegans* Reichb. b. (Orchidaceae)
    Ornamental, rare occurrence, threatened due to trade.
16. *Dendrobium densiflorum* Wall. ex Lindl. (Orchidaceae)
    Highly ornamental, exploited in trade.
17. *Dioscorea deltoidea* Wall. ex Kunth (Dioscoreaceae)
    Used in washing silk, wool, dyeing etc.
18. *D. prazeri* Prain & Burkil (Dioscoreaceae)
    Used as fish poison, also to kill mouses.
19. *Dischidia rafflesiana* Wall. (Asclepediaceae)
    Roots chewed with betel to cure cough.
20. *Drosera peltata* Sm. (Droseraceae)
    Used in preparation of Gold Bhasm.
21. *Gentiana kurroo* Royle (Gentianaceae)
    Bitter tonic for improving appetite, urinary trouble. Threatened due to trade.
22. *Grewia sapida* Roxb. Dc. (Tiliaceae)
    Economically important for fibres, fodder and fuel, Exploited in trade.
23. *Lagerstroemia hypoleuca* Linn. f. (Lythraceae)
24. *Mahonia jaunserensis* Ahrendt. (Berberidaceae)

Medicinal plant, threatened due to trade.

25. *Meconopsis betonicifolia* Franchet (Papaveraceae)
Due to medicinal value exploited in trade.
26. *Nardostachys jatamansi* DC (Valerianaceae)
Used as diuretic, luxative, and in hysteria.
27. *Nepenthes khasiana* Hook. f. (Nepenthaceae)
Used in urinary trouble and catching of eyes.
28. *Nymphaea pygmaea* Ait. (Nymphaeaceae)
Root used medicinally.
29. *Papliopedilum harsutissimum* (Lindl). Pfitz. (Orchidaceae)
Flowers are ornamental, extremely rare due to indiscriminate collections from the wild state.
30. *P. venustum* (Lindl). Pfitz. (Orchidaceae)
Flowers ornamental, rare due to over exploitation from the wild state.
31. *P. villosa.* (Lindl.) Pfitz. (Orchidaceae)
Flowers ornamental, rare and threatened due to over collections.
32. *Podophyllum hexandrum* Royle (Podophyllaceae)
Purgative, as source of medicinal resins.
33. *Primula sikkimensis* Hook. f. (Primulaceae)
Used for perfumery purposes.
34. *Rauwolfia serpentina* (Linn.) Benth ex Kurx. (Apocynaceae)
Used in antihypertensive and in nervous diseases.
35. *Rheum emodi* Wall ex Neissr. (Polygonaceae)
Powdered roots used as tooth poweder and paste, used against swelling.
36. *R. nobile* Hook. f. & Thomas. (Polygonaceae)
Dry beans are used as substitute of tobacco.
37. *Rhododendron arizelum Balb.* & Farr. (Ericaceae)
Ornamental flowers.
38. *R. edgeworthii* Hook. f. (Ericaceae)
Leaves are used in fish poisoning.
39. *Santalum album* Linn. (Santalaceae)
Timber & heart wood have economic value.
40. *Saussurea lappa* clarke (Asteraceae)
Used as perfumary, cosmetics and antiseptic.

List of Rare and Endangered Himalayan Plants

TREES

1. *Aglaia perviridis* Hiern. (Meliaceae)
Local name—Thaidubriki-buphang (Assami)
Locality—Cultivated in India.
Uses—Medicinally used.
2. *Abies delavayi* Franch (Pinaceae)

Locality—Balipara Frontier Tract Mountain.

3. *Castanopsis tribuloidis* A.D. (Fagaceae)
   Local name—Chongom, Bakhalai.
   Locality—Himalayas.
   Uses—Fruits edible.
4. *Elaeocarpus prunifolius Wall.* (Elaeocarpaceae)
   Local name—Dieng-la-khmar, Diengruin (Khasi).
   Locality—Sylhet, Khasi, Jaintia Hills.
   Uses—Fruits edible.
5. *Euonymus echinatus Wall.* (Celastraceae)
   Local name—Laduli.
   Locality—In Himalayan region (Khasi & Jaintia Hill).
6. *Grewia sapida* Roxb. ex DC. (Tiliaceae)
   Local name—Phuhura (Assami).
   Locality—Assam.
   Uses—Fodder & edible fruits.
7. *Homalium schlichii* Kurz. (Somyaceae)
   Local name—Dieng-soh-mara (Khasi).
   Locality—Khasi Hills.
8. *Larix griffithiana*, Gord, Larix griffithi, Hook. f. & Thoms.
   Local name—Saar.
   Locality—*Himalayas, Eastern Nepal to Bhutan.*
   Uses—Non-medicinal.
9. *Mahonia jaunsarensis* Ahrendt. (Berberidaceae)
10. *Magnolia griffithii* Hook. f. & Thoms. (Magnoliaceae)
    Local name—Gauri-sopa, Gahorisopa (Assami).
    Locality—Common in Lakhimpur, Sibsagar and Darrang Distt.
    Uses—Not used for timber.
11. *M. gustavigustavi* (King)
    Local name—Khorokia-sopa (Assami).
    Locality—Makum Forest Lakhimpur.
12. *Magnolia pealiana* King (Magnoliaceae)
    Local name—Gahori-Sopa (Ass.).
    Locality—*Makum* Forest, Lakhimpur.
    Uses—Wood is white soft and light, fairly strong.
13. *M. pterocarpa* Roxb. (Magnoliaceae)
    Local name—Patpate.
    Locality—Himalayas to Assam.
    Uses—Wood used as fuel and tea boxes.
14. *M. pterocarpa Roxb.* (Magnoliaceae)
    Local name—Patpate.
    Locality—Himalayas to Assam.

Uses—Wood used as fuel and tea boxes.

15. *Malus baccata* Desf. (Rosaceae), *Pyrus baccata* Linn
Local name—Banmehal (Hindi).
Locality—Siberia to Manchuria & Japan, Southwards to Himalayas.
Uses—Ornamental, fruits edible.
16. *Michelia lanugiorosa Wall.* (Magnoliaceae)
Local name—Gogichamp (Nepali).
Locality—South Asia to China.
Uses—In timber, fuel and making charcoal.
17. *Palaquium polyanthum* Engl. (Sapotaceae)
Local name—Tali (Bengali).
Locality—In Garo Hills.
Uses—In carpentary work, timber.
18. *Pinus gerardiana Wall.* (Coniferae)
Local name—Chilgoza.
Locality—Upper Assam.
Uses—Edible proteinaceous kernel; commercial timber.
19. *Populus gamblei* Haines (Salicaceae)
Local name—Bahan, Bhan.
Locality—Punjab plains, Himalayas.
Uses—Plywood, boats, shoe-heels.
20. *Rhododendron arboreum* Sm. (Eriaceae)
Local name—Burans (Nepali).
Locality—Himalayas, from Kashmir to Bhutan.
Uses—Tender leaves are used as vegetable and to relieve headache.
21. *Populus euphratica* Oliv (Salicaceae)
Local name—Bahan, Bhan.
Locality—Punjab plains, Himalayas.
Uses—Plywood, boats, shoe-heels.
22. *Rhododendron edgeworthii* Hook. f. (Eriaceae)
Locality—Sikkim Himalayas (7,000–9,000 ft).
23. *Rhododendron dalhousiea* Hook. f. (Eriaceae)
Local name—Sikkim Himalayas (6,000–9,000 ft).
24. *Zanthoxylum khasianum* Hook. f. (Rutaceae)
Local name—Soh-mrit.
Locality—Khasi Hills (5,000–6,400 ft).
25. *Picea brachytila* Masters (Pinaceae)
Locality—N.E. Assam.
Uses—As timber.

