CHAPTER 4

BIODIVERSITY AND ITS CONSERVATION

4.1 WHAT IS BIODIVERSITY ?

Simply stated, biodiversity is the variety of life on earth and its myriad of processes. It includes all life forms—from the unicellular fungi, protozoa and bacteria to complex multicellular organisms such as plants, birds, fishes and mammals. In simple terms, biodiversity means the large variety of flora and fauna on this planet earth. According to the World Resources Institute—"Biodiversity is the variety of the world's organisms, including their genetic diversity and the assemblage they form. It is the blanket term for natural biological wealth that undergirds human life and well-being. The breadth of the concept reflects the inter-relatedness of genes, species and ecosystems. Because genes are the components of species, and species are the components of ecosystems. Therefore, altering the make-up of any level of this hierarchy can change the others—species are central to the concept of biodiversity".

The term biodiversity is a relatively new term. It is a contraction of 'biological diversity'. The phrase 'biological diversity' was in use around 1980 and was used to refer mainly to the number of species present in some given area. While, the contracted form 'biodiversity' was coined as an umbrella term to cover the wide range of topics—including species and habitat loss, the use, value and management of biological resources and the urgent need for conservation action. The term 'biodiversity' gained immediate acceptance and was brought to popular attention by the world media during the Earth Summit in Rio de Janeiro in the year 1992. The final text of the Global convention on Biological Diversity (1992) defined it as follows :

"Biological diversity is the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part ; this includes diversity within species and of ecosystems".

Since biodiversity covers a wide range of concepts and can be examined at different levels ; therefore, it has now become customary to study the concept of biodiversity at three hierarchical levels (Fig. 4.1) :

(*i*) Genetic diversity,

(*ii*) Species diversity, and

(*iii*) Ecosystem diversity.

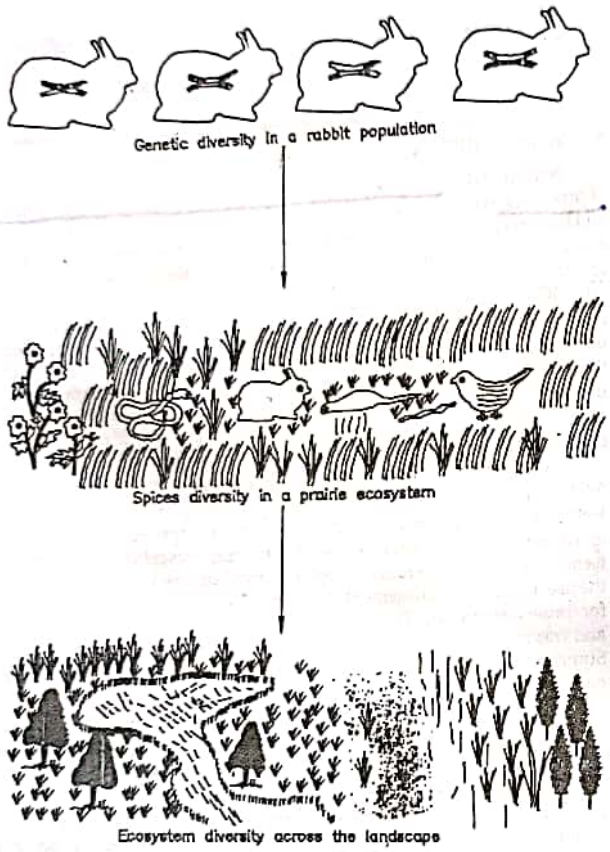

Fig. 4.1. Different levels of biodiversity.

However, it is important to note here that diversity or heterogenity is evident at all levels of biological organization from molecules to ecosystems,

and this diversity has different functional significance at each level. In practice, most attention is generally given to '*species diversity*'. It refers to the number of different kinds of organisms found at a particular place, and how it varies from place to place and even seasonally at the same place. A less obvious aspect of biodiversity, '*genetic diversity*', is the variety of building blocks found within individuals of a species. Genetic diversity allows populations of a species to adapt to environmental changes. '*Ecosystem diversity*' is the distinctive assemblage of species that live together in the same area and interact with their physical environment in unique ways. The interaction of organisms within the ecosystem is often much more than the simple sum of its parts. Sometimes, the phrase '*landscape diversity*' is used on a broad regional scale. Landscape diversity refers to the placement and size of various ecosystems across the land surface and the linkage between them.

4.1.1 Genetic Diversity

At finer levels of organisation, biodiversity includes the genetic variation within each species. Within any given species, there can be several varieties, strains or races which slightly differ from each other in one or more characteristics such as size, shape, resistance against diseases, pests, insects, etc., and resilience to survive under adverse environmental conditions. Such a diversity in the genetic make-up of a species is termed as the 'genetic diversity'. The species having large number of varieties, strains or races are considered as rich and more diverse in its genetic organization. The differences between individual organisms arise from variation in the genetic material possessed by all organisms and passed on to successive generations (heritable variation), and from environmental influence on the growth and development of each individual organism. Heritable variation serves as the raw material for both, evolution by natural selection and by artificial selection, and is ultimately the basis for all biodiversity. New genetic variation arises :

- in individuals, by gene and chromosome mutation ; and
- in population of sexually reproducing organisms, by the recombination of genetic material during cell division preceding sexual reproduction.

In terms of the number of different genes and the number of various possible combinations of gene sequence, the magnitude of global genetic diversity is beyond calculation. Therefore, the concept of global genetic diversity is essentially meaningless. However, some kinds of genetic diversity at the individual, population or species level can be assessed. At the individual, population or species level, genetic diversity occurs as variation in :

- the nucleatide sequence of particular gene segments,
- chromosome number and structure,
- linkage between genes, and so on.

Opportunities for evolutionary change, the survival of species and the formation of new species are in part a function of the amount of genetic diversity in populations. The various applications of biotechnology, such as crop or animal breed improvement, depend on the identification of genetic material that give rise to desirable traits and the incorporation of this genetic material in appropriate organisms.

4.1.2 Species Diversity

Biodiversity at its most basic level includes the full range of species on earth—from unicellular micro-organisms such as viruses, bacteria, fungi and protists through the multicellular kingdom of plants and animals. The richness of species in an ecosystem is called as 'species diversity'.

Species are the basic and most important units in modern systems for classifying living organisms. The number of species on earth is very large and no one knows the exact number of species because new species are being discovered all the time, especially in little-explored areas such as tropical rain forests and the deep oceans. Species make-up one level of a complex taxonomic hierarchy. Similar species are grouped together in genera, similar genera in families, families in orders and so on until the highest level of the kingdom. Five kingdoms are generally recognized at present—animals, plants, fungi, protists (algae) and prokaryotes (bacteria).

In terms of species diversity, it must be noted that merely counting the number of species is not enough to describe biological diversity. Diversity has to do with the relative chance of seeing species as much as it has to do with the actual number present. A community in which each species has the same number of individuals as all others would be the most diverse; whereas, a community with one species making up most of the individuals would be least diverse. Further, species that are very different from each other contribute more to overall diversity than species which are similar to each other. Therefore, some taxonomists are of the opinion that in some circumstances diversity is better measured at higher taxonomic levels (for example; genera or families), arguing that an area, say, with twenty species in the same genus is less diverse than an area with twenty species each in a different genus. Similarly, a single species placed in its own unique family should be weighted more highly than another species placed in a family with many others, because the former species is considered to be genetically more distinct.

4.1.3 Ecosystem Diversity

Both genes and species in a sense define themselves through replication or reproduction, but ecosystems have no such clear identity. Ecosystems represent parts of a highly variable natural continuum and perception of change within this continuum is highly scale-dependent. Therefore, a global quantitative evaluation of ecosystem diversity is not possible.

Ecosystem diversity is generally assessed in terms of the global or continental distribution of broadly-defined ecosystem types, or in terms of the species diversity within ecosystems. Ecosystems assessed in terms of the diversity of species may include estimation of richness in particular groups and evaluation of their relative abundance. A system having the component species present in nearly equal abundance is considered as more diverse than one having extremes of high and low abundance.

4.1.4 Landscape Diversity

It refers to size and distribution of several ecosystems and their interaction across a given land surface.

4.2 MEASURING BIODIVERSITY

At the simplest level, diversity may be defined as the number of species present in a community, a measure termed as 'species richness'. Diversity, infact, is a single statistic in which the number of species and evenness are compounded. Several methods of calculating diversity have been proposed that combine these two types of information. The mathematical indices of biodiversity that have been developed to represent species biodiversity at different geographical scales are—alpha, beta and gamma diversity:

(*i*) **Alpha diversity :** It refers to number of species in a single community and can be used to compare the number of species in different ecosystems. Alpha diversity, infact, refers to the popular concept of 'species richness' in an ecosystem.

(*ii*) **Beta diversity:** It refers to the degree to which species composition changes along an environmental gradient. For example, beta diversity is high if the species composition of moss communities changes at successively higher altitudes on a mountain slope, but it is low if the same species occupy the whole mountain side.

(*iii*) **Gamma diversity :** It refers to the species turnover rate with distance between sites of similar habitat or with expanding geographical areas. Gamma diversity is applicable on larger geographical scales and is defined as the rate at which additional species are encountered as geographical replacements are made for a given habitat type in different localities.

4.3 BIOGEOGRAPHICAL CLASSIFICATION OF INDIA

India lies to the north of the equator between 8° 4' and 37° 6' north latitude and 68° 7' and 97° 25' east longitude. It measures 3,214 km from north to south and 2,933 km from east to west with a total land area of 3,287,263 sq. km. It is bounded on the south-west by the Arabian sea and on the south-east by the Bay of Bengal. On the north, north-east and north-west lie the Himalayan ranges. Kanyakumari constitutes the southern tip of the

of spreading coastal vegetation like mangrooves, beech forests and in the interior some of the best preserved evergreen forests of tall trees. Rhizophora, Calophyllum, Mimusops, Lagerstroemia, Terminalia and Dipterocarpus are some of the important species of Islands' vegetation.

(10) **Coast :** India has a coastline of about 7,516.5 km. Mangrooves vegetation is the characteristic of estuarine tracks along the coast, for instance, at Pichavaram near Chennai and Ratna Giri in Maharashtra.

4.4 VALUE OF BIODIVERSITY

Why should we care about all this diversity of life ? Because—"Wild plants, animals and micro-organisms have provided essential products since humans first walked the earth, including virtually everything we eat ; and they continue to provide a basis for human society to respond to future changes".

Humans depend on other species and the ecosystems that support them, for the basic needs of existence. Our homes, livestock, vegetables, fruits, grains, air and water, all are derived from the products of diverse and healthy ecosystems. Diverse communities of plants, animals and micro-organisms also provide indispensable "ecological services" such as soil formation, nutrient cycling, solar energy absorption, management of biogeochemical and hydrological cycles, waste disposal, air and water purification, maintain the chemical composition of atmosphere and play a major role in determining the world's climate. Moreover, diversity of biological communities in ecosystems (such as lakes, forests, wildlife sancturies, mangrooves, etc.) are useful for pichicking, camping, fishing, wildlife watching, visiting seashores and a variety of other outdoor recreational activities. Further, in many societies (cultures), diversity and the maintenance of mountains or other landforms are valued because of their regligious significance.

Not only this, the value of biodiversity goes far beyond into the future. Just a fraction of the species have been identified till date, while many more species are believed to exist ; and every year numerous species are lost before we have a chance to know anything about them. Who can guess what potentially valuable foods, medicines and commercial products are forever lost with each extinction ?

Although ecological values have grown stronger in recent years, it is often difficult to determine whether a specific species is ecologically valuable or essential because we do not fully understand the complex inter-relationships between organisms. But we often are amazed at the effects of removing seemingly insignificant members of biological communities. For instance, wild species provide a valuable but often unrecognized service in suppressing pest and disease carrying organisms. Frog is supposed to consume insects equalling its own weight per day. A recent study indicates that the decrease in frog population in India and Pakistan might be the cause of increased damage of crops by pests and recurrence of Malaria.

In this context, preserving a diversity of life on this planet has come to be an accepted goal. But when this goal comes into conflict with other goals, such as economic development, the question becomes—How much diversity and at what cost ? To find the answer, it is important to think carefully about the values of biodiversity. Environmental economics (or ecological economics) provides methods of assigning economic values to species, communities and ecosystem. These values include the harvest (or market place) value of resources, the value provided by un-harvested resources in their natural habitat, and the future value of resources. For example, the Asian wild gaur could be valued for the meat the could be harvested from its current populations, its value for eco-tourism, or its future potential in cattle breeding.

The values can be divided as :

(1) Direct Values :

Also known as use values and commodity values are assigned to the products harvested by people. Direct values can be readily estimated by observing the activities of representative groups of people, by monitoring collection points for normal products and by examining the export/import statistics. These values can be further sub-divided as :

(a) **Consumptive use value :** It can be assigned to goods such as fuelwood and goods that are consumed locally and do not figure in national and international market.

(b) **Productive use value :** It is assigned to products that are derived from the wild and sold in commercial markets, both national as well as international markets.

(2) Indirect Values :

Indirect values are assigned to benefits provided by biodiversity that do not involve harvesting or destroying the natural resource. Such benefits include ecological benefits such as soil formation, nutrient cycling, waste disposal, air and water purification, education, recreation, future options for human beings, etc. Indirect value can be further sub-divided as :

(a) **Non-consumptive use Value :** It is assigned to benefits such as soil formation/protection, climate regulation, waste disposal, water and air purification, eco-tourism, medical research, etc.

(b) **Aesthetic, Social and Cultural Value :** The diversity of life on Eath brings us many aesthetic and cultural benefits. It adds to the quality of life, providing some of the most beautiful and appealing aspects of our existence.

Biodiversity is an important quality of landscape beauty. Many species of birds, large land mammals, sea animals and flowering plants are appreciated for their beauty. Millions of people enjoy hiking, camping, picnics, fishing, wildlife watching, and other recreational activities based on nature. These activities provide invigorating physical exercise and allow

us to practice pioneer living skills. Contact with nature can also be psychologically and emotionally restorative. In many cultures, nature carries spiritual connotations, and a particular plant or animal species or landscape may be inextricably linked to a sense of identity and meaning.