HERBS

1. *Acorus calamus* Linn. (Araceae)
Local name—Bach (Hindi, Bengali).

Locality—Throughout India, 6,000 ft in the Himalayas, Kashmir & Simoor, Sikkim.

Uses—Rhizome carminative, emetic, Antispasmodic use in Dyspepsia and in chronic Diarrhoea.

2. *Alpinia galanga* S-W. (Zingiberaceae)
   Local name—Kulanjan.
   Locality—Throughout India, from the foot of Himalaya to Ceylon.
3. *Allium stracheyi* Baker (Liliaceae)
   Locality—Western Himalaya, from Kashmir at altitude 9,000 ft to Kumaon 10,000–12,000 ft.
4. *Angelica glauca* Edgew. (Umbelliferae)
   Local name—Chora.
   Locality—From Kashmir to Simla, alt. 8000–10,000 ft.
5. *Atropa acuminata* Royle (Solanaceae)
   Local name—Belladonna.
   Locality—Western Himalayas, alt. 6,000–11,000 ft from Kashmir to Simla.
   Uses—To reduce hypertension.
6. *Allium clarkei* Hk. f. (Liliaceae)
   Locality—Kashmir to Skrado, alt. 7,000–11,000 ft.
7. *A. consanguineum* Kunth (Liliaceae)
   Locality—Western Himalayas, Kashmir, alt. 8,000–10,000 ft.
8. *Allium thomsonii* Baker (Liliaceae).
   Locality—Kashmir, alt. 12,000 ft.
9. *Anemone tetrasepala* Royle (Ranunculaceae)
   Locality—Western Himalaya, Marri, Kashmir and Kistwar, alt. 8,000–11,000 ft.
10. *Aquilegia nivalis* Folc. ex Jackson (Ranunculaceae)
11. *Artemisia amygdalina* Dcne. (Compositae)
    Locality—Kashmir, Pir Panjal.
12. *Botrychium virginianum* (Sw.) (Ophioglossaceae)
    Local name—Clark's Fern.
    Uses—In dysentery and Healing of wounds.
13. *Balanophora involucrata* H.k. f. (Balanophoraceae)
    Local name—Gajpipal.
    Locality—Tropical Himalaya, Simla, alt. 6,000 ft Sikkim, 7,000–10,000 ft.
    Uses—Used as illumination in Java.
14. *B. dioica* brown (Balanophoraceae)
    Locality—Tropical and subtropical Himalaya, From Nepal to Mishmi, alt. 3,000–7,000 ft Khasia Hills 4,000–6,000 ft.

15. *Coptis teeta* Wall.
    Local name—Mamira.
    Locality—Assam.
    Uses—As Antibiotics.
16. *Colchicum luteum* Baker (Liliaceae)
    Local name—Hiran tutiya.
    Locality—Western, Temperate Himalaya Kashmir, altitude 4,000–7,000 ft.
    Uses—Carminative, Laxative, Rheumatism.
17. *Cyathea gigantia* Halltt. (Cyatheaceae), afrn.
18. *Cardus nutans* Linn. (Compositae)
    Local name—Kanchari.
    Locality—Western Himalaya.
    Uses—Blood purifier.
19. *Dioscorea prazeri* Prain & Burkill
    Locality—Assam.
    Uses—To kill mouses and as fish poison.
20. *D. deltoidea* Wall ex Kunth (Dioscoreaceae)
    Locality—Assam.
    Uses—To kill mouses and fish posion.
21. *Drosera peltata* Sm. (Droseraceae)
    Local name—Mukhjali.
    Locality—Throughout India.
    Uses—In preparation of Gold Bhasm.
22. *Dischidia rafflesiana* Wall. (Asclepiadaceae)
    Local name—Hankhao jharmona (Assami).
    Uses—Roots chewed with betel to cure cough.
23. *Dianthus cachemiricus* Edge (Caryophyllaceae)
    Locality—Kashmir.
24. *Dicentra roylei* Hook. f. & Thoms. (Fumariaceae)
    Locality—Temperate Himalaya, alt. 5,000–6,000 ft. Simla Khasi Hills.
25. *Gentiana kurroo* Royle (Gentianaceae)
    Local name—Kutki.
    Locality—Kashmir & N-W. Himalaya.
    Uses—Bitter tonic for improving appetite, Urinary trouble.
26. *Helminthostachys zeylanica* Linn. Fern. (Ophioglossaceae)
    Local name—Kamraj.
    Locality—Eastern part of India.
    Uses—In toxication, in Sciatica & in cough.
27. *Iris aurea* Lindl (Iridaceae)
    Locality—Western Himalaya.
28. *I. gilgitensis* Baker (Iridaceae)

Locality—Western Tibet, alt. 12,000 ft.

29. *Impatiens acuminata* Benth (Balsaminaceae)
    Locality—In West rocks in the Khasia, alt. 4,000–5,000 ft.
30. *I. bella Hk.* f. & Thoms. (Balsaminaceae)
    Locality—In marshes in the Khasia, 4.6000 ft.
31. *I. fimbriata* Hook. (Balsaminaceae)
    Locality—In marshes in the Khasia, 4,6000 ft.
32. *I. paludosa* Hk. f. (Balsaminaceae)
    Locality—Khasia, 5,000–6,000 ft.
33. *Meconopsis betonicifolia* Franch (Papaveraceae)
    Locality—Himalayan region.
34. *Nardostachys jatamansi* DC. (Valerianaceae)
    Local name—Jatamansi.
    Locality—Eastern & Western Himalaya.
    Uses—Spasmodic, Diuretic, Luxative, in hysteria.
35. *Nepenthes khasiana* Hk. f. (Nepenthaceae)
    Local name—Ghatparni.
    Locality—Khasia, Garo Hills.
    Uses—In Urinary trouble, etching of eyes.
36. *Nymphaea pygmaea* Ait (Nymphaeaceae).
37. *Osmunda regalis* Linn. (Osmundaceae)
    Locality—Khasi Hills, Eastern Ghats.
    Uses—In Intestinal grip, Rheumatism, Dysentery.
38. *Podophyllum hexandrum* Royle (Podophyllaceae)
    Local name—Bhavanbakara.
    Locality—Himalayan, from Kashmir to Sikkim.
    Uses—Purgative, Source of Medicinal Resin.
39. *Potentilla clarkei* Hk. f. (Rosaceae)
    Local name—Cinquiefoils.
    Locality—Kashmir, Sirimiggur, alt. 7,000 ft.
40. *P. curviseta* Hk. f. (Rosaceae)
    Locality—Kashmir, alt. 12,000 ft.
41. *Primula sikkimensis* Hk. f. & P. Repenta Hk. f. (Primulaceae)
    Locality—Temperate region of Himalaya.
    Uses—Delicious perfume.
42. *Rauwolfia serpentina* Benth & Kurz. (Apocynaceae)
    Local name—Sharpagandha, Chandrika.
    Locality—In Himalayas, Sikkim.
    Uses—Antihypertensive, and in nervous disorder.
43. *R. tetraphylla* Linn. (Apocynaceae)

Local name—Bara chandrika.
Locality—Western India, U.P.
Uses—Poisonous, inc pain mouth & in burning sensation of Stomach.

44. *Rheum nobile* Hk. f. & Thoms. (Polygonaceae)
Local name—Tchuka.
Locality—Himalaya from Nepal to Bhutan.
Uses—Dry beans are used as substitute of tobacco.
45. *R. emodi* Wall. ex Meissn. (Polygonaceae)
Local name—Gandhini (Sankrit).
Locality—In Himalaya region.
Uses—Powdered roots as tooth powder.
46. *Saussurea obvallata* Wall. (Compositae)
Local name—Brahma Kamal.
Locality—Himalaya from Kashmir.
47. *S. bracteata* Done (Compositae)
Locality—Eastern Tibet, North Kumaon.
48. *Saussurea gynaphaloides* Sch.–Bip (Compositae) (Royle, Sch. Bip).
49. *S. clarkei* Hook. f. (Compositae)
Locality—Kashmir.
50. *S. elliptica* Ck. (Compositae)
Locality—Eastern Tibet, Karakoram, alt. 14,000 ft.
51. *S. glandulifera* Schultz. (Compositae)
Locality—Eastern, Tibet, Ladakh alt. 14,000–16,000 ft.
52. *S. chultzii* Hook. f. (Compositae)
Locality—Western Tibet from North Kashmir to Karakoram alt. 14,000–17,000 ft.
53. *S. lappa* C.B. Clarke (Compositaeae)
Local name—Kuthkur, Pachak.
Locality—Valley of Kashmir.
Uses—In Perfumery, Cosmetic, Antiseptic.
54. *Swertia thomsonii* Cl. (Gentianaceae)
Locality—Eastern Himalaya, Kashmir nuttalli (C.B. Clarke) Sleum.
55. *Vaccinium nuttallii* Sleumer nuttallii (C.B. Clarke) Sleum.
56. *Viola falconeri* Hook. f. & Thoms. (Violaceae).
Locality—Kashmir.
57. *Senecio jocquemontianus* Benth (Compositae)
Local name—Hatermul Poshkar.
Locality—Western Himalaya.
Uses—Roots in skin diseases.

58. *Salvia hians* Royle (Malvaceae)
    Locality—Kashmir to Himalaya region.
    Uses—Essential oils is extracted.
59. *Psilotum nudum* Beauv. (Psilotaceae)
    Locality—In moist shady places throughout India.
    Uses—Purgative, in diarrhoea, antibiotic.

QUESTIONS

1. What do you know about Natural depletion of vegetation?
2. How will you protect endangered and threatened plants?
3. What are causes of disappearance of plants? How will you conserve threatened plants?
4. Write brief notes on :
   (*i*) Social Forestry
   (*ii*) Red Data Book
   (*iii*) "Chipko Andolan"

19

BIODIVERSITY

Biological diversity or Biodiversity refers to the variability among the living organisms; plants, animals and microbes from all sources including terrestrial and aquatic ecosystems and ecological complexes of which they are part. In brief, it refers to the variabilities within species, among the species of plants, animals and micro-organisms; ecosystems and the ecological complexes on the earth. Biodiversity is the assemblage of different life-forms. It can also be defined as the number of different organisms and their relative frequency in an ecological system. For biological diversity, the organisation of organisms are considered at many levels ranging from complete ecosystems to the chemical components that form the molecular basis of heredity. Thus the term biodiversity includes variability of genes, varieties, species, population in different ecosystems and their relative abundance.

It has been estimated that more than 50 million species of plants, animals and micro-organisms are existing in the world. Out of these, about two million organisms have been identified so far. Scientists are also aware of the immense potentials of various life-forms existing on the earth. Our planet's requirements and services depend mainly on the biological resources. Biological resources not only provide us nourishment, clothing, housing, fuel and medicine but also meet our several other requirements. Therefore the knowledge of biodiversity is of immense utility in planning sustainable livelihood and conserving the natural resources.

Significance of Biodiversity

Biodiversity, besides its ecological significance provides a socio-economic and monetary asset to the nation. Human society depends on biological resources, their diversity and the ecosystems that sustain them provide essential goods and services. Values related to biodiversity can be grouped into three categories as below :

Productive use. This is assigned to products that are commercially harvested for exchange in formal markets and is, therefore, the only value of biological resources that is concerned in national income. Biodiversity provides us many products, such as fuel, timber, fish, fodder, skin, fruits, cereals and medicinal plants. In 1994-95 the income from

agriculture, forestry and fisheries in India was nearly 30 per cent or 736.88 billion rupees.

Consumptive use. Consumption value is related to natural products that are consumed directly, *i.e.*, the goods which do not come under normal circulation of trade. For example, a significant number of such non-timber forest products as soft broom grass and cane come under this category.

Indirect use. Indirect use of biodiversity is of much significance because this value is related primarily with functions of ecosystem and is concerned with national accounting systems. They may provide us indirect benefits as non-consumptive values. Maintenance of ecological balance, conservation of natural resources and prevention of soil erosion may be considered as the examples of indirect use of biodiversity.

Types of Biodiversity

Biodiversity or Biological diversity is of two types :

1. *Ecological diversity or species diversity.* It refers to the variability among the living organisms in different ecosystems or ecological complexes and includes variability within the species and variability among the species of plants, animals and micro-organisms. In other words, it pertains to richness of species of flora and fauna and micro-organisms in an ecosystem or biotic community.

2. *Genetic diversity.* Genetic diversity pertains to range of diversity in plant and animal genetic resources. It includes diversity among individuals of a species as well as variability among the species.

On the earth there are about 30 million insects; 15,210 mammals, reptiles and amphibians; 9,225 birds; 21,000 fishes; 3 million invertebrates and micro-organisms and 4,80,000 plants. Many among them have not been identified. For example, out of 30 million insects, only 7,51,000 have been identified. Similarly 3,22,311 out of 4,80,000 plants have been identified. Table 19.1 gives an idea about the flora and fauna which have been identified.