Throughout the human history, people have emphasized the importance of biodiversity to the purpose and meaning of our existance. Hundreds and thousands of years of drawings and paintings, dating back to Stone Age, testify to the fundamental aesthetic role of nature and its biodiversity in human existence. Also, literature (from ancient epics to modern novels), films, television, etc. celebrate the beauty and diversity of life on this planet. Nature appreciation is economically important too. Now a days, people spend large sums every year on tourism to areas of lush vegetation, coral reef islands and other areas of natural beauty to enjoy nature and to experience other cultures. This can be a good form of sustainable economic development, but we have to be careful that we don't abuse the places and cultures we visit.

Today we continue to imbue certain animals and plants with cultural significance ; for instance, in India tiger and peacock, which are endangered, are especially valued because they have been adopted as national animal and bird respectively.

(*c*) **Option Value :** The option value of a species is its potential to provide our economic benefit to human society in the near future. For instance, there are several plant species which are edible and superior than those which are currently in use ; e.g. Katemfe, a plant found in W. Africa, produces proteins that are 1,600 times more sweeter than sucrose.

(*d*) **Existence Value :** It is assigned to protect wildlife. Since, for many people, the value of wildlife goes beyond the opportunity to photograph or even see a particular species. They argue that 'existence value', based on simply knowing that a species exist, is a sufficient reason to protect and preserve it. This right to exists was also stated in the U.N. General Assembly World Charter for Nature, 1982.

(*e*) **Ethical Value :** Moral justification for conservation of biodiversity is based on the belief that species have a moral right to exist, independent of our need for them. Consequently, the argument follows that in our role as the most intelligent species on Earth we have a responsibility to try as much as possible for the continuance of all forms of life.

Ethical values are deep rooted within human culture, a religion and society, but, those who look on cost benefit analysis, they overlook these ethical values. International boycotts of furs, teak and ivory are the good examples of moral justification.

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4.4.1 Importance (uses) of Biodiversity

Various uses of biodiversity regarding direct and indirect values are as follows :

1. Timber : Wood is one of few commodities used and traded worldwide that is mainly harvested from wild sources. It is also one of the economically most important commodities in national and international trade. Wood export constitutes a significant part of the export earnings of many tropical developing countries. Malaysia, Papua New Guinea and Indonesia are among the major exporters of hardwoods, including prized timbers such as teak and mahogany, produced mainly from natural forests. Potentially valuable resources in many parts of the world, particularly tropical forests, are being degraded through excess harvesting, inadequate management and habital loss.

2. Fishery : Fish and other fishery products make up another class of commodities of great economic importance in international trade that are harvested mainly from wild sources. These resources are also of crucial importance to global food security. Annual landings of aquatic resources have increased nearly five-times in the past four decades ; and more than 80% was harvested from marine capture fisheries, the remainder was from inland fisheries and from aquaculture, both inland and marine. Capture fisheries have declined in the last decade and the deficit has been filled by aquaculture production. This can have production benefits, but in many parts of the world the coastal environment has been severely damaged by conversion to mariculture.

Though there are over 22,000 species of fish, but just ten individual marine fish species make up one-third of marine capture landings. The most important are the herrings, sardines and anchovies group.

3. Food : Food plants exemplify the most fundamental values of biodiversity. Originally, plants were consumed directly from the wild and gathering of wild produce continues throughout the world even today. Only a few thousand of the estimated 2,50,000 species of angiospherms (flowering plants) have been treated as direct food sources ; others provide forage and browse for animals which in turn hunted or farmed by people. Presently, around 200 species have been domesticated as food plants and of these about 15 to 20 are crops of major international economic importance. Although relatively few plants contribute to food production globally, but at a local level and particularly in the tropics, a very wide range of plants provide fruit and other foods. For instance, villagers in Indonesia are thought to use about four thousand native plants and animal species for food. Noted tropical ecologist N. Meyers estimates that about eighty thousand edible wild plant species could be utilized by humans.

The evolution of crop plants began between 5,000 and 10,000 years ago in various parts of the world. While evolution of food crops under centuries of domestication has increased the range of diversity, the development of high-yeilding varieties is now rapidly reversing this trend, leading to a dangerous reliance on genetically uniform crops. As intensive agriculture has spread widely, local varieties have been displaced and have often disappeared entirely. Overgrazing, forest clearing, conversion of natural landscape, and other forms of human disturbances are destroying potentially valuable food species and the wild ancestors of our domestic crops.

4. Medicinal Value: Living organisms provide us with many useful drugs and medicines (Table 4.2). *Digitalis*, an important drug in the treatment of certain heart ailments, comes from a small flowering plant—purple foxglove ; *Penicilin* is a derivative of fungus ; and so on. The UNDP estimates the value of pharmaceutical products derived from Third World plants, animals and microbes to be more than $30 billion per year.

There are still numerous organisms that may produce useful medical compounds that are as yet unknown and untested. For instance, coral reefs offer a particularly promising use in pharmaceutical drugs, because many coral reef species produce toxins to defend themselves. Many plant species native to India such as Neem, Tulsi, etc. too have potential medicinal applications.

Table 4.2. Natural medicinal products

S. No.	Product	Source	Use
1.	Aspirin	Willow bark	Anti-inflammatory
2.	Allantoin	Blowfly larva	Wound healer
3.	Bacitracin	Bacterium	Antibiotic
4.	Bee venom	Bee	Arthritis relief
5.	Cytarabine	Sponge	Leukemia cure
6.	Cortisone	Mexican yam	Anti-inflammatory
7.	Digitalis	Foxglove plant	Heart stimulant
8.	Diosgenin	Mexican yam	Birth-control drug
9.	Erythromycin	Bacterium	Antibiotic
10.	Morphine	Poppy plant	Analgesic
11.	Penicillin	Fungus	Antibiotic
12.	Quinine	Chincona bark	Malaria treatment
13.	Reserpine	Rauwolfia	Hypertension drug
14.	Tetracycline	Bacterium	Antibiotic
15.	Vinblastine	Rosy periwinkle plant	Anticancer drug
16.	Vincristine	Rosy periwinkle plant	Anticancer drug

5. Genetic Value: Biological diversity is a valuable genetic resource. Most of the hybrid varieties of crops under cultivation have been developed by incorporating useful genes from different species of plants to produce better quality of the product with longer self-life or having better resistance to pests. Though such breeding techniques are unlimited in scope ; but, for getting better strains in future, it is essential to build-up a gene-pool because the quality, yield, and resistance to pests, disease and adverse climatic conditions mostly depend on genetic factors and combination of genes which may be different in different strains/varieties of species. There are hundreds of examples which illustrate how genetic modification helped in improved quality of the product. A few of them are mentioned as under :

- The genes from a wild variety of melon grown in U.P. helped in imparting resistance to powdry mildew in musk-melons grown in California (USA).
- The genes from the Kans grass (Saccharum Spontaneum) grown in Indonesia helped in imparting resistance to red rot disease of sugarcane.
- A wild variety of rice from U.P. saved millions of hectares of paddy crop from Grossy-Stunt virus.

6. Tourism : Tourism industry is mainly based on observation of wildlife within protected areas and is a major source of income for many developing countries. Tourism is the major source of foreign income for Kenya. Eco-tourism, is now getting more attention and it includes interest in the all species of plants and animals, and forests.

7. Poor and Indigenous People : Poor and indigenous people of under-developed countries are dependent on diversity in forests and wildlife for food, shelter, tools, fuel, and materials for clothing and medicines. Further reduction in the biodiversity can further increase the poverty of these poor people.

8. Pollution Control : Plants and certain micro-organisms in particular can remove toxic substances from the air, water and soil. Since the different species have different characteristics and capabilities, therefore, a diversity of species can provide wide range of pollution control. For example, toxins like carbon-di-oxide and sulphur-di-oxide are removed by vegetation, carbon-monoxide is controlled by soil fungi and bacteria.

4.5 BIODIVERSITY AT GLOBAL, NATIONAL AND LOCAL LEVELS

Biodiversity—a composite of genetic information, species and ecosystems, provides material wealth in the form of food, fibre, medicine and inputs into industrial processes. It supplies the raw material that may assist human societies to adapt to future and unforseen environmental stresses.

Cellular life has existed on Earth for probably more than 3,500 million years, but for more than half this time consisted only of prokaryotes (*i.e.*

4.	Nanda Devi National Park	Uttar Pradesh
5.	Sundarban National Park	West Bengal

4.7 HOTSPOTS OF BIODIVERSITY

The most remarkable places/areas on earth are also the most threatened ones, and many of them have been reduced to less than 10 percent of their original vegetation. These places/areas are called *hotspots of biodiversity* for preservation. Hotspots are the main areas of focus for biodiversity conservation. These are the areas that are extremely rich in biodiversity, have high level of endemism, and are under constant threat of species extinctions and habitat destruction. The hotspots approach to the conservation of threatened ecosystems and species is a highly targeted strategy for tackling the overwhelming problem of biodiversity loss at the global level. The hotspots strategy makes the extinction crisis more manageable by enabling us to prioritize and target conservation investments in order to have the greatest impact.

Recently, Norman Myers and a team of scientists have brought out an updated lists of 25 hotspots (Myers et al. 2000). These identified hotspots of biodiversity are :

Caribbean, California Floristic Province and Mesoamereca in North and Central America ; Tropical Andes, Choco-Darien-Western Ecuador, Atlantic Forest, Brazilian Cerrado and Central Chile in South America ; Caucasus and Mediterranean Basin in Europe and Central Asia ; Madgascar and Indian Ocean Islands, Eastern Arc Mountains and Coastal Forests, Guinean Forests of West Africa, Cape Floristic Region and Succulent Karoo in Africa ; Mountains of Southwest China, Indo-Burma and Western Ghats of India in Mainland Asia ; and Philippines, Sundaland, Wallacea, Southwest

eastern India and extreme Northern Myanmar. It is bounded by the dry Qinghai-Xizang Plateau in the Northwest, Tao River in the north, and Sichuan Basin and plateau of Eastern Yunnan in the east. It is estimated that about 64,000 square kilometers or 8% of the original extent of the hotspot is in pristine condition.

The hotspot is characterized by extreme fluctuations in topography, with peaks ranging from less than 1,000 meters to more than 7,500 meters in altitude. The tremendous altitude variations lead to much local climate variation, from tropical monsoon rain forests on the lower slopes to alpine areas on mountain peaks of permanent ice caps. There are a vide variety of ecosystems, among these mountains and valleys including broad-leaved and coniferous forests, bamboo groves, savannah, meadow, prairie, freshwater wetlands and alpine scrubs.

17. **Indo-Burma :** The Indo-Burma hotspot covers about 2 million square kilometers of tropical Asia east of the Indian subcontinent. The hotspot includes all of Cambodia, Vietnam and Laos, and nearly the entire areas of Thailand, Myanmar and Bhutan, as well as part of Nepal, far eastern India and extreme southern China. In addition, it covers several offshore Islands including Mainan Islands in the South China Sea, and the Andaman and Nicobar Islands in the Indian Ocean. Today, it is estimated that about 1,00,000 square kilometers or 5% of the original extent of the habitat is in pristine condition.

The entire hotspot was originally covered with broad-leaf forests ; but, today, only fragments remain. In these fragments, a wide variety of ecosystems is represented including deciduous, wet evergreen, dry evergreen and montane forests. Also, there are patches of shrublands, woodlands and scattered heath forests. The hotspot has the world's highest diversity of freshwater turtle species. Moreover, the hotspot is still revealing its biological treasures, for example, three large mammal species have been discovered in recent years.

18. **Western Ghats and Sri Lanka :** The hotspot encompasses the montane forests in the southwestern parts of India and on the neighbouring Island of Sri Lanka. Although the two forest blocks are separated from each other by about 400 kilometers of land and water, yet they are similar enough that they can be grouped into a single hotspot. Though the entire extent of the hotspot was originally about 1,82,500 square kilometers ; but, due to tremendous population pressure, now only 12,445 square kilometers or 6.8% is in pristine condition.

The Western Ghat Mountains stretch from India's southern tip to Gujarat in the North, and run parallel to the country's western coast. They cover an area of about 1,60,000 square kilometers. The western slopes of the mountains receive heavy annual rainfall, whereas the eastern slopes are

drier. The wet tropical southwestern zone of Sri Lanka is remarkably similar to the Western Ghats because of the repeated appearance and disappearance of a land bridge between them over many thousands of years.

The predominant vegetation of the entire hotspot includes deciduous and tropical rain forests, montane forests and grasslands, as well as scrub forests in lower, drier areas. The hotspot is home to a diverse and endemic assemblage of plants, reptiles and amphibians. The important populations include Asian elephants, Indian tigers and the endangered lion-tailed macaque.

19. **Philippines :** The Philippines is the world's second largest archipelago after Indonesia. It includes more than 7,000 Islands in the western-most Pacific Ocean. The Philippines has been identified as one of the world's biologically richest countries, with tremendous levels of biodiversity and endemism despite its tiny portion of remaining natural habitat (21,000 square kilometers). The diversity places the Philippines among the top five priority hotspots for global conservation.

Hundreds of years ago, the bulk of the country was blanketed by lowland rain forests. Small areas of seasonal forest, mixed forest and savanna, and pine-dominated cloud forest covered the remaining land area. But, now only 7% of the original lowland forest remains. At higher elevations, the lowland forests are replaced by montane and mossy forests that consist primarily of smaller trees and vegetation, and are last refuges of many endemic species.

Further, the Philippines is also a hotspot of marine biodiversity. Coral reefs of this hotspot contain more than 500 of the world's 700 known coral species. The coastal habitats also include seagrass beds, soft bottom communities and mangrooves.

Some of the important endemic species of this hotspot are the Cebu flowerpecker, the golden-crowned flying fox, the Negros forest frog, the Philippine Cockatoo and the Philippine eagle.

20. **Sundaland :** The Sundaland encompasses the western half of the Indo-Malayan archipelago, an arch of about 17,000 equatorial Islands between the Asian mainland and Australia. The Sundaland hotspot is bordered by the Indo-Burma, Philippines and Wallacea hotspots. Most of area of Sundaland hotspot falls within Indonesia (75%) and Malaysia (21%), and the remaining 4% falls in Singapore, Brunei and Southern Thailand. Originally, the entire Sundaland was probably covered with forest ; but today only 1,25,000 square kilometers or 7.8% of the original extent of the forest is in pristine condition. Further, the surving area is highly fragmented, and the most enduring pristine habitat lies in the interior of Borneo and protected areas in Sumatra and Peninsular Malaysia.