Table 19.1. The number of species of plants and animals

Organisms	*Total number of species*	*Identified number*
Mammals, reptiles and amphibians	15,210	14,484
Birds	9,225	9,040
Fishes	21,000	19,056
Plants	4,80,000	3,22,311
Microbes and invertebrates	3,00,000	2,76,594
Total	33,525,435	1,392,485

Biodiversity of India

Varying physiographic features at different places have resulted in almost all sorts of ecological conditions in India. Indian flora and fauna present very rich biodiversity. Varied physiographic and climatic conditions in

different parts of India have resulted in a high level of biodiversity in the country from sea level to the highest mountain ranges in the world, the long coastal line (7500 km long with a shelf zone of over 43 m and exclusive economic zone of over 210 m), hot arid conditions in the west, cold desert conditions in the north and humid tropical conditions in other parts of the country. Thus, India, with a geographical area of 329 million hectare has almost all the ecological zones found in the world. By virtue of being a meeting ground for three major global biogeographic region : (*i*) Indo Malayan (*ii*) Eurasian and (*iii*) Afrotropical, India is one of the twelve major or mega diversity centres in the world. It also has two of the 18 recognized biodiversity "hot spots" in the world—Eastern Himalayas and Western Ghats. "Hot spots" are areas that are usually very rich in species, most of which are endemic and are under constant threat of being overexploited. Their floral wealth is very rich.

India is very rich in all aspects of biodiversity and in one of the most significant biodiversity centres of the world. About 48,000 species of plants which represent 11 per cent of the total world flora and 81,000 species of animals representing 6.4 per cent of the world's fauna are found in India. India's floral diversity includes over 64 species of Gymnosperms; 1,022 species of Pteridophytes; 2843 of Bryophytes; 1940 species of lichens; 13,000 species of fungi and 12,281 species of Algae. Similarly, the faunal diversity of our country includes 5,000 species of Molluscs; 57,000 species of insects; 2546 species of fishes; 204 species of Amphibians; 420 species of Reptiles; 12,281 species of Aves (birds) and 372 species of Mammals. According to an estimate 35 per cent of the flowering plants and 18 per cent of the total flora are endemic to India. The endemism among the animals is high and it may be as high as 62 per cent in case of Amphibia. Biologically rich areas of India are either unexplored or under-explored. Thus recorded biological diversity of India may be only a part of the actually existing biological wealth. Besides, the present knowledge about the diversity in micro-organisms, wet land flora and fauna and marine life is scanty and the major gap in our knowledge still persists. The knowledge of diversity in plant and animal genetic resources will provide a sound basis for generating additional resources for conservation and sustainable use.

The Indian subcontinent commonly known as "Hindustan Centre" is one of the Twelve centres of origin and diversity of crop plants which alone has given to the world nearly 167 species of domesticated agri-horticultural crop plants. Over 320 species of wild progenitors of these domesticated crop plants are native to this country. The important crop plants are : rice, sugarcane, millets, brassica, Asiatic vignas, egg plant, banana, citrus, mango, jack fruit, jute, black pepper, cardamom, turmeric, ginger, several umbellifers, cucurbits, colocasia and many herbal drugs as jasmine, rhododendron, some orchids, betal nut and bamboos.

The rich germplasm reserve of Indian subcontinent includes 51 species of cereals and millets, 104 species of fruits, 27 species of spices and condiments, 55 species of vegetables and pulses, 24 species of fibre crops, 12 species of oilseeds and various strains of wild tea, coffee, tobacco and sugar cane. Besides above, 1,000 species of plants are of ethnobotanical interest (Plants used by tribal population) and 2,000 species are used in various traditional systems of medicine. Further diversity has been increased through genetic engineering technology by transferring genes in the species which enhance agricultural productivity.

India's indigenous livestock diversity includes about 27 breeds of cattles, 40 breeds of sheep, 22 of goats, 8 of camels, 6 of horses, 2 of donkeys and 18 types of poultry. Eight indigenous breeds of buffalo in India represent the entire range of its genetic diversity on the earth. These prized plants and animals together with their ancestral wild forms are used by plant and animal breeders for the development of improved varieties.

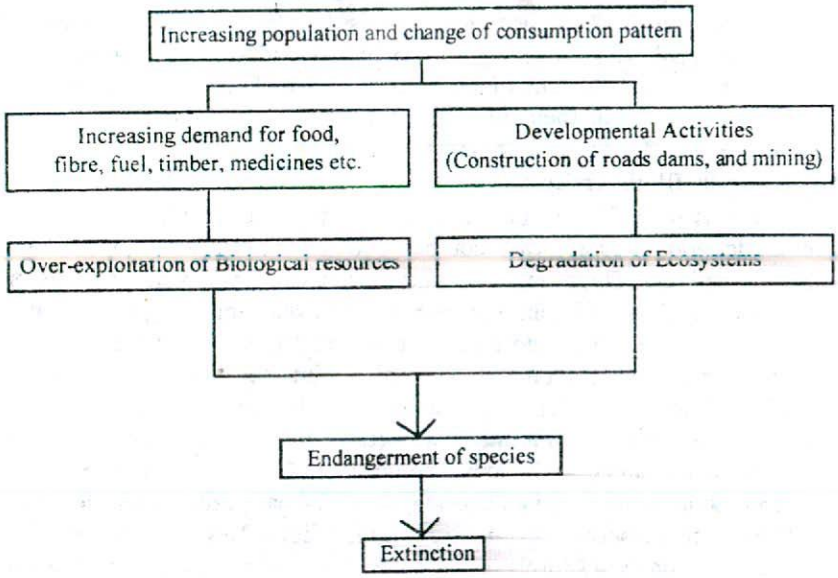
Depletion of Biodiversity

The loss of biological diversity is mainly due to habitat destruction, over-exploitation of biological resources, pollution and introduction of exotic plants and animals. There are many other reason also for significant depletion of biodiversity. Prominent among them are the expansion of agriculture and industries, urbanisation, road construction and large scale developmental projects. Excessive and uncontrolled biotic interference also results in depletion of biodiversity. The introduction of exotic species has also affected qualitative as well as quantitative changes in India's biodiversity. These activities have resulted in the extinction of over 23 wild species from both flora and fauna of India. Indian cheetah, the pink headed duck and Mountain quail have already become extinct from Indian fauna. Besides these, several species of mammals, 47 forms of birds, 15 species of reptiles, 3 amphibians and a large number of butterflies, moths, beetles are facing danger of extinction. Similarly over 1500 species of vascular plants are considered to be endangered. The threat to their survival is also affected by illegal trade of various endangered plant and animal species and introduction and expansion of selected "high yielding varieties" (HYV) of crops and livestocks. Many wild-wild strains of rice, millets, oil seeds, vegetables and legumes have disappeared, while several indigenous breeds of domesticated animals such as three cattle, five sheep, five camels, four horses and all varieties of poultry are endangered. Thus the major genetic bases of these plants and animals which could have served as germplasm banks for desired plants and animals have been destroyed.

The factors responsible for the loss of biodiversity may be natural or artificial. The natural causes include drought, land slides, flood, storm, earthquakes, diseases etc. The artificial causes include grazing, industrialization, urbanisation, scientific and educational research, road and dam construction all leading to destruction of habitat and over-exploitation

of plants and animals for commercial purposes. Besides these, improper agricultural practices, indiscriminate exploitation of natural resources, fragmented population of species and introduction of alien species, have all led to both quantitative as well as qualitative loss of biodiversity.

At global level, the impacts of environmental pollution, particularly the thining of ozone layer, acid rains and global warming etc. are bound to affect biodiversity adversely. Rapid destruction of forest vegetation is the main reason for loss of biodiversity on land. Causes of loss of biodiversity can be depicted in the following chart :



Conservation of Biological Diversity

Man has been directly or indirectly, dependent on biodiversity for sustenance to a considerable extent. Increasing population, pressure, urbanization and industrialization, however, have led depletion of the natural resources. The immediate task before the country is not only to manage and conserve the existing natural resources and ecosystems but also the restoration of degraded ecosystems through cooperation and support of people. Conservation of biowealth and genetic resources is essential for providing security of food to the nation. The best way is to concentrate on conservation of phytodiversity which will automatically take care of animal and microbial diversity because most of the plants provide food, shelter and congenial habitat to a large number of animals and microbes.

Taxonomic study of the components of any ecosystem is essential not only for understanding and assessing the richness of biodiversity but also for the conservation of biodiversity. Biological diversity is to be preserved to achieve sustainable development.

Conservation of biodiversity is of two types :

1. *In-situ* conservation
2. *Ex-situ* conservation

In-situ conservation. In situ conservation measures are related to the biodiversity of the ecosystems of the original habitats or natural environment. It is the best, easiest, most advantageous and most feasible method to conserve natural biodiversity which aims at :

1. Consolidating the network of protected areas for wild life to ensure the conservation of ecosystems and biogeographic units.
2. Establishing new protected areas based on utility, distinctiveness and endangerment of species.
3. Coordinating new and existing protected areas to facilitate gene flow and migration among populations and to ensure proper representation of species and habitats.
4. Ensuring conservation of biodiversity and rich ecosystems outside the network of protected areas.
5. Minimising or banning the activities like over-exploitation, pollution, poisoning and introduction of exotic species leading to loss of biodiversity including habitat destruction.
6. Encouraging continuous and traditional agricultural practices.
7. Encouraging public participation in planning and management of protected areas.
8. Enhancing the ecological and social value of protected areas and providing incentives for biodiversity conservation on adjacent private lands.
9. Initiating regional cooperation for conservation of ecosystems and species.
10. Conducting periodical reviews of protected areas and plan for assessing present and future needs.

Ex-situ conservation. Sometimes the populations of species may decline or may become extinct due to genetic or environmental factors such as genetic drift, inbreeding, demographic and environmental variations, habitat loss, deteriorating habitat quality, competition with exotic species, diseases and over-exploitation. In such cases In-situ conservation may not proves to be effective and a species can be protected from becoming extinct only through maintaining individuals in artificial conditions under human care and protection. Such measures are included under *Ex-situ* or *Off-situ* conservation. Examples of *Ex-situ* conservation are zoos, sport forms, aquaria, botanical gardens, parks, arboreta, genes, gametes, embryo, seed banks, captive breeding programme, etc.

The following *Ex-situ* steps have been suggested to restore and conserve biodiversity.

1. Strengthening the capacity of *Off-situ conservation* to facilitate biodiversity conservation, public education and sustainable development.

2. Encouraging the establishment of seed or gene bank of endangered species.
3. Strengthening the facilities for conservation of crop and livestock genetic resources.
4. Collection and maintenance of microbial cultures.
5. Developing cooperation between *In-situ* and *Ex-situ* conservation, habitat restoration and habitat rehablitation.
6. Encouraging captive farming and breeding facilities for highly exploited areas of biological resources.
7. Establishment of captive farming and breeding facilities, zoo, aquaria, botanical gardens, national parks, biosphere reserves etc.
8. Initiating legal action against damage of biodiversity.
9. Developing long-term and short-term action plans for diversity conservation and sustainable use.
10. Emphasising the role of women in the conservation and sustainable utilization of biodiversity.
11. Preparation and enactment of National Biodiversity Acts with provision for preservation of biodiversity.
12. Creating an international fund for biodiversity conservation.
13. Development of Database on biodiversity.

Proposed Mechanism for Monitoring Conservation and Utilization of Biological Resources

A model for monitoring conservation and utilization of biological resources have been proposed. In this model it is suggested to set up conservation and utilization board which should have the powers to regulate a National Biodiversity fund. The biodiversity monitoring and conservation efforts should be initiated at the grass-root level and involve people, students, teachers and scientists. The information generated may be stored and documented at several levels involving villages, talukas, districts and states. Finally the Information may be passed on to a National Biodiversity Resources and Information Data bank. The resources and information can be assessed by multinational companies and National industrial houses for a fee, which becomes a part of the National Biodiversity Fund. However, biological resources and information should be made available to the National Research and Development (R and D) establishment free of charge, with an understanding that any outcome or product of these resources and information will be National property.

Present Information on Biodiversity

At present regional, National and International institutes are working on collection and compilation of information and research activities on biodiversity. Botanical Survey of India (BSI), Zoological Survey of India

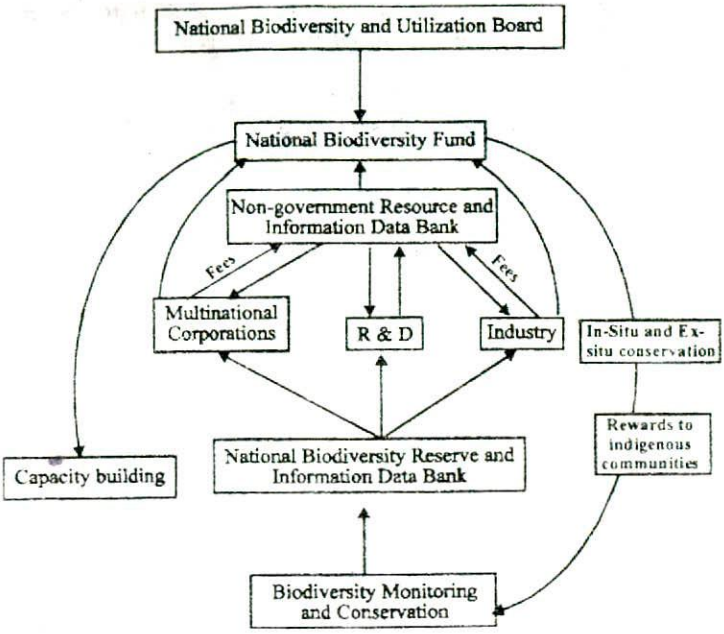


Fig. 19.1 Proposed Model for Sustainable utilization of Biological Resources

(ZSI), Forest Survey of India (FSI), Indian Council of Forestry Research and Education (ICFRE), Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR) laboratories, such as National Botanical Research Institute (NBRI), Lucknow, Central Drug Research Institute (CDRI), Lucknow, Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow and various regional research laboratories are prominent. Other centres are G.B. Pant Institute of Himalayan Environment and Development (GBPIHED), Wild Life Institute of India (WII), World Widelife Fund for Nature (WWFN), Institute of Ethnobotany (IOE) and various educational institutes and universities. These institutes are engaged on different lines as data collection, survey, documentation of floral and faunal diversity, identification of endangered plants and animals, habitats survey of National Resources, use of Remote Sensing Techniques for mapping and assessment of bioresources and Monitoring of changes in biodiversity in different ecosystems. More attention is needed for transfer of the informations to the agencies implementing conservation of genetic resources.