4.8 THREATS TO BIODIVERSITY

Extinction, the elimination of a species, is a normal process in nature. Species die out and are replaced by others, generally by their own descendants, as part of evolutionary change. The rate of extinction, in undisturbed ecosystems, is estimated to be about one species per decade. In the last many decades, however, human impacts on populations and ecosystems have accelerated that rate, causing hundreds of species, subspecies and varieties to become extinct every year. And, if the present trends continue, millions of kinds of plants, animals and microbes may be destroyed in the next few decades.

4.8.1 Causes of Extinction

The causes of extinction are broadly grouped into five risk categories—population risk, environmental risk, natural catastrophe, genetic risk and human actions.

1. Population Risk : Random variations in population rates (*i.e.* birth rates and death rates) can cause a species in low abundance to become extinct. It is a risk especially to species that consist of only a single population in one habitat. For example—blue whales. As they swim over the vast areas of ocean, and if in one year most whales were unsuccessful in finding a mate then births could be dangerously low.

2. Environmental Risk : Environmental risk means variation in the physical or biological environment, including variations in predator, prey, symbiotic or competitor species. In case of species that are sufficiently rare and isolated, such normal environmental variations can lead to their extinction.

3. Natural Catastrophe : A natural catastrophe is a sudden change in the environment (not as a result of human action). It includes fires, storms, floods, earthquakes, volcanic eruptions, changes in oceanic currents and upwellings, etc. Such a natural catastrophe may cause the local extinction of most forms of life there.

4. Genetic Risk : Deterimental change in genetic characteristics in a small population of a species, due to reduced genetic variation, genetic drift or mutation, makes the species more vulnurable to extinction because it lacks the variety once present or because a mutation that leads to poor health becomes fixed in population.

4.8.2 Human Actions

Humans have caused extinctions over a long time, not just in recent decades. The earliest humans probably caused extinctions through hunting ; with the invention of fire, humans began to change habitats over large areas ; with the development of agriculture and the rise of civilization, rapid habitat changes took place ; as new areas were

explored, the introduction of exotic species became an important cause of extinction ; later, in the twentieth century, with the introduction of industrial chemicals and emissions, pesticides, etc. into the environment, pollution has become an increasingly significant cause of extinction.

Human actions cause extinction of species through :

1. Habitat Loss and Degradation : Habitat loss and degradation are the most proximate causes of species extinction, affecting 89% of all threatened birds, 83% of mammals and 91% of all threatened plants assessed globally (IUCN, 2000). The main causes of habitat loss are agricultural activities, harvesting or extraction (including mining, fishing, logging, etc.) and development of human settlements, industry and associated infrastructure.

Habitat destruction inevitably results from the expansion of human populations and human activities. The ever-expanding human settlements have been causing destruction of natural ecosystems to meet their requirements of food, space, shelter, etc. The greatest destruction of biological communities has occurred during the last 150 years during which the human population went from just one billion in 1850 to 6.2 billion in 2002, and will reach an estimated 7.8 billion in 2025. In many countries, particularly islands and where human population density is high, most of the original habitat has already been destroyed. According to IUCN, UNEP report, more than 50% of the wildlife habitat has been destroyed in 49 out of the 61 Old World Tropical Countries. Destruction of forests, wetlands, grasslands, mangroves and other biologically rich ecosystems around the world threatens to eliminate thousands or perhaps millions of species in a human-caused mass extinction that could rival those of geological history. By destroying habitat, we eliminate not only the prominent species, but also many obscure ones of which we may not even be aware.

2. Habitat Fragmentation : It is a process where a large, continuous area of habitat is both, reduced in area and divided into two or more fragments. Habitat fragmention may take place due to the development of roads, towers, canals, fields, industries, etc. in an original large habitat. The fragments thus formed are oftenly isolated from one another by highly modified or degraded landscapes. Habitat fragmentation divides populations into isolated groups that not only limit the potential of species for dispersal and colonisation but also reduces the foraging ability of animals. These isolated, small, scatterred populations are increasingly vulnurable to inbreeding depression, high infant mortality and susceptible to environmental hardships, and consequently, in the end, possible extinction.

3. Diseases : Pathogens, or disease organisms, may also be considered predators. The incidence of disease in wild species may increase due to human activities. The extent of disease increases further when animals are kept in captivity (even in

4.8 THREATS TO BIODIVERSITY

Extinction, the elimination of a species, is a normal process in nature. Species die out and are replaced by others, generally by their own descendants, as part of evolutionary change. The rate of extinction, in undisturbed ecosystems, is estimated to be about one species per decade. In the last many decades, however, human impacts on populations and ecosystems have accelerated that rate, causing hundreds of species, subspecies and varieties to become extinct every year. And, if the present trends continue, millions of kinds of plants, animals and microbes may be destroyed in the next few decades.

4.8.1 Causes of Extinction

The causes of extinction are broadly grouped into five risk categories—population risk, environmental risk, natural catastrophe, genetic risk and human actions.

1. Population Risk : Random variations in population rates (*i.e.* birth rates and death rates) can cause a species in low abundance to become extinct. It is a risk especially to species that consist of only a single population in one habitat. For example—blue whales. As they swim over the vast areas of ocean, and if in one year most whales were unsuccessful in finding a mate then births could be dangerously low.

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3. Diseases : Pathogens, or disease organisms, may also be considered predators. The incidence of disease in wild species may increase due to human activities. The extent of disease increases further when animals are kept in captivity (even in sanctuaries or reserves) rather than being

disperse over a large area. Animals, as compared to plants, are more prone to infection when they are under stress.

4. Genetic Assimilation : Some rare and endangered species are threatend by genetic assimilation because they crossbreed with closely related species that are more numerous or more vigrous. Opportunistic plants or animals that are introduced into a new habitat by human actions may genetically overwhelm local populations. For example, hatchery-raised trout introduced into lakes or streams may genetically dilute indigenous stocks.

5. Pollution: Environmental pollution is the most subtle form of habitat degradation. The most common causes of which are pesticides, industrial effluents and emissions, and emission from automobiles. Toxic pollutants can have disastrous effects on local populations of organisms. Pesticides-linked declines of fish-eating birds and falcons was well documented in the 1970s. Mysterious, widespread deaths of thousands of seals on both sides of Atlantic in recent years are linked to an accumulation of chemicals such as DDT, PCB's and dioxins. Lead poisoining is another major cause of mortality for many species of wildlife.

6. Poaching : Poaching is another insidious threat that has emerged in recent decades as one of the primary reasons for the decline in number of species. Poaching pressures, however, are unevenly distributed since certain selected species are more heavily targeted that others are. Despite legal protection in many countries, products from endangered species are widely traded within and between nations.

Wildlife is sold for live specimens, folk medicines, furs, hides, skin (or leather) and other products such as ivory, antlers and horns amounting to millions of dollors each year. Developing countries in Asia, Africa and Latin America with the richest biodiversity in the world are the main source of wild animal and animal products, while Europe, North America and some Wealthy Asian countries are the principal importers.

7. Introduction of Exotic Species : Organisms introduced into habitats where they are not native are termed as *exotics*. They can be thought of as biological pollutants and are considered to be among the most damaging agents of habitat alteration and degradation in the world. Since the beginning of the age of exploration, human beings have been conducting a gigantic experiment in biogeography, intentionally and unintentionally moving many species of plants and animals around the world. Inducing species intentionally or unintentionally (accidently) from one habitat into another where they have never been before is a very risky business. Freed from the parasites, pathogens, predators and competitors that normally keep their numbers in check, exotics often exhibit explosive population growth that crowds out native species. Their aggresive invasion might be considered a kind of ecological cancer. Alien invasive species are a significant threat affecting 30% of all threatened birds and 15% of all threatened plant species.

Introductions of exotic species have caused especially severe problems on Islands.

The above mentioned causes of biodiversity loss due to human actions, however, are poverty, macroeconomic policies, international trade factors, policy failures, poor environmental laws/weak enforcement, unsustainable development projects and lack of local control over resources. Population pressures and accompanying increases in the collection of fuelwood and fodder, and grazing in forests by local communities too take their toll on the forests, and consequently its biodiversity.

4.9 ENDANGERED SPECIES

The International Union of Conservation of Nature and Natural Resources (IUCN) maintains what may be called a '*Red Database*' at the World Conservation Monitoring Centre (WCMC) in which information on endangered and vulnerable species of plants and animals is kept. From time to time, this database is translated into popular form and published as '*Red Data Books*'. As an aid in appreciating the degree of danger that a species is thought to be in, the IUCN has developed categories that can be assigned to species of plants and animals under threat based on :

- the present and past distribution of the species ;
- the decline in the number of population of the species in the course of time ;
- abundance and quality of natural habitat of the species ; and
- the biology and potential value of the species.

The categories are as follows :

(i) **Endangered Species (E) :** The species that are considered in imminent danger of extinction and whose survival is unlikely if factors causing their decline continue to operate. These are species whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are in immediate danger of extinction.

(ii) **Vulnerable Species (V) :** The species that are under threat such that they may have to be classified as endangered in the near future if causal factors continue to operate. These include species whose populations have been seriously depleted and whose ultimate security is not assured, as well as those species whose populations are still abundant but are under threat throughout their range.

(iii) **Rare Species (R) :** These are species with small total population size in the world. In their distribution, they are usually localized within restricted habitats or geographical area or are thinly scattered over an extensive range. It is necessary to mention here

Further, India is a centre of crop diversity—the origin place of 167 species of cultivated plants and 320 species of wild relatives of cultivated crops (Table 4.15).

Table 4.15. Wild relatives of some crops and medicinal plants

Crop	No. of wild relatives
Millets	51
Fruits	104
Spices and condiments	27
Vegetables and pulses	55
Fibre crops	24
Oil seeds, tea, coffee, Tobacco and Sugarcane	12
Medicinal plants	3,000

India is particularly rich in floral wealth and endemism, not only in flowering plants but also in reptiles, amphibians, swallow-tailed butterflies, and some mammals. About 62% of the known amphibian species and nearly 50% of the lizards of the country are endemic with the majority occurring in the Western Ghats (Table 4.16).

Table 4.16. Animal species endemic to India

Group	No. of Species
Mollusca	878
Land	89
Freshwater	16,214
Insecta	110
Amphibia	214
Reptilia	69
Aves	38
Mammalia	

4.10 CONSERVATION OF BIODIVERSITY

One of today's most pressing environmental issues is the 'Conservation of Biodiversity'. Many factors are threatening the world's biological heritage. The challenge is for nations, government agencies, organisations and individuals to protect and enhance biodiversity while continuing to meet people's needs for natural resources. This challange exists from local to global scales. If not met, future generations will live in a biologically impoverished world and perhaps one that is less capable of producing desired resources as well.

Conservation is defined as 'the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generation while maintaining its potential to meet the needs and aspirations

of future generations'. Conservation of our natural resources has the following three specific objectives :

(*i*) to maintain essential ecological processes and life-supporting systems ;

(*ii*) to preserve the diversity of species or the range of genetic material found in the organisms on the planet ; and

(*iii*) to ensure sustainable utilization of species and ecosystems which support millions of rural communities as well as the major industries all over the world.

The wildlife conservation efforts are mostly centred on protecting plant and animal life in protected habitats, such as—botanical fordens, zoos, sanctuaries, national parks, biosphere reserves, etc. The two basic approaches to the wildlife conservation in protected habitats are :

(*i*) In-situ conservation ; and

(*ii*) Ex-situ conservation.

4.10.1 In-situ Conservation

In-situ or on-situ conservation means conservation of species in its natural ecosystem or even in man-made ecosystems (*i.e.* Artificial ecosystems). This type of conservation applies only to wild fauna and flora, and not to the domesticated animals and plants because conservation is possible by protection of population in nature. In-situ conservation is a comprehensive system off "protected area", which involves setting aside large portions of earth's surface for wildlife with emphasis either to save the entire area or an endangered species. According to World Conservation Union, '*protected area*' is defined as—"an area of land and/or sea specially dedicated to the protection and maintenance of biological diversity and of natural and associated cultural resources and managed through legal or other effective means". There are different categories of *protected areas* which are managed with different objective. These include—national parks, sanctuaries, biosphere reserves, etc.

A national park is an area which is stricktly reserved by the betterment of the wild life and where activities such as forestry, grazing or cultivation are not permitted, and no private ownership is allowed. A national park is hitched to the habitat for particular wild animal species like, lion, tiger, rhinosorous, etc. and its boundaries are circumscribed by legislation. Except for the buffer zone (where limited human activity is allowed), no biotic interference is allowed.

A *sanctuary* is generally species-oriented as Great Indian Bustard, pitcher plant, etc. and its boundaries are not sacrosant. Operations such as harvesting of timber, collection of minor forest products and private ownership rights are permitted so long as they do not interfere with the well-being of animals. In other words, limited biotic interference is allowed.

In *biosphere reserve*, multiple land use is permitted. A biosphere is not hitched to any one, two or more species, but to the whole ecosystem *i.e.* totality of all forms of life. In it, wild populations as well as traditional life styles of tribals and varied domesticated plant and animal genetic resources are protected. A biosphere, thus, is ecosystem-oriented. Its boundaries are circumscribed by legislation; and no biotic interference is allowed, except in the buffer zone.

In-situ conservation is the best strategy for the long term protection of biodiversity. Large pockets/areas of protected zones are essential for not only conserving vast number of species of living organisms but also provide opportunities to evolve. Otherwise, man-made habitats (e.g., zoo, acquarium, etc.) may end-up with static gene-pool. Further in-situ conservation are always preferred because, in most cases, it is cheaper to protect populations in their natural habitat than to reintroduce captive-bred ones.

Some of the limitations or factors that reduce the laudable advantages of in-situ conservation to some extent are:

- many protected habitats are not large enough, not maintained properly, and are not properly protected from environmental pollution; and
- many protected habitats are used for logging, tourism or other profitable activities; thus, diluting the objective of conservation of biodiversity.

Good management of the extant populations in the wild is also very important for their survival. This includes habitat protection, facilitating gene flow through the creation of corridors, introduction of new genetic stock, and translocation of animals.

4.10.2 Ex-situ Conservation

Ex-situ conservation means conservation of species (sample of genetic diversity), particularly of endangered species, away from their natural habitat under human supervision. Infact, we can say that ex-sity or off-site conservation is conservation in captivity under human care. Captive breeding aims at maintaining viable and healthy genetic captive stocks in conservation facilities and is meant to supplement *in-situ* initiatives. Though in-situ conservation is the best strategy for the long-term protection of biodiversity; however, for many rare species or species having small remaining population, it is not a viable option in the light of increasing human disturbances. Further, species may decline and go extinct in the wild due to genetic drift and inbreeding, environmental and demographic variation, deteriorating habital quality, competition from exotic species, disease or over-exploitation. Under such circumstances, the only possible way a species can be prevented from going extinct is to maintain individuals in artificial conditions under human

care. This strategy of conservation of biodiversity is termed as 'ex-sity or off-site preservation'. In ex-situ conservation, the endangered species of animals are collected and bred under controlled conditions in zoos, game farms, aquaria, etc., while plant species are maintained in botanical gardens, arboreta and seed banks.

Some of the steps that are involved in the ex-situ conservation are:

- establishing minimum target population goals to provide for maintenance of captive genetic diversity for at least the next 100 years;
- distributing founders through the various captive breeding programmes;
- circulating compiled animal husbandry programmes to all breeding facilities; and
- implementing an overall plan that contributes to the objectives of maintaining viable populations across the globe—a strategy popularly known as GASP (Global Animal Survival Plan).

The advantages of ex-situ conservation are:

- The organism is assured of food, shelter and security, and hence can have longer life-span and breeding activity. Thus, increasing the possibility of having more number of offsprings.
- Under human care and secure conditions, the chances of survival increase.
- Ex-situ conservation also provides the possibility of using genetic techniques to improve the concerned species.
- Captive breeding can provide animals for possible reintroduction to the wild at a later stage or for supplementing current populations with new stock.

However, there are certain limitations and disadvantages of ex-situ conservation:

- Ex-situ conservation can be adopted only for a few selected species because of limitations of space, finances and facilities in the institutions that undertake capitive breeding. This limitation, however, can be solved to a certain extent by having more mini zoos and deer parks which can act as a sink for the surplus, hybrid, aged and infirm animals while the larger zoos can focus on serious captive breeding of endangered species.
- Ex-situ conservation, under a set of favourable environmental conditions, deprives the organism the opportunity to adopt to the ever-changing natural environment. As a result, new life-forms cannot evolve and the gene-pool gets stagnant.

In case of wide-ranging animals or migratory animals or birds, a network should be established to safeguard the habitat of the species.

7. The countries should determine the productive capacities of the exploited species and convince the industries and communities, that are over-exploting their living resources to keep their utilisation at a sustaintable level.

At the international level, conventions, such as Ramsar Convention on Wetlands, World Heritage Convention and the recent Bio-Diversity Treaty in 1992, are of much significance to accelerate conservation.

Biodiversity Treaty समझौता

The Biodiversity Treaty was signed by 171 countries, including India, at the Earth Summit in Rio De Janeiro (Brazil) in June 1992. It came into effect in December 1993. Some of its salient features, whose importance the treaty recognises, are as under :

- Intrinsic value of biological diversity.
- Sovereign rights of states over thick biological resources.
- Desirability of sharing equitably the benefits arising from the use of traditional knowledge, skills, innovations and practices.
- Facilitation of access of genetic resources on mutually agreed terms and with prior informed consert of the country providing these, with commitment on the recipient country to share in the benefits of utilizing the resource thus provided.
- Transfer of relevant technologies, including biotechnology, on fair and most favourable terms, from the developed to the developing nations, who are the main providers of genetic resources.

PROBLEMS

IUCU {World conservation Union} classified different species into 9 red list categories:

① extinct ② extinct in wild ③ Critically Endangered
④ Endangered ⑤ Vulnerable ⑥ Lower risk
⑦ LR near threatened ⑧ Data deficient ⑨ Not evaluated

International union for conservation of nature & Natural Resources.

Category of IUCN Red lists →

① Extinct → no known individuals remaining

② Extinct in wild → known only to survive in captivity

③ Critically endangered → extremely high risk of extinction in wild.
world = 3947 species
Birds = 16 , Animals = 37

④ Endangered → High risk of extinction in wild.
world = 5766 more
Birds =

⑤ Vulnerable → High risk of endangerment in wild
10000+ more

⑥ Near threatened → likely to become endangered in near future

⑦ Least concern → lowest risk. widespread and abundant

⑧ data deficient → Not enough data

⑨ Not evaluated → Has not been evaluated against the criteria

Conservation of Biodiversity :→

D P 4.47

① Ex - situ

- away from natural and under human supervision
- Botanical garden
- Zoo, gene bank etc.
- Seed bank
- Cryopreservation {−196°C liq N_2}
- Aquarium

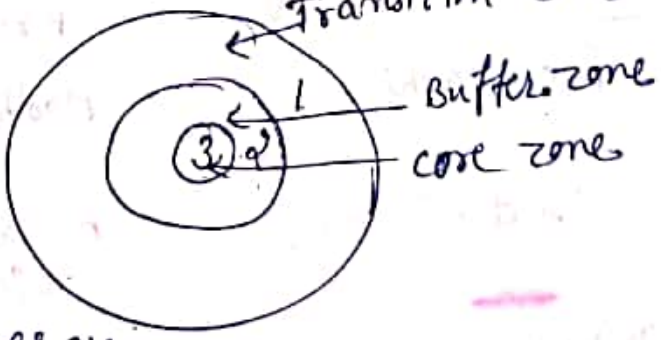
② Insitu / on - situ

- Conserve in natural ecosystem or man-made ecosystem
- applicable to wild life fauna & flora.
- National park
- Sanctuaries
- Biosphere Reserve
- Small garden (Sacred groves)

Biodiversity Treaty:

- signed by 171 countries at Earth Summit in Rio De Janeiro (Brazil) in June 1992. But effect in Dec 29, 1993, has 27 principles for conservation and given in 21th Century so called Agenda 21.

① Biosphere :



Bio sphere reserves are

① Core zone : No activity permitted

② Buffer zone : Scientific research activity

③ Transition zone : Humans, croping, foresty are allowed.

P.T.O

② National Park:

6555 in 2006 in world park.

→ Ist idea of N.P was in United states. Yellowstone National Park, 1872

→ largest N.P in world Northest Greenland N.P, 1974

→ World Ist N.P was established May 19, 1911 in Canada.

→ India Ist N.P was Hailey N.P or Jim Corbett N.P for tiger in 1935 in Uttrakhand.

→ In 1970, 5 N.P ~~2~~ 4

→ Now 120 N.P in india.

→ whole part conserved in N.P.

③ Wild life Sanctuary:

→ India has 515 animal santuaries called wild life Sanctuaries. And among 568, 53[illegible] are tiger Reserves. Some are bird sanctuaries

→ Oldest one was Spike Island Wildlife Sanctuary in Anadaman and Nicobar Island.

→ in Sanctuary not whole part conserved.

Top 15 endangered wild animals species

1. Indian Tiger
2 Ganges Dolphin
3 Gharial
4 Great-Indian Bustard
5 Indian Rhinoceros
6 Lion Tailed Macaque
7. Nilgiri Tahr
8. Sangai Deer
9. Indian Pangolin
10. Wild Water Buff
11. Indian Wild do
12. Red Panda
13.

Endemic Species

1. Asiatic Lion (Gir forest)
2. Kashmir stag
3. Purple frog
4. Sangai Deer
5. Nilgiri Tahr (sheep)
6

Biodiversity

→ The biodiversity refers to totality of genes species & Ecosystem of a region. or simply
→ The biodiversity is the variety of life on earth & their process.
→ This term popularised by Sociobiologist Edward Wilson.
→ various thing which produce variations
(1) Mutation (2) Sexual Recombination
(3) Genetic drift (4) Gene flow

levels of biodiversity:— (old copy also)

① Genetic diversity: genetic variation within each species arises by • nucleotide seq. of particular gene segments
• chrosome number & structure
• linkage bet^{n} genes

② Species diversity: include full range of species on earth The richness of species called species diversity.
Five kingdoms are: animal, plants, fungi, protists (algae prokaryotes (bacteria).

③ Ecosystem diversity:
— global ecosystem type.
— It describes niche, trophic level, energy flow & f
webs.

④ landscape diversity: refers to size and distribution several ecosystems & their interaction with land surf

become concentrated in certain tissues of higher organisms including humans : For example, DDT and polychlorinated biphyenyls (PCBs) in the fat ; radioisotopes like strontium-90 in the bone and radio-iodine in the thyroid. This can damage the affected and surrounding tissues. Pollutants or wastes initially discharged into water or the atmosphere may exchange between these two segments : For example, airborne dust may settle on water and sink ; or polluted water may form aerosols or contaminate ground water which surfaces at a different time and place.

The various types of pollutions, namely, air, water, soil, marine, noise, thermal and nuclear (radioactive) pollution (along with their causes/sources, effects and control measures) are discussed subsequently in this chapter followed by solid waste management and disaster management.

5.2 AIR POLLUTION

Air pollution is basically the presence of foreign substances in air in excessive concentration which adversely affects the well being of the individual or causes damage to property. Wherever we live, the air is contaminated to some degree. The earliest pollutants noted in the atmosphere were of natural origin; like smoke, fumes, ash and gases from volcanoes and forest fires, or sand and dust from windstorms, or any other natural sources. But the real problems of air pollution came on the scene when human induced or anthropogenic sources started emitting pollutants. Considering all these, specific definitions of air pollution are given or adopted by different organisations and countries.

According to World Health Organisation, air pollution is defined as, "substances put into air by the activity of mankind into concentration sufficient to cause harmful effect to his health, vegetables, property or to interfere with the enjoyment of his property."

Indian Standards Institute define air pollution as, "Air pollution is the presence in ambient atmosphere of substances, generally resulting from the activity of man, in sufficient concentration, present for a sufficient time and under circumstances which interfere significantly with the comfort, health or welfare of persons or with the full use or enjoyment of property."

AIR POLLUTION

Unit – II, Unit – VI

Sources:

Sources of air pollution :→

① Stationary { Point — eg. industries, powerplants etc.
Area — eg. residential heating, open burning etc.

② Mobile sources { line — highways, railway etc.
Area — airports, railway stations etc.

Classification: ① Acc. to origin:

① Primary – CO, SO_x, NO_x, HC, particulates
more than 90% pollution

② Secondary – ozone, PAN, formaldehyde, Mists, smog etc.

② Acc. to Chemical Composition :→

(i) Organic : C & H also have O, N, S, P eg. HC, aldehydes, ketones, organic sulphur etc.

(ii) Inorganic: CO, CO_2, SO_x, NO_x, O_3 etc.

③ Acc. to State of Matter :→

(i) Particulates :→ solid and liquids dispered into gaseous media

Solid particulate : dust, smoke, flyash, fumes etc.
liquid " : mist, spray, fog etc.

(ii) Gaseous :→ organic: benzene, CH_4, butane, aldehydes, ketones
inorganic: CO_2, SO_x, CO, NH_3, H_2S, NO_x etc.

2. According to Chemical Composition

On the basis of chemical composition, air pollutants can be divided as—organic and inorganic air pollutants. Organic compounds contain carbon and hydrogen, and many also contain certain elements such as oxygen, nitrogen, sulphur and phosphorus. Examples of *organic air pollutants* are hydrocarbons, aldehydes, ketones, carboxylic acids, organic sulphur compounds, etc. *Inorganic air pollutants* include compounds, such as CO, CO_2, SO_x, NO_x, O_3, etc.

3. According to State of Matter

On this basis, air pollutants are classified as—particulate and gaseous air pollutants. *Particulate air pollutants* include finely divided solids and liquids dispersed in gaseous media. Dust, smoke, fly ash, flumes, etc., are examples of solid particulates ; while mist, spray, fog, etc., are liquid particulate air pollutants. *Gaseous air pollutants* are organic gases like benzene, methane, butane, aldehydes, ketones, etc., as well as inorganic gases like CO_2, SO_x, CO, NH_3, H_2S, NO_x, etc.

5.2.4 Effects of Air Pollution on Human Health

The air we breathe has not only life sustaining properties, but also life damaging properties. An average man breathes 22,000 times a day and takes in 16 kg of air each day. The impurities in the inhaled air can affect human health in a number of ways, depending upon the nature and concentration of the pollutants, duration of exposure, and age group of the receptor. Depending upon the chemical nature of the pollutants, some pollutants may be harmful when present in small concentrations and others only if they are present in high concentrations. The duration of exposure to polluted air is also an important factor. The infants, elders and those with chronic diseases of the lungs or heart are more susceptible to the effects of air pollution. It has also been observed that the effect of air pollution on human health is worst or maximum during winter season, when pollution levels reach a climax. The various health effects are as under :

(*i*) Eye irritation can be caused by many air pollutants such as NO_x, O_3, PAN, smog, particulates, etc.

(*ii*) Nose and throat irritation can be caused by SO_2, NO_x, insecticides, pesticides, etc.

(*iii*) Gaseous pollutants like H_2S, SO_2, NO_2 and hydrocarbons can cause odour nuisance even at low concentrations.

(*iv*) Irritation of the respiratory tract can be caused by SO_x, NO_x, O_3, CO, etc.

(v) Increase in mortality and morbidity rate.

(vi) A variety of particulates, particularly pollens, can initiate asthmatic attacks.

(vii) High concentrations of SO_2, NO_2, SPM (suspended particulate matter) and photochemical smog can aggravate chronic pulmonary diseases like bronchitis and asthma.

(viii) Carbon monoxide, which is two hundred times more reactive than oxygen, combines with haemoglobin in the blood and consequently increases stress on those suffering from cardiovascular and pulmonary diseases. Similarly, nitric oxide (NO) can react with haemoglobin and reduce the oxygen carrying capacity of the blood.