India has already established a network of protected areas measuring 1,40,675 sq km which account for 4 per cent of the geographic area of the land. The existing protected area consists of 95 National Parks, 421 Sanctuaries. These are to be further expanded to 148 National Parks and

503 Sanctuaries. Besides these, 21 wetlands, 15 Mangroves and 4 Coral Reef areas have also been identified for conservation.

QUESTIONS

1. What is Biodiversity? Describe different types of Biodiversity.
2. What are different causes of loss (depletion) of Biodiversity? In what ways it can be checked?
3. Write brief notes on the following :
   (*i*) Ex-situ and In-situ conservation.
   (*ii*) Genetic and Ecological Biodiversity.
   (*iii*) Present information on Biodiversity.

SOIL SCIENCE

20

THE SOIL

The word soil is derived from a Latin word *'solum'* meaning earthy material in which plants grow. The study of soil is known as *Soil science* or *Pedology* (pedos = earth) or *Edaphology* (edaphos = soil). The study of soil is important in many respects. Soil is natural habitat for plants and animals. It provides water and nutrients to the living organisms. Knowledge of soil is helpful in agricultural practices, such as cultivation, irrigation, artificial drainage and use of fertilizers. It is also important from geological, petrological, mineralogical and paleobotanical points of view.

The earth is, more or less, spherical and its surface is highly irregular, marked by deep oceans, high mountain ranges and plains in between. The internal composition of earth is not known exactly. According to a generally accepted interpretation, the earth has three zones, viz., core, mantle and crust (Fig. 20.1). The core is the central fluid or vapourised sphere having diameter of about 2,500 kms from the centre and is possibly composed of nickel-iron (Urey, 1952). The mantle extends about 2,900 kms above the core. This is in molten state. The outermost solid zone of the earth is called crust which is about 8 to 40 kms above the mantle. The crust is very complex. We live on its surface. Soil developed from the pre-existing rocks, the regolith of the crust. Here soil means the *loose, friable, unconsolidated top layer of the earth crust.* The soil is differentiated into several layers or horizons which can be distinguished from one another by their colours, textures and other characteristics. It contains water, gases, complex minerals, organic substances and micro-organisms. The dead remains of plants and animals are degraded by micro-organisms and after degradation a number of organic substances, generally called humus, are contributed to the soil. The mineral component of the soil is derived from the rocks.

Definition of Soil

Soil may be defined as "the part of earth crust in which humus is present".

According to R.F. Daubenmire, "soil is the upper part of earth crust in which plants are anchored." He defines soil as weathered superficial layer

of earth crust with which are mingled living organisms and products of their decay.

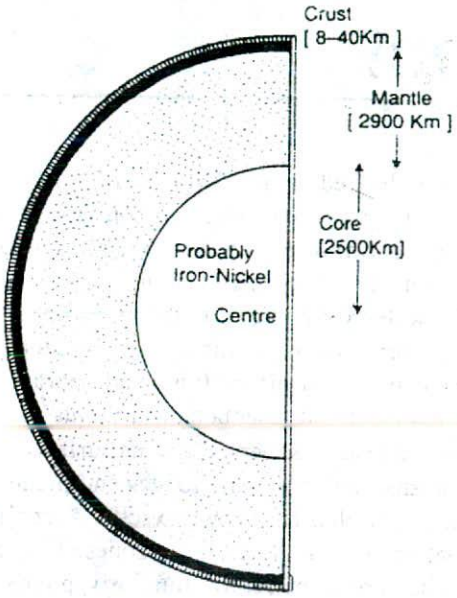


Fig. 20.1. Diagram of the supposed cross section of the earth.

According to Hilgard, 1917 (American school), "it is, more or less, loose, friable material in which, by means of their roots, plants may or do find a foothold, nourishment as well as other conditions of growth."

According to Raman, 1928 (German school), "soil is the upper weathering layer (*i.e.*, layer subjected to physical and chemical changes) of the solid earth crust."

Joffe and Marbut, two well-known American soil scientists, have defined soil in the following way : "soil is a natural body developed by natural forces acting on natural materials. It is usually differentiated into horizons of minerals and organic constituents of variable depths which differ from the parent materials in morphology, physical constitutions, chemical properties, composition and biological characteristics."

According to Russian school, "soil is natural body differentiated into horizons of usually unconsolidated minerals and organic constituents of variable depths."

According to Wadia (1945), "soil is the topmost layer of earth crust capping the rock." It is natural body of variable thickness, composed of disintegrated rock materials together with variable proportions of organic

matters, generally differentiated into zones or layers and mostly unconsolidated.

In brief, soil can be defined as that region on the earth surface where geology and biology meet each other.

Components of Soil

The soil is made up of the following components :

(1) Mineral particles,
(2) Dead organic matter or humus,
(3) Soil atmosphere,
(4) Soil water, and
(5) Biological system or soil micro-organisms.

1. Mineral Components

The mineral constituents of the soil are derived from the parental rocks or regolith. They may be found in the form of particles of different sizes; from clay (.0002 mm or less in diam) to large pebbles and gravels. The minerals represent about 90% of the total weight of the soil. Important elements which are found in compound state are Oxygen, Si, Fe, Al, N, P, K, Ca, Mg, C, H, etc. In soil, nitrogen comes from atmosphere in the form of nitrogen salts.

2. Organic Matter or Humus

Besides inorganic minerals, some organic residues derived either from dead remains of plants and animals or through metabolic activities of living organisms are present in the soil. When the plants and animals die, their dead remains are acted upon by a number of microorganisms and are finally degraded or decomposed into simple organic compounds. A product of this microbial decomposition is **humus** which is a dark coloured, jelly-like amorphous substance, composed of residual organic matters not readily decomposed by soil microoganisms. The process of humus formation is called **humification**. The chief elements found in humus are carbon, hydrogen, oxygen, sulphur and nitrogen. The important compounds found in it (humus) are carbohydrates, phosphoric acid, some organic acids, fats, resins, urea, etc. Tree litter (very little decomposed dead matter) also contains some inorganic substances as lime, potash, Mn, Mg, silica, Cu, Al, Ca, Na, K, etc. Humus is a dynamic product and is constantly changing because of its oxidation, reduction and hydrolysis. Hence, it has no definite chemical composition. It has much carbon content and less nitrogen.

Humus is not soluble in water. It is present in soil in the form of organic colloids. The amounts of humus in different soils vary greatly. Humus percentage in the soil is affected by climatic and biological factors. It is less in arid soils and very high in humid soils. In the top layer of the soil, humus quantity is greater than in the deep layers. In dark humid areas which are thickly covered with vegetation, the humus may be found in the following three stages of degradation :

(*i*) The top floor is covered with dead organic parts showing low degree of decomposition. These poorly decayed dead parts of plants form *litter*. (Fig. 20.2).