(ix) Hydrogen fluoride can cause fluorosis and mottling of teeth.

(x) Air pollutants such as polycyclic organic compounds, aliphatic hydrocarbons, etc. can cause cancer.

(xi) Dust particles can cause dust specific respiratory diseases, such as, *silicosis* (associated with silica dust), *asbestosis* (associated with asbestos dust), etc.

(xii) Heavy metals, like lead (emitted from vehicles), may enter the body through the lungs and can cause poisoning. Its high concentration can damage liver and kidney, and can cause abnormality in fertility and pregnancy, and mental development of children gets affected.

(xiii) Exposure to radioactive isotopes like Iodine 131, Phosphorus 32, Cobalt 60, Radium 226, etc. can cause *anaemia* (iron deficiency), *leukaemia* (RBC deficiency), cancer, and genetic defects.

5.2.5 Effects of Air Pollution on Plants

The primary factor that governs the gas absorption by the plant leaves is the degree of opening of the *stomata*. The stomata are the openings in the leaf, generally in the bottom of the leaf, through which CO_2 enters to play its role in photosynthesis. When the stomata are wide open (day time), the absorption is maximum and vice-versa. As a result, the same conditions that enhance the absorption of CO_2, also expose the plant to injury by absorbing a pollutant gas. Most of the plants close their stomata during night and are, therefore, much more resistant at night. The effects of some of the important air pollutants on plants are given in Table 5.2. The air pollutants that affect plants include SO_2, O_3, fluorides, NO_x, PAN, ethylene, NH_3, mercury, smog, herbicides, etc.

Table 5.2. Effects of Air Pollutants on Plants

S. No.	Pollutant	Effects on plants
1.	SO_2	Bleaching of leaves, *necrosis* (killing of tissues).
2.	O_3	Premature aging, suppressed growth, *necrosis*, bleaching, collapse of leaf.
3.	NO_2	Suppressed growth, bleaching.
4.	Fluorides	*Necrosis* at leaf tip.
5.	Ethylene	*Leaf abscission* (dropping of leaves), *leaf epinasty* (downward curvature of leaf).
6.	PAN	Suppressed growth, silvering of lower leaf surface.

These pollutants interfere with plant growth/yield, and the phenomenon of photosynthesis. Dust, smog, etc. reduce the amount of light reaching the leaf, and also by clogging the stomata may reduce the intake of carbon dioxide. Plant response to air pollutants varies from species to species, for example, some plants are sensitive to fluoride but resistant to sulphur dioxide. The sensitivity of plants to air pollutants depends on many factors, such as, climatic conditions (that include duration of light, temperature, humidity, and light intensity), soil, water and fertility.

5.2.6 Effects of Air Pollution on Animals

The process by which the animals get poisoned is entirely different from that by which human beings exposed to air pollutants are poisoned. In case of animals, it is a two-step process :

(*i*) accumulation of air pollutants in the vegetation and forage; and

(*ii*) subsequent poisoning of the animals, when they eat the contaminated vegetation/forage.

The pollutants mainly responsible for most livestock damage are :

Fluorine : Of all the farm animals, cattle and sheep are the most susceptible to fluorine toxicity. Horses are quite resistant, while poultry are probably the most resistant to fluorine of all the farm animals. Fluorine is a cumulative poison under conditions of continuous exposure to subacute doses. Its effects are lack of appetite, rapid loss of weight, lameness, periodic diarrhoea, muscular weakness, wearing of teeth, and death.

Lead : Chronic lead poisoning has been observed frequently in animals that have been grazing near smelters and lead mines. It causes paralysis and difficulty in breathing. In case of acute lead poisoning, the

onset is sudden and the course is relatively short. There is complete loss of appetite, paralysis, and diarrhoea.

Arsenic : In acute cases, it can cause severe salivation, thirst, vomiting, irregular pulse and respiration, abnormal body temperature, and death in few hours. Chronic arsenic poisoning causes cough, diarrhoea, anaemia, abortion, paralysis, and death.

5.2.7 Economic Effects of Air Pollution

Air pollution damage to property/material is a very important economic aspect of pollution, and it covers a wide range :

(*i*) *Corrosion* : Air pollution damages materials chiefly by corrosion of metals. The prime air pollutant responsible for metallic corrosion is SO_2. In the presence of oxygen and moisture, it is converted to sulphuric acid. Deposition of this acid on metal parts of building roofs, railway tracks, overhead wires, metal on bridges, and other structures cause enormous loss due to corrosion.

(*ii*) *Damage to building materials* : The acid deposition reacts with lime stone, marble, and other building materials to cause deterioration and disfigured the building materials.

(*iii*) *Damage to paints and protective covering* : Pollutants like SO_2, O_3, H_2S, and aerosols damage protective coating and paints of the surface.

(*iv*) *Damage of textile dyes and textile fibres* : The fading of textile dyes and deterioration of natural and synthetic textile fibres is caused by SO_x, NO_x, and O_3.

(*v*) *Rubber Cracking* : Rubber cracking of tyres and various forms of electrical insulation is caused by ozone and PAN.

(*vi*) *Deterioration of leather and paper* : Sulphur dioxide causes leather to lose much of its strength and ultimately disintegrate; which has posed a serious problem of storage of leather bound books in libraries. The impurities in paper absorb SO_2 and convert it into H_2SO_4 in the presence of moisture, which makes the paper extremely brittle and decreases its folding resistance.

(*vii*) *Effect on glasses and ceramics* : Although glasses and ceramics are especially resistant to the chemical action of air pollutants, but long exposure for years showed a change in their surface appearance.

(*viii*) *Damage to objects of art and architecture* : *Acid rains* cause intangible loss to objects of art and architecture throughout the world. For example, effects on the Taj Mahal, Belur Temple, Cleopatra's needle (a stone structure in London), Statue of Liberty, and many more monuments, paintings (such as Ajanta frescos), antique costumes and other art objects.

(*ix*) Increased transportation costs in period of smog.

(*x*) Loss due to reductions in tourists traffic due to effects of air pollutants on art treasures and tourist centres.

(*xi*) Expenditures due to the adoption of technical measures for the reduction of smoke or other emission from factories.

(*xii*) Expenditures in connection with the administrative organisation of pollution control.

5.2.8 Air Pollution Control

The treatment facilities designed by the environmental engineer are based on the principles of self-cleansing observed in nature ; but the engineered processes amplify and optimize the operations observed in nature to handle larger volumes of pollutants and to treat them more rapidly. Therefore, it becomes necessary to understand the atmospheric self-cleansing processes before studying the approaches to air pollution control.

Atmospheric Self-Cleansing Processes

The atmosphere, like a stream or river, has natural built-in self-cleansing processes. Dispersion, gravitational settling, flocculation, absorption, rain out, and adsorption are some of the most significant natural removal mechanisms at work in the atmosphere.

Though not literally a removal mechanism, *dispersion* of pollutants by wind decreases the concentrations of pollutants at any place. *Gravitational settling* is one of the most important natural mechanisms for removing particulates from the atmosphere, especially particles larger than 20 μm in size. It also plays an important role in several of the other natural atmospheric cleansing processes. In *flocculation*, larger particles act as receptor for smaller ones to form a unit, and the process is repeated until a small floc is formed, which is large and heavy enough to settle under gravity. In the natural *absorption* process, particulates or gaseous pollutants are collected in rain or mist and then settle-out with moisture. This phenomenon is known as *washout or scavenging*, it takes place below cloud level. *Rainout* is another natural cleansing process that occurs

Since there are only a very few devices which are effective in the control of both particulate and gaseous contaminants, therefore, the control devices are normally designed to control either one or the other. In terms of volume of pollutants, the control of gaseous air pollutants is of primary importance ; however, in actual practice, greater emphasis is toward the control of particulate contaminants, perhaps because they are more easily seen. Therefore, control of particulates from stationary sources is discussed first ; while the control of gaseous contaminants from stationary sources is discussed after. The control of particulate and gaseous contaminants from mobile sources is discussed later in article 5.2.14 —air pollution from automobiles.

(A) CONTROL DEVICES FOR PARTICULATE CONTAMINANTS

The various types of control devices or equipments used for the removal of particulate matter from stationary sources are briefly discussed as under :

(1) Settling Chamber. It is the simplest type of equipment used for the collection of solid particles. The settling chamber (Fig. 5.1) consists of a chamber in which the carrier gas velocity is reduced, so as to allow the particulates to settle out of the moving stream under the action of gravity on the base of the chamber. The gas velocity in the chamber is kept sufficiently low, so that the settling time of a particle entering the chamber at the top is same or less than the time taken by the flue gas to pass through the chamber.

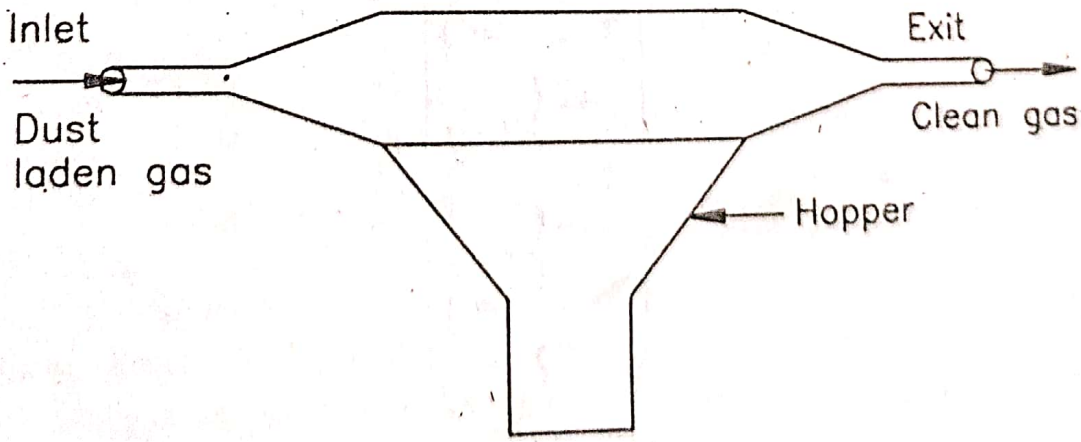


Fig. 5.1. Settling Chamber.

Advantages :

- Low initial cost.
- Simple construction (in brick or stone masonry or concrete).
- Low maintenance cost.
- Dry and continuous disposal of solid particulates.

Disadvantages :

- Large space requirement.
- Comparatively larger size (>10 μm) particles can be collected.

(2) **Cyclone.** It is a structure without moving parts, in which the velocity of an inlet dust laden gas stream is transformed into a combined vortex from which centrifugal forces tend to drive the suspended particles to the wall of the cyclone body. Cyclone (Fig. 5.2) consists of a vertically

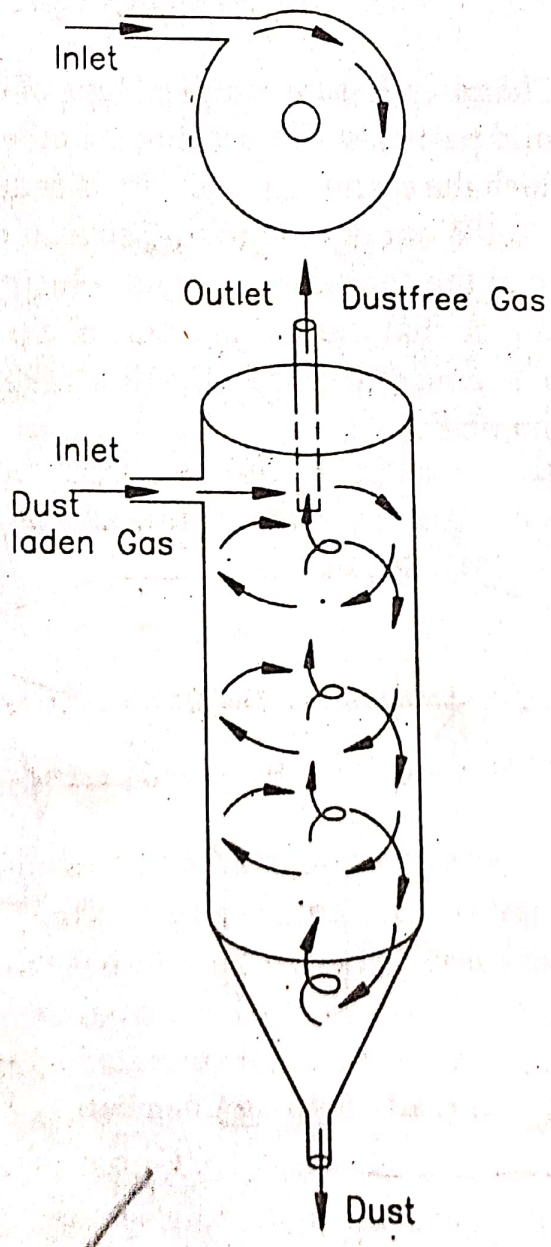


Fig. 5.2. Cyclone.

placed cylinder which has an inverted cone attached to its base. The particulate-laden gas stream enters tangentially at the inlet point into the cylinder. The gas path generally follows double-vortex. First, the gas spirals downwards at the outer periphery of the cylindrical portion, continues through the conical portion and reaches the bottom. The gas stream then moves upwards in a narrower inner spiral, concentric with first one, and leaves through the outlet pipe provided at the top. Due to rapid spiralling movement of the gas, the particles are thrown towards the wall by centrifugal force and they drop downwards by gravity to the bottom of the cyclone body, where they are collected in a storage hopper. The magnitude of centrifugal force employed in cyclone designs vary from 5 to 2500 times gravity depending on the diameter of the cyclone. Cyclone efficiencies are greater than 90% for particles with dia. of the order of 10 μm. For particles with dia. higher than 20 μm, the efficiency is about 95%.

Advantages :

- Low initial cost.
- Simple construction and operation.
- Low pressure drop.
- Low maintenance requirements.
- No moving parts.
- Can be constructed of any material, which will meet the temperature and pressure requirements, and the corrosion potential of the flue gas.

Disadvantages :

- Low efficiency for particles below 5 to 10 μm in size.
- Equipment is subjected to severe abrasive deterioration.

(3) Filters. Particulate matter can be filtered, if the fumes containing them are forced to pass through a filtering device. The particles are held, while the gases pass through the media. Cloth fabric or fibrous medium, like mats of wool, cellulose, etc. may be used as a separator (or filter media). The most common type of fabric collector, used in industries, is *'Bag Filter'* (Fig. 5.3). It consists of numerous vertical bags, 120 to 400 mm dia. and 2 to 10 m long. Dust laden fumes are passed through, under pressure. Periodically, the bag contents are shaken out in dust collection containers. There are several models of bag-filters, in which shaking,

damping and cleaning devices are also added for an overall greater efficiency.

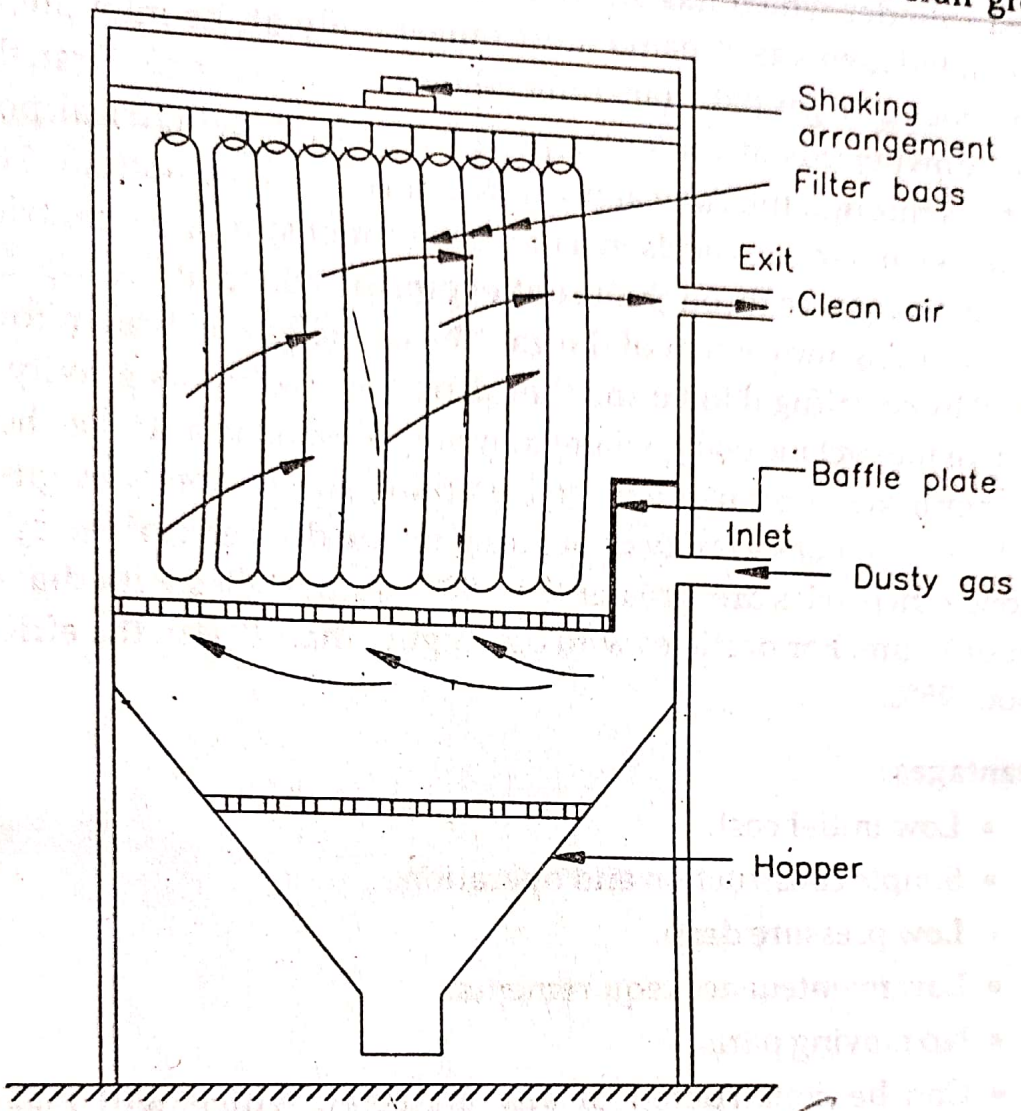


Fig. 5.3. Bag filter.

Advantages :

- High collection efficiency for particles less than 10 μm in diameter.
- Simple construction and operation.
- Normal power consumption.

Disadvantages :

- High maintenance and fabric replacement cost.
- Large size of equipment.
- Operating limits are imposed by high temperature of carrier gas and high humidity.

The concentration of a gas given in $\mu g/m^3$ can be converted in ppm, by using the formula given as under :

$$\mu g/m^3 = \frac{\text{ppm} \times \text{molecular wt. of the gas}}{22{,}400 \times 10^{-6}}$$

5.3 WATER POLLUTION

Generally speaking, *water pollution* is a state of deviation from the pure condition, whereby its normal properties and function are affected. To be more precise, water pollution can be defined as the presence of some foreign substances or impurities in water in such quantity so as to constitute a health hazard by lowering the water quality and making it unfit for use.

Some of the earliest noticeable signs of water pollution are offensive odours from rivers, streams, lakes and ocean beaches ; oily and greasy material floating on surfaces of water bodies ; unchecked growth of aquatic weeds in water bodies ; bad taste of drinking water ; decrease of aquatic life (say fish) in fresh water bodies ; and many more.

Usually, water pollution is studied under the three sub-heads, viz., inland fresh surface water pollution, ground water pollution, and marine water pollution. And it is the inland fresh surface water pollution which is most significant.

5.3.1 Sources of Water Pollution

The main sources of water pollution are natural, agricultural, mining, municipal, industrial and accidental :

(a) Natural pollution may be due to aerial contaminants entering the water body due to rainfall or melting of ice. Decaying of plants, animals and organic matter ; leachates from animal excreta will introduce micro-organisms in water.

(b) Agricultural pollution of water will be due to soil and silt washings from land surfaces, fertilisers, insecticides, pesticides and weed killers.

(c) Mining pollution of water will be due to fines or tailings from ore washing, inert suspended solids, soluble toxic materials and acid drainage.

(d) Municipal pollution of water will be due to sewage obtained from domestic premises, institutions, commercial and industrial buildings.

(e) Industrial pollution of water will be due to the effluents coming from various industries such as food and drugs, chemical, materials and energy.

(f) Accidental spillage of chemicals during loading and transit ; and accidental leakage from industrial storage tanks, oil refineries etc.

The sources of water pollution can be divided into two categories, namely point sources and diffused sources.

1. Point Sources

Those sources which can be readily identified at a single location are known as point sources. For instance—industries, municipal sewage, treatment plants, combined sewer overflow, raw sewage discharges, etc. This type of discharge can be controlled. And the water pollution caused by these sources can be minimized if the effluents from these sources are centrally collected, treated upto acceptable levels and reused.

2. Diffused Sources

Diffused sources or non-point sources are the sources of generalized discharge of waste water whose location cannot be easily identified. Here, the pollutants scattered on the ground ultimately reach the water sources and cause water pollution. For instance—run-off from agriculture lands, forestry, mining, construction, etc. This type of discharge of waste-water cannot be easily controlled. However, water pollution caused by diffused sources like agriculture can be controlled by changing the crop patterns, tillage practices and advanced farm management practices.

5.3.2 Effects of Water Pollution

As we know, water is a vital resource essential for sustaining life ; therefore, its contamination has immediate as well as far reaching effects on the health and environment of living beings. The adverse effects of water pollution can be studied under the following heads :

(*i*) Physical effects.
(*ii*) Oxidation effects.
(*iii*) Toxic chemical effects.
(*iv*) Chemical nutrient effects.
(*v*) Micro-organism effects.
(*vi*) Radionuclide effects.

(i) Physical Effects. These will be due to suspended particle solids, cooling water from power stations and oily surface of films. Solids may be inert material wastes or insoluble finely divided organic solids. Inert material in water may slowly accumulate on vegetation foliage, and produce a deposit on the river bed. These may also cause reduction in solar energy absorption thereby decreasing rate of photosynthesis causing low oxygen conditions on the river bed. Suspended materials

may also cause turbidity which reduces light penetration, reduces plant synthesis and restricts plant growth. Turbidity also reduces food gathering capacity and respiratory efficiency of animals. Finely divided organic solids will be biodegraded and will cause reduction of the dissolved oxygen in water. All these physical effects will cause a disturbance of the balanced ecosystem.

Cooling water from power stations can cause a rise in water temperature and bring about thermal pollution. Variations in temperature will affect the metabolic rate of physiological processes. Increased temperature will cause decrease in fresh water fauna population and increase in flora population. At higher temperatures blue green algae and sewage fungus will grow more which will result in plant death. The oxygen saturation percentage will be reduced and biodegradation will be increased. Both these factors will cause oxygen deficiency in water.

Waste oil, fats and grease can enter water from several sources. These will form a thin film on the water surface which prevents the exchange of oxygen with the atmosphere causing reduction of water oxygen saturation. Spillage from oil tankers in sea will cause marine pollution and shore contamination. Oil slicks are responsible for the death of many birds. Oil reduces the thermal insulation and resisance to cold, irritates digestive system and produces toxic effects. A badly oiled shore can be largely denuded of animal life and sea weeds are also affected.

(*ii*) **Oxidation Effects.** There are two types of oxidation namely :

(*a*) Oxidation by the action of bacteria upon organic pollutants.

(*b*) Chemical oxidation of other pollutants.

Both types of oxidation involves the use of dissolved oxygen. It will cause increase in Biological Oxygen Demand (BOD) resulting in deficiency of oxygen in water. In bacteriological oxidation sulphides are converted into sulphates, ammonia into nitrite and then to nitrate.

In chemical oxidation ferrous salts are converted into ferric salts which are deposited as rusty red gelatinous masses associated with filamentous bacteria which are toxic to biological life.

(*iii*) **Toxic Chemical Effects.** Some organic and inorganic chemical substances are toxic to plants, animals and humans. These toxic substances are absorbed into the tissues from polluted water. They can cause injury leading to death of living organisms. The effects will depend upon the concentration, period of action and the metabolism of the organism.

Chemical toxic substances can be broadly classified as metals and salts, pesticides, acids and alkalies, and organic compounds such as

phenols, cyanides etc. Very small quantities or traces of metals are required for normal growth and metabolism. If Threshold Limiting Value is exceeded then metals may produce physiological poisoning, respiration difficulty, decreased photo-synthesis and growth. Metallic toxicity may be caused by feeding on polluted marine bony and shell fish. Cadmium, mercury lead, chromium etc. may cause damage to liver, kidneys and brain.

Pesticides pollution is due to leachates from agricultural and horticultural land and from food processing plants. DDT, one of the so many pesticides, produces harmful effect over the body.

Acids and alkalies may change the pH value of water from its neutral value of pH 7. Most animals and plants can grow between a pH value of 5 and 9. Changes in pH value may affect physiological processes and actions of toxins.

Polychlorinated biphenyls are by-products of the plastic, lubricant, rubber and paper producing industries. They are stable, insoluble in water, and soluble in oils. These substances are harmful to fishes, predatory birds, marine and shore birds. Cyanides are very toxic to all biological life, and probably prevent enzyme action and immobilize the nervous system in animals and humans. Chlorophenols are toxic to bacteria and fish.

(*iv*) **Chemical Nutrient Effects.** Chemical nutrients are required by plants and animals for maintaining their growth and metabolism. Nitrates and phosphates occur in water in small quantities. These are sufficient to maintain balanced biological growth. The nutrient levels slowly rise as a result of the bio-degradation of dead organic material. This rise in nutrients is called ageing or eutrophication.

Phosphorus is required for the photosynthetic process in plants, for respiration and the production of nuclear DNA. Nitrogen is an essential constituent of proteins. Increased concentrations of nitrates and phosphates in water produce the overall effect of an increase in the rate of growth of plants and animals. Unicellular green and blue green algae and blanket weed reduce light penetration and restrict reoxygenation of water. It will cause adverse conditions for river and canal navigation, and for swimming, bathing and fishing. Nitrates are taken into body by food and drink and excess will cause blood diseases and gastric cancer.

(*v*) **Micro-organism Effects.** Wastes that are discharged into water contain pathogenic organisms that are capable of transmitting human diseases. Bacteria are responsible for cholera, typhoid fever, bacillary dysentery, gastroenteritis. Virus may cause poliomyelitis, infective hepatitis, and echo and consackil fevers. Round worm, beef and pork tape worms may also cause diseases.

(*vi*) **Radio-Nuclide Effects.** The increasing development of nuclear energy is producing more radioactive wastes to be disposed of into the environment, and it contains various radionuclides with long half lives. The nuclear waste into the atmosphere may enter water by a settling process by rains. Solid waste (nuclear) filled in containers is dumped into sea bed. The corrosive action of sea water may cause leakage of radioactive waste in water and it may pose health hazards. Radionuclides can enter the human body through dusts and aerosols and can also be absorbed by plants and animals.

(*vii*) **Eutrophication of Lakes.** The condition of exessive growth of plants, both attached and planktonic, in a water body is called *'Eutrophication'*. It is a natural process of aging of a water body (particularly lakes). It is a result of a very slow process of natural sedimentation of microscopic organisms which takes geologic times to complete. The completion of the process results in the extinction of the water body (lake).

The process of eutrophication is propelled by increasing concentrations of nutrients necessary for biological activity. A lake starts its life cycle as *oligotrophic* (*i.e.*, a clear body of water). In this condition, since the nutrients (P, N, etc.) available are minimal, there is no significant biological activity in the water column that can support sedimentation; and thus, the water body is heathly. With the introduction of nutrients, as time progresses, the lake collects a good amount of organic substances due to algae and other aquatic plant growth.