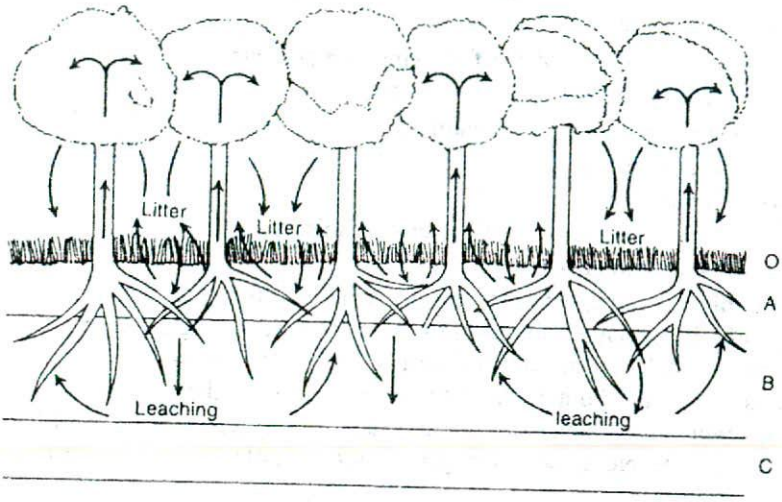


Fig. 20.2. Litter covering the floor of the forest.

(*ii*) Below the litter may be found a layer of partially decomposed organic matter which is known as *duff layer*.

(*iii*) When the duff is decomposed completely into organic substances, the decomposition products, generally called *leaf moulds*, are accumulated below duff layer.

Sometimes under anaerobic conditions, the dead remains are not at all acted upon by the microorganisms. Accumulation of such undecomposed organic remains is termed as *peat*.

Humus plays many important roles in the soil, such as :

(*a*) It makes the soil fertile.

(*b*) It provides nutrients to the plants and microorganisms.

(*c*) On complete decomposition, it forms several organic acids which serve as solvents for soil materials. Thus humus increases the availability of minerals in dissolved state to plants.

(*d*) Because it is porus, it has got high capacity for retaining water.

(*e*) Humus makes the soil porous, thus increases the aeration and percolation which make the soil more suitable for the plant growth.

(*f*) It also acts as weak cement thus binds the sand particles.

(*g*) Presence of humus in the soil increases the rate of absorption in plants.

The factors which influence the rate of humifications are outlined below :

(*i*) Nature of plants, animals or soil organisms.
(*ii*) Rate of decomposition.
(*iii*) Temperature (increase in temperature upto a certain limit increases the rate of humification).
(*iv*) Aeration and moisture. These *increase* the rate of humification.

3. Soil Atmosphere

Gases found in soil profiles are said to form the soil atmosphere which is one of the most important components of the soil. The spaces between soil particles and soil organisms are called *pore spaces*. These are filled with moisture and air in varying quantities which account for approximately half of the total volume of soil. In dry soils, percentage of moisture is lesser than that in wet soils.

The soil atmosphere contains three main gases, namely oxygen, carbon dioxide and nitrogen. In soil atmosphere, oxygen is 20%, nitrogen is approximately 79 per cent and carbon dioxide is 0.15 to 0.65 per cent by volume. In the cultivated land, percentage of CO_2 is much higher than that of atmospheric CO_2, but oxygen content in such soil is poorer than the percentage of oxygen in atmospheric air. Oxygen of soil is absorbed by plant roots and soil microorganisms in respiration and CO_2 is given out which accumulates in spaces. The amount of CO_2 increases with the increase in depth of the soil due to decomposition of accumulated organic matter and abundance of plant roots. Heavy accumulation of CO_2 in the soil is harmful for the plant growth. Presence of oxygen in the soil is important in the sense that it helps in the process of break down of insoluble rocky mass into soluble minerals and also in the humification (a process in which insoluble minerals and organic nutrients locked up in the dead remains of plants and animals are converted into soluble forms). The accumulation of soluble nutrients in the soil makes it more productive. If the soil is deficient in oxygen, the rates of microbial activities are slowed down and may be eliminated. Under such conditions, several undesirable processes, such as evolution of nitrogen, methane, accumulation of sulphides, ferrous, manganous ions and organic inhibitors, and so many other processes may come into play which may be injurious to the plants.

The important factors which bring about changes in the soil atmosphere are temperature, atmospheric pressure, wind and rainfall. Temperature and atmospheric pressure cause expansion and contraction of the soil air. Wind helps the soil in sucking the air in and rain water displaces the soil air. Any considerable change in the soil atmosphere affects the size and function of microflora and other biological populations.

4. Soil Water

Soil water plays very important role in the plant growth. Plants absorb a small quantity of rain water and dew directly from their surfaces but most of water absorbed by them comes from the soil.

Soil water maintains the soil texture, arrangement and compactness of soil particles. It is good solvent for minerals and it makes the concentration of nutrients low so that nutrients may be absorbed by plants easily. Water affects the plant growth and other physiological activities. In plant growth, water forms a major part of the plant itself. It is essential for the process of photosynthesis, it maintains the turgidity of the plants and acts as a medium by which mineral salts essential for plant growth enter the plants from the soil. In brief, water regulates the physical, chemical and biological activities in the soil.

Water in the soil comes mainly through infiltration of precipitated water (rain, sleet, snow and hail) and irrigation whereas it is lost from the soil chiefly through evaporation, percolation, stream flow and transpiration.

The quantity of water available in the soil varies from place to place. The amount also depends upon the quality of soil. In loamy, silty and clay soils, the amount of water is greater than that in coarse sandy soil. Water is held in the soil in the following forms :

(*i*) Gravitation water,
(*ii*) Capillary water,
(*iii*) Hygroscopic water,
(*iv*) Water vapour, and
(*v*) Combined water.

(*i*) **Gravitational water.** After complete water saturation of soils the excess water displaces air from the pore spaces between soil particles and percolates downwardly under gravitation influence and finally it is accumulated in the pore spaces. This excess water is called *gravitational water*. The amount of water held in the soil, when all pores are filled and when drainage is restricted, is ***maximum water holding capacity***.

When the gravitational water percolates down and reaches to the level of parental rock it is called *ground water*.

(*ii*) **Capillary water.** The amount of water present around the soil particles at saturation stage, when gravitational water has drained away through capillaries or channels, is called *capillary capacity* or *field capacity* and the water which is held by surface tension and attraction force of water molecules as thin film around soil particles in the capillary spaces is called *capillary water*. It moves in the direction where capillary tension is more.

(*iii*) **Hygroscopic water.** Water which is adsorbed on the soil particles and held on the surface of soil particles by forces of attraction and cohesion of its molecules is called hygroscopic water.

(*iv*) **Water vapour.** This is the water present in the soil atmosphere in the vapour form.

(*v*) **Combined water.** It is water of chemical compounds held by chemical forces of molecules (as for example, $CuSO_4.5H_2O$). It can be driven out from the compounds only at bright red heating.

Water requirement of plants varies from individual to individual. Some absorb large quantity, while some others require very small quantities of water for their normal growth. A major fraction of total water absorbed from the soil is transpired by the plants and only a small quantity of it enters the composition of protoplast. The availability of soil water to plants depends primarily on its diffusion pressure deficit, often termed the *soil moisture stress*. The total of all the forces which the plants must overcome to take up water from soil is called *soil moisture stress*.