A lake with nutrient concentration supporting biological activity that is not objectionable but above that of oligotrophic conditions is considered *mesotrophic*. In the next stage, the initial lush green growth is followed by the death of primary producers (aquatic plant life) ; and then there begins the process of decreased D.O. (Dissolved Oxygen), increased B.O.D. (Biological Oxygen Demand), and emission of foul gases. This is because, the balance between the production of aquatic life and its destruction by bacterial decomposition is disturbed. The bacterial decomposition fails to keep pace with the productivity of organic matter, and, thus, sedimentation is accelerated—whereby, the lake becomes *eutrophic*. This is characterised by murky water with an accelerated rate of sedimentation. The eutrophic lake begins to stink, emitting foul smell due to excessive growth of decomposer organisms, exhaustion of D.O. by them, and decomposition and putrefaction of dead algae and macrophytes. The final life stage before extinction is a marsh or swamp.

The life cycle depicted above takes geologic times to complete. However, human activities encourage the production of nutrients and shorten the eutrophication cycle. The major cause of eutrophication of lakes is the excessive discharge of nutrients, particularly phosophorus, from anthropogenic sources. Water bodies around cities, towns and

villages receive enough nutrients from sewage and industrial effluents, and fertilizer rich run-off from agricultural lands and lawns. Despite being an essential element, phosphate (and other nutrients) enrichment of water beyond desired level is a very common feature, and this results into increased fertility, rapid and lush growth of blue-green algae and/or aquatic weeds like water-hyacinth, almost choking the entire water body. This process of over-fertility leads to eutrophication. Continued eutrophication leads to rapid upwelling of the water body and, thus, the limiting capacity of the fresh-water body reduces by silting. This is a serious kind of water pollution, resulting into the death of fishes and an overall disuse of the lake (water body). In fact, many lakes have permanently lost their aquatic entity and have become terrestrial in nature due to eutrophication.

The lakes (water bodies) can be protected from eutrophication, only by preventing the sewage/waste waters and specific industrial wastes which are rich in phosphorus and nitrogen from entering the lakes (water bodies). As far as eutrophication control is concerned, the nutrient of utmost importance is phosphorus.

Algae, particularly blue-green algae which can survive almost anywhere and can easily outgrow other algae under adverse conditions, is the prime cause of eutrophication. It has been observed that blue-green algae can fix nitrogen from the atmosphere as nutrient. Therefore, it is not prudent to control nitrogen. The control of phosphorus is recommended.

In brief, water pollution can lead to spread of epidemics like cholera, jaundice, dysentery, typhoid, etc. ; can cause nervous disorder due to the presence of metals like mercury, lead, copper etc. discharged from industrial effluents ; can affect biological processes of humans and animals if they consume water contaminated by the release of dyes, etc.; and, last but not the least, increased water treatment costs.

5.3.3 Control of Water Pollution

The following measures can be taken to control water pollution :

(*i*) Input control—that is pollutants should be prevented from being generated in the first place.

(*ii*) Output control—that is to control the pollutant and/or its effect after it has been produced.

(*iii*) Developing of proper sewage and industrial effluent systems can reduce incoming point source of pollution.

(*iv*) Extensive afforestation can help in minimizing non-point sources of pollution.

(*v*) Domestic and industrial waste waters should be disposed of (in water bodies or on land) after treatment to the required level/degree.

(*vi*) Strict enforcement of pollution control laws.

In light of the above control measures, the following remedial measures for the control of water pollution are suggested :

(*i*) No intermixing of solid waste or effluent in water source should be done.

(*ii*) Treatment plant for domestic sewage should be designed in such a manner that effluent to be discharged in river may be utilised for irrigation purposes.

(*iii*) Sources of water, for example, ponds, rivers, lakes etc. should be protected by providing enclosures or other suitable methods for the prevention of waste entry.

(*iv*) Bathing, washing, etc. should be prohibited in the vicinity of sources. Pollution caused by animals should also be prevented.

(*v*) Treated effluents from industries should be discharged into water sources. It will be better to treat the effluent from each component of an industry separately.

(*vi*) Excess use of fertilizers, pesticides, insecticides should be discouraged.

(*vii*) Ponds, lakes etc. should be regularly cleaned of aquatic weeds and plants.

(*viii*) Special type of fish breeding which live on mosquito eggs, bacteria, aquatic weeds should be encouraged.

(*ix*) Public awareness regarding water pollution should be created.

(*x*) Legislative controls should be more punitive.

5.3.4 Classification of Water Pollutants

Water is used for various purposes including bathing, excretion, washing, food preparation, cleaning of floors and equipment, industrial operations, agricultural needs, and many more. After using, it is discharged as waste-water which is contaminated by various pollutants. The various types of water pollutants can be broadly classified into following categories :

(*i*) Organic pollutants ;

(*ii*) Inorganic pollutants ;

(*iii*) Radioactive pollutants ; and

(*iv*) Suspended solids and sediments.

1. Organic Pollutants

Organic chemical compounds are of great importance to the human beings and other life forms on this planet. Most of the substances of which living things are composed are organic compounds. In addition, the main foodstuffs (such as fats, proteins and carbohydrates), as well as a number of materials and substances necessary for modern living

Fig. 5.28. Process flowsheet using stabilization pond.

5.4 SOIL POLLUTION

The area of earth which is capable of supporting life is represented by a thin mantle and there is a very complex relationship between this land and the other components of the environment. Man and other animals exhaust the resources of a given area and so natural forces cannot maintain the balance between the material consumed and returned to the soil.

Soil pollution was originally defined as the "contamination of the soil system by considerable quantities of chemical or other substances, resulting in the reduction of its fertility (or productivity) with respect to the qualitative and quantitative yield of the crops". However, if some of the contaminants are such that if they are taken up by the plants (with or without any detrimental effects on the plants), and enter into the food

chain and impart detrimental/toxic effect on the consumers (*i.e.* animals and human beings), then that should also be treated as soil pollution. The soil gets polluted by the following ways :

1. By Agricultural Practices. Agricultural wastes are common pollutants of soil as well as water pollution. Agro-chemicals such as fertilizers, pesticides, insecticides and weedicides cause soil pollution. DDT, BHC, etc. and chemicals like lead, mercury, arsenic, etc. accumulate in the soil permanently.

Soil pollution resulting from excessive use of insecticides, herbicides and fertilizers adversely affect the physical, chemical and biological properties of soil.

2. By Radioactive Materials. Radioactive substances resulting from explosion of nuclear devices also penetrate the soil and enter into food chain. The presence of radioactive substances causes many harmful effects in body tissues. Radioactive radiations also bring about changes through mutation and can cause death of organisms. Hiroshima and Nagasaki, which were bombarded in 2nd World War, are good examples of radioactive soil pollution.

3. By Biological Agents. Other important pollutants are the biological agents including various biological organisms from human and animal excreta. In addition to excreta, faulty sanitation, waste water disposed etc. includes land as well as soil pollution. These also spread various diseases.

Household refuse, Industrial water, Agricultural wastes are tipped on land. By these many chemicals undecided substances enter into surface and get mixed with ground water. These chemicals are harmful for living beings and affect plant and animals' growth.

5.4.1 Soil Pollutants

Natural and synthetic materials that can adversely affect the physical, chemical and biological properties of soil and seriously affect its productivity are called soil pollutants and this phenomenon is called soil pollution. The problem of soil pollution differs from air and water pollution in the respect that the pollutants remain in direct contact with the soil for relatively longer periods. The widespread industrialization and increasing consumption have changed the very complexion of soil. Thus the soil is getting heavily polluted day by day by toxic material and dangerous micro organisms which enter the air, water and food chain. For all this, man is the original and basic pollutant responsible for pollution hazards and toxic effects (Table 5.11).

Table 5.11. Nature of Pollutants in soil

Source	Gases	Colloids	Suspended Particles	Dissolved Cations	Dissolved Anions
Soil	CO_2	Clay, Fe_2O_3, Al_2O_3, MnO_2	Clay Sand Silt	Na^+, K^+ Ca^{2+}, Mg^{2+} Mn^{2+}, Co^{2+} Fe^{3+}	Co_3^{2-}, HCO_3^-, OH^-, Cl^-, SO_4^{2-}, F^-, HSO_3^-
Decomposed Organic matter	SO_2, H_2 NH_3, CH_4, CO_2	Organic waste materials	Humus organic wastes	H^+, Na^+, NH_4^+	Organic radicals NO_3^-, NO_2, SO_4^{2-}, Cl^-
Soil Organisms	—	Algae, Fungi Bacteria, Protozoa, viruses Ascaris etc.	Algae Bacteria	—	—

5.4.2 Sources of Soil Pollution

Soil pollution mainly results from the following sources :

1. Industrial wastes
2. Urban wastes
3. Radioactive pollutants
4. Agricultural practices
5. Chemical and metallic pollutant
6. Biological agent.

1. By Industrial wastes. Disposal of industrial waste is the major reason for soil pollution. These industrial pollutants are mainly discharged from pulp and paper mills, chemical industries, oil refineries, sugar factories, tanneries, textiles, steel industries, distilleries, coal and mineral mining industries, drugs, glass, cement, petroleum industries etc. Thermal, atomic and electric power plants are also the villain to add pollutants to the soil.

Fly ash, many industrial effluents are either discharged into streams or dumped into the surrounding land. Industrial wastes mainly consist of organic compounds alongwith inorganic complexes and non-biodegradable materials. The pollutants affect and alter the chemical and biological properties of soil.

2. By urban wastes. Urban wastes comprise both commercial and domestic wastes consisting of dried sludge of sewage. All the urban solid wastes are commonly referred to as refuse.

Solid wastes and refuse contribute to soil pollution. This refuse contains garbage and rubbish materials like plastics, glasses, metallic cans, fibers, paper, rubbles, street sweepings, fuel residues, leaves, containers, abandoned vehicles and other discarded manufactured products.

Pollution concentration in urban areas and unplanned industrial progress have to a greater extent contributed to soil pollution problems.

3. Radioactive pollutants. Radioactive substances resulting from explosions of nuclear devices, atmospheric fall out from nuclear dust and radioactive wastes penetrate the soil and accumulate there creating soil pollution. Radioactive substances Radium, Thorium, Uranium, Carbon (C-14) are very common in soil, rock, water and air.

The product of nuclear fission, rain water (Sr-90, Cs-137) to be deposited on the soil emit gamma radiation. Recently it has been indicated that some plants such as lichen and mushroom can accumulate Cs-137 and other radio nuclides which concentrate in grazing animals.

4. Agricultural Practices. Agricultural practices pollute the soil to a large extent. Advanced Agro-technology, huge quantities of fertilizers, pesticides, herbicides, weedicides and soil conditioning agents are employed to increase the crop yield. Many agricultural lands have now excessive amounts of plants and animals wastes which are posing soil pollution problems. Farm wastes, manure slurry, debris, soil erosion containing mostly inorganic chemicals are responsible for soil pollution. Some of the agents responsible for this pollution are as follows :

(*a*) **Fertilizers.** Fertilizers are the chemical compounds that contain one or more of the plant nutrients *i.e.*, nitrogen, phosphorous and potassium. Excessive use of fertilizers makes soil pollutate. Fertilizers are retained by the soil and crop efficiently but there are some possibilities for the nitrates to be washed out due to negligence and appliances in applying fertilizers to arable lands. These nitrates cause several undesirable effects on the water quality of low land lakes or rivers creating numerous health hazards.

(*b*) **Pesticides.** By growing population density it is necessary to increase food production. Due to this it led to manipulation of land resources. Different kinds of pesticides used to control pests are causing a stress in the natural environment. With the increasing use of pesticides it is observed that pesticide residues coexist within biological system with other forms of life.

(*c*) **Soil conditioners and other chemical agents.** In addition to the fertilizers, pesticides and biocides, soil conditioners and fumigants are also employed to the land system to increase and protect the soil

fertility, to kill the hazardous insects. These chemical agents are reported to cause alterations in both agricultural and horticultural soil areas. They contain several toxic metals such as Pb, As, Cd, Hg, Co etc. which when applied to a land will accumulate on the soil permanently thereby introducing these chemical components into growing crops.

(*d*) **Farm Wastes.** Increasing population of cow, cattles etc. have resulted in considerable soil pollution. Buildings in which grazing animals are housed can be cleaned using water but the manure is also washed out and deposited as wet slurry on the land. This slurry deposited on soil may seep into ground water and pollute it. Cattles faecal matter mainly consists of phosphates which in conjunction with nitrates cause numerous undesirable effects in the soil texture.

5. Chemical and metallic pollutants. A number of industries including textiles, dyes, soap and synthetic detergents, drugs, cement, rubber, paper and pulp etc. and metal industries pour their hazardous effluents in soil and water creating disastrous effects on living organisms.

Synthetic chemicals and fertilizers are a source of trace metals which are added to the soil either deliberately or as an impurity. In many soils 50 to 100% of soil carbon is found complexed with clay containg organic and inorganic components which affect the soil texture, its fertility and stabilization of soil organic matter.

6. Biological Agents. Soil gets large quantities of human, animals and birds excreta which constitute the major source of land pollution by biological agents. Digested sewage sludge as well as heavy application of manures to soil without periodic leaching could cause chronic salt hazard to plants within a few years. Sludges to have faults as they contain enough live viruses and viable intestinal worms. The pathogenic organisms that pollute the soil may be classified into three major categories :

(*a*) **Pathogenic organisms occurring naturally in contaminated soil.** Bacteria algae, protozons nematodes etc. These organisms are important agents in increasing or decreasing the soil fertility, in altering the physical texture of the soil and in attacking roots of plants.

(*b*) **Pathogenic Organisms Excreted by Man.** Human excreta includes pathogens such as enteric bacteria and parasitic worm such as tenia solium. These organisms are transmitted to the man by the consumption of vegetables or fruits.

(*c*) **Pathogenic Organisms Excreted by Animals.** This category includes pathogenic bacteria and worms excreted by animals like earth-worms, millipedes, dipterous larvae, snails including higher animals carry fungal and bacteria spores. The disease producing organisms are transmitted from animals to soil and then from soil to man.

7. Other Sources. Some other sources by which soil gets polluted are :

(*a*) By absorption of toxic metals.
(*b*) By soluble salts.
(*c*) By mining.
(*d*) By waste water added to soil.
(*e*) By solid waste applied to soils.
(*f*) By food processing wastes.
(*g*) By sugarcane trash in field.
(*h*) By municipal garbage and composts.