Water lost from the soil surface by evaporation and through absorption by plants is replaced by rise of capillary water from root zone. The continuous loss of water may finally result in a stage at which water content of the soil becomes so poor as it (soil) cannot supply water to growing plants rapidly enough to maintain them turgid. Under such conditions, permanent wilting occurs in the plants. At permanent wilting stage, the percentage of moisture in the soil is termed as *wilting coefficient* or *permanent wilting percentage* (Fig. 20.3 C, G).

The difference between field capacity and wilting coefficient is termed as **maximum available water** and the water content of the soil at any time over and above the wilting coefficient is referred to as *available water*. The amount of water to be added to a soil at the wilting point to reach the field capacity is called the *available water capacity*. It need not be emphasized here that the actual moisture content of a soil has little meaning in respect to plant growth unless (*i*) the field capacity and (*ii*) the permanent wilting percentage of the soil are also known. Water contents above field capacity displace so much of the soil air that the plant roots usually suffer from inadequate aeration and serve to be detrimental. Although plants usually continue to absorb water in the soil drier than at permanent wilting stage, absorption is too slow to replace water losses and the resulting water deficit causes cessation of growth and finally results in death from dehydration.

The moisture at the field capacity is held with a force of one-third atmosphere and that at permanent wilting stage is held with a force of 1.5 atmosphere.

5. Biological System of the Soil or Soil Microorganisms

Organisms present in the soils are called soil organisms. Important group of soil organisms are given below (Fig. 20.4).

Soil Flora

1. Bacteria
2. Soil fungi
3. Soil actinomycetes
4. Algae
5. Root, rhizoid and rhizome bearing higher plants.

Soil Fauna

1. Protozoa
2. Nematodes
3. Insects and mites
4. Rodents and earthworms
5. Burrowing vertebrates

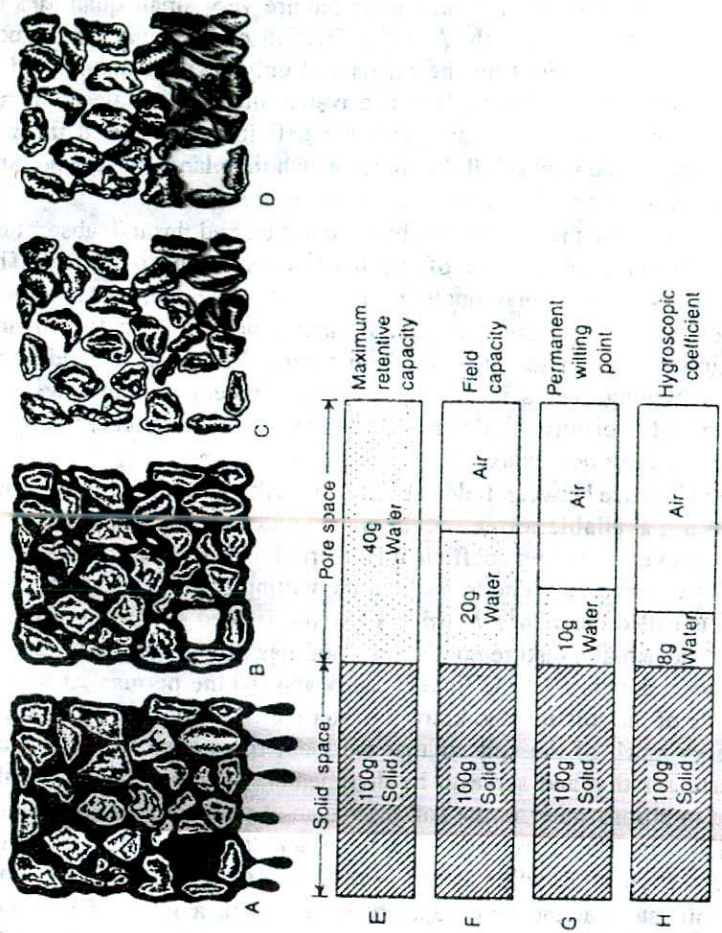


Fig. 20.3. Illustrations of the water contents of a soil show it at saturation (A, E), at field capacity (B, F), at its permanent wilting point (C, G), and in a state of extreme desiccation, the hygroscopic coefficient (D, H).

Many of these soil organisms are stable, many are mobile, but some are held in the colloidal films of the soil particles. Protozoa, mites and insects are example of moving organisms. They move in or on the surface of soil in search of food. Earthworms by the burrowing habit make the soil loose and fertile. They are found in abundance. In some forests their number may reach up to 10,000 per square foot. These soil organisms feed on the organic matter of the soil.

The majority of soil fungi are found in acidic soils. Actinomycetes prefer saline soils and soil bacteria grow fairly well in the neutral soils richly supplied with organic nutrients. These microorganisms are found in the soil at variable depths.

Algae are found in the top layer of soil under the conditions of constant shade and moisture.

It is estimated that in soil microflora bacteria form about 90 per cent of the total microbe population. Fungi and algae together represent only one per cent and actinomycetes cover 9 per cent.

Density of microbial population is actually governed and influenced by climatic conditions, physical and chemical nature of soil and vegetation cover. The greatest amount of microbes (10,00,000 per cubic cm) is found in the top layer of soil at a depth of 5 to 15 cm. In deeper layer (1.5 to 5 m) individual microbes are found. However, they have been discovered at a depth of 17.5 m in coal, oil and artesian water. It has been calculated that in the ploughed layer of cultivated soil over an area of one hectare there may be from 5 to 6 tons of microbial mass and one gram of ploughed soil contains 1-10 thousand million bacteria.

Role of Soil Organisms

Soil organisms take part in a number of processes in the soils. Some of their important roles are as follows :

(1) to decompose the dead organic matter and to increase plant nutrients in available forms,
(2) production of toxins,
(3) production of growth stimulating substances,
(4) nitrogen fixation in the soil,
(5) mixing of soil,
(6) improvement in soil aeration,
(7) improvement in the aggregation of soil particles or soil binding, and
(8) cause injury to the plants.

1. **Decomposition of dead organic matter.** A number of soil microbes attack the dead remains of plants and animals and cause decomposition. In the process of decomposition, complex organic matters are converted into simple organic compounds. Compounds like sugars, starch and proteins are decomposed first in the decomposition process and then cellulose, fatty substances and lastly lignin and woody substances are degraded. Proteins when acted upon by microbes are converted into amino acids, ammonium salts, nitrates and nitrites. Humus, an intermediate product of decomposition process, is formed by micro-organism in optimum physical conditions. In the decomposition process, a number of complex mineral compounds are also converted into simpler and soluble compounds. Organic acids and carbon dioxide that are released by decomposition make insoluble phosphates and other unavailable compounds more easily available to plants.

Decomposition of dead organic matter primarily helps in the feeding and growth process of these micro-oganisms and secondly, increases the nutrient contents of the soil. Bacteria and soil fungi are main agents which bring about the process of decomposition in the soil.