5.4.3 Causes of Soil Pollution and their Control

The causes of soil pollution can broadly be classified as—direct causes and indirect causes. Direct causes include poor waste management, application of agro-chemicals, faulty sanitation practices, salination due to irrigation and floods, and soil erosion. Indirect causes include acid rain and disposed radioactive substances.

The above-said causes of soil pollution along with their control are briefly discussed as under.

1. Poor Waste Management

Wastes are unwanted and useless substances resulting from different human activities. The wastes can be solid wastes and/or liquid wastes.

(*i*) Solid Waste and its Control. Unwanted or discarded substances that have weight size are called solid wastes. It includes sewage sludge, domestic and municipal solid waste, industrial solid waste and agricultural solid waste.

The waste preventive approach, which considers solid waste as a resource, suggests two measures—reduction in solid waste, and reuse and recycling. Solid waste can be reduced by manufacturers by using less material and redesigning manufacturing processes. Further wastes can be reused after repairs and also can be recycled. For example solid waste like glass, metals, plastic, paper, etc. can be segregated and recycled.

Finally, the control of solid waste can be done by using proper disposal methods such as composting of biodegradable solid waste, incineration of non-biodegradable, pulverization, sanitary landfilling, etc. (as discussed in earlier chapter).

(*ii*) Liquid Waste and its Control. Liquid waste from point sources, such as domestic and industrial waste waters, not only cause water pollution but soil pollution too.

To control soil pollution from these sources, municipal and industrial waste waters have to be properly collected, treated and disposed-of scientifically in water bodies or on lands. Proper care must be taken in treating heavy metal and other toxic waste materials.

(*vii*) The degradation of agro-chemicals in the environment is slow and this results in increasing concentration. This is dangerous for all living things.

(*viii*) Due to the overuse of these harmful chemicals pests, insects have developed resistance.

(*ix*) The chance of accidents increases where these agro-chemicals are manufactured. *e.g.* Bhopal gas tragedy.

(*x*) These substances disturb predators, and thus may disturb the ecological balance in nature.

Control. Soil pollution due to agro-chemicals can be controlled by the following ways :

(*a*) **Biological control.** The utilisation of one or more organisms for the suppression of population of a particular pest.

It includes all pest control measures except the use of chemical pesticides. The organisms which are commonly used for the control of pests are predators, parasites, pathogens, etc.

Biological control is based upon the principle that in any stable habitat, the resident species show only minor inter-relationships among them. There are four types of biological control of pests :

(*i*) Classical biological control

(*ii*) Inoculation

(*iii*) Augmentation

(*iv*) Inundation.

(*i*) Classical biological control deals with introduction of *exotic* species for long term suppression and regulation of pest population.

(*ii*) Inoculation deals with periodic establishment of controlling agents as these cannot thrive throughout the year.

(*iii*) Augmentation deals with supplemental release of local natural enemies for increased suppression of the pest population.

(*iv*) Inundation is the process where several agents are released to control a single generation of the pest without caring for the effects on subsequent generations.

(*b*) **Microbial control of pests.** The use of pathogens for the suppression of pest population is commonly known as microbial control. Nematodes, protozoas, bacteria, fungi and viruses are the pathogens which are used for microbial control of pests.

(*c*) **Integrated pest management instead of use of pesticides for the purpose of soil conservation.** The biological control, genetic control,

chemical control, cultural control, environmental control, behavioural control, mechanical control etc. are integrated to control the target species. Specific method is used to suppress the pest at specific time at the specific stage of life cycle.

Environmental control involves the alteration of biotic and abiotic environment. Crop diversity, time of plantation can be altered etc. Method can be used to control the pollution.

The pest management is needed today keeping the following points :

(*i*) Destroying bugs and weeds by hands.

(*ii*) Use crop rotation, hetero culture, time planting, natural predators, genetically resistant plants and animals.

(*iii*) Minimum use of insecticides and pesticides.

3. Faulty Sanitation Practices

Sanitation means the whole field of controlling the environment with a view to prevent disease and promote health. The term "environmental sanitation is now being replaced by environmental health." WHO explained environmental sanitation as— "The control of those factors in man's physical environment which exercise or may exercise a deleterious effect on his physical development, health and survival." Faulty methods of sanitation cause soil or land pollution. The soil conservation depends upon proper use of methods of checking soil pollution as a result of faulty sanitation methods. We should use methods for efficient collection, removal and disposal of solid waste. Human secretes is a source of infection.

4. Salination due to Irrigation and Flood

Water soluble salts have adverse affect on soil productivity and degrades the quality of land as well as soil. Intensive farming with poor drainage is causing serious salination damage in large areas of our country.

5. Soil Erosion

Soil erosion is a comprehensive natural process of detachment and removal of loosened soil materials by exogenetic process *i.e.*, by water, wind, ice or gravity. In other words, erosion is the wearing away of the land surface by running water, wind, ice or other geological agents.

Soil erosion is increased due to agricultural development, construction and strip-mining activities. There are numerous ways by which the fertile top layer is lost and wasted. This slow removal of the top soil and disturbances in the soil texture is called soil erosion. According to Rama Rao, "Soil erosion is creeping death of soil". It is also a part of soil pollution, Increasing deforestation in the watershed areas has led to massive soil erosion.

(*ii*) The wastes including building materials, sludge, dead animal skeletons, and thrown away garbage pile up at public places and cause obstruction in daily life.

(*iii*) Sewage is the good medium for the growth of pathogenic bacteria, viruses etc. Vibriocholera found in sewage causes cholera.

(*iv*) Solid wastes result in offensive odour and cause clogging of ground water filters. Suspended matter in sewage can blanket the soil, thereby interfering with the soil moisture.

(*v*) The use of polluted ground water containing human excreta, sewage sludge decrease soil fertility by killing micro organisms.

3. Effects of Radioactive Pollutants. The problem of radioactive wastes dumped into the soil is more complicated. Radioactive elements can remain active in soil for long times. Harmful effects of radioactive pollutants are :

(*i*) Radioactive pollutants can produce great human misery when food containing radionuclides is taken by man, some of them concentrate in specific body organs and cause undesirable diseases.

(*ii*) Radiation actually affects the soil and soil fertility. These radiations kill plant species.

Variations in radio sensitivity among tree and shrubs are due to differences in their chromosome number and size.

(*iii*) A recent report indicates that a large number of induced radio nuclides as carbon-14, Fe-55, Mn-54, Co-57 etc. get concentrated in biological systems.

4. Effects of Modern Agro-technology

Effects of Fertilizers :

(*i*) Potassium fertilizers in soil decrease the valuable nutrient ascorbic acid (vitamin C) and carotene in vegetables and fruits.

(*ii*) Excessive use of nitrogenous fertilizers in land leads to accumulation of nitrate in the soil. This excess accumulation can cause diarrhoea and cyanosis in children.

(*iii*) Phosphate fertilizer is considered detrimental to crop production.

(*iv*) Cereal crops like jawar, maize etc. grown on alkaline soil absorb higher amounts of fluorides and are responsible for the spread of fluorosis.

Effects of Pesticides :

(*i*) Pesticides retained in soil concentrates in crop, vegetables etc. which taint them to such an extent that they are not usable.

(*ii*) Pesticides like DDT, endrin etc. are known to seep gradually through soil into ground water and contaminate drinking water supplies.

(*iii*) Organo phosphates pesticides cause extreme muscular weakness, tremors and dizzines in poisoned animals.

(*iv*) Longer lasting effects of pesticides are visible in animals and man where they affect the tissues and interfere in the normal metabolic activities.

5.4.5 Diseases Caused by Soil Pollution

Soil flora and fauna make the biological system of soil complex. Some organisms also help in maintenance of soil fertility while majority of microorganisms act as chronic pollutants. Soil has been a potential carrier of microbial growth, non-biodegradable matters and pathogens which endanger human health and life.

(*i*) Pathogenic soil bacteria are (chronic disease carriers) transmitted from man to soil or vice versa causing cholera, typhoid etc.

(*ii*) Pathogenic soil bacterial mycobacterium, Leptospira etc. are causes of infection of amoebic dysentery, cholera, polio, hepatitis etc.

(*iii*) The eggs of parasitic worms helminthes get incubated in the soil, and causes *intestinal* hook worm diseases.

(*iv*) Common viruses (polio, hepatitis) present in sewage added to soil are causes of paralysis.

(*v*) Some of the animals' diseases are transmissible to man and soil. Leptospirosis, Anthrax and fever are some of diseases belonging to this category.

(*vi*) Fungus generally develop in soil or *vegetation*. They cause serious subcutaneous and systemic mycoses.

(*vii*) Algae poison is considered to be the most virulent poison which produces cirrhosis of liver.

Soil provides the best medium for the growth of eggs, *larvae* and flies etc. Many important tropical diseases (like malaria, filariases) have blood sucking flies as vectors; while schistomiases is transmitted by *snails*. Table 5.12 states some diseases associated with pathogens present in soil and water.

Table 5.12. Some Soil and Water Diseases

Pathogen	*Diseases*
1. Salmonella choleraesuis	Chronic fever
2. Lice	Typhus
3. Hook worm	Skin diseases
4. Mosquitoes	Urban yellow fever
5. Anopheles mosquito	Malaria fever

ention of erosion of radioactive waste disposal sites.
ention of any drilling activity in and around the waste
osal site.

(*iv*) Periodic and long term monitoring of such disposal sites and areas of naturally occurring uranium rich rocks.

5.9 SOLID WASTE MANAGEMENT

All solid and semi-solidwastes arising from human and animal activities, except human-excreta and sullage (liquid wastes from bathrooms, kitchens, etc.), are discarded as useless or unwanted are included in the term 'Solid-Wastes' or 'Refuse'. It includes garbage, rubbish, ashes and residues, demolition and construction wastes, dead animals, radioactive wastes, etc. The quantity of solid-wastes produced depends upon the living standards of the population, It will be more for an industrialized modern society. It also depends on seasons.

A few important terms used in solid-wastes are :

Rubbish. It includes combustible and non-combustible solid-wastes, excluding food wastes or putrescible materials. Combustible rubbish includes paper, card-board, textiles, plastic, rubber, wood, garden-trimmings, etc. Non-combustible rubbish consists of glass, crockery, tin-cans, aluminium cans, metals, construction wastes, etc.

Garbage. It includes putrescible organic waste like the animal, fruit or vegetable residues resulting from the handling, preparation, cooking and eating of foods.

5.9.1 Types and Sources of Solid-wastes

There are three general categories of solid-wastes :

(*i*) Municipal wastes,

(*ii*) Industrial wastes, and

(*iii*) Hazardous wastes.

Municipal wastes. Municipal wastes are those wastes which arise from household activities, restaurants, public places, institutions, markets, street-sweepings, etc. and typically include garbage, rubbish, ashes (due to burning of coal, wood etc.), demolition and construction wastes, street-sweepings, dead animals, etc. and also treatment plant waste. The general sources of municipal solid-waste are residential, commercial (markets, hotels, garages, institutions, etc.) and open areas (streets, parks, beaches, highways, play grounds), etc.

Industrial wastes. Industrial wastes are those wastes which arise from industrial activities, and typically include rubbish, ashes, construction and demolition wastes, special wastes and toxic wastes.

Hazardous Wastes. Are those wastes that pose a substantial danger immediately or over a period of time to human, plant or animal life. A waste is said to be hazardous if it exhibits any of the following characteristics, viz., ignitability, corrosivity, reactivity or toxicity. Typical hazardous wastes are radioactive substances, chemicals, biological wastes, flammable wastes, and explosives. The sources of hazardous wastes are industries, nuclear plants, hospitals, research institutes, laboratories, etc.

5.9.2 Causes of Solid Wastes

The main causes for the rapid growth in the quantity of solid wastes are :

(*i*) **Over-population.** The ever increasing population is increasing all types of pollution. Same is true for solid waste pollution too.

(*ii*) **Urbanization.** Solid waste is primarily an urban probem, though it is not exclusively urban. Solid waste pollution increases with the increase in urbanization. In developed countries, for instance in USA urban areas produce about 7.0 lac tons of solid wastes each day—an amount sufficient to cover more than 1.6 sq. km. of land every day to a depth of 3.0 m.

(*iii*) **Affluence.** With production or per capita consumption, there is a tendency to declare items as obsolete, resulting in their discard. This leads to solid waste pollution.

(*iv*) **Technology.** Rapidly growing technologies for most economic goods are leading to returnable packaging to non-returnable packaging. For example, returnable glass bottles/containers being replaced by non-returnable cans, plastic containers, etc.

5.9.3 Effects of Solid Wastes Pollution

The improper handling and transfer of the solid wastes results in various health and environmental hazards, such as :

- Diseases like bacillary dysentery, diarrhoea and amoebic dysentery may result in humans from food and water contamination through flies, which breed on the refuse dump and solid waste.
- Rats depending upon these solid wastes may also cause plague, salmonellosis, trichinosis, endemic typhus like diseases through direct bite.
- The crops and water supply may also get contaminated and

may result in large scale epidemic of cholera, jaundice, gastro-intestinal diseases, hepatits etc.

- Solid wastes may also choke the drains and gully pits resulting in water logging, which in turn results in the breeding of mosquitoes and thus danger of malaria and dengue.
- There is also aesthetic danger to the surrounding environment, as the stray animals and scavengers invade the garbage dumps of roadsides.
- Obnoxious ordours also pollute the air due to decomposition of organic solid wastes.
- Noxious fumes may pollute air due to the burning of waste products especially plastic containers.
- Percolation of decomposed garbage dumps into soil may result into pollution of underground water and land.

5.9.4 Methods of Solid-wastes Disposal

The various methods of solid-wastes disposal are :

- Land filling,
- Incineration,
- Pulverization,
- Composting,
- Pyrolysis, and
- Disposal into sea.

1. Disposal of Solid-Wastes by Land Filling

In this method, solid-wastes are carried and dumped into the low lying areas. The refuse is filled up or dumped in layers of 1.5 m or so and each layer is covered by good earth of atleast 20 cm thickness, so that refuse is not directly exposed. Each layer is left out for atleast seven days and compaction by trucks is carried out for its settlement, before starting filling the next layer. Insecticides like DDT should be sprayed on top to prevent breeding of mosquitoes and flies.

With the passage of time, the filled up solid-wastes will get stabilized by the decomposition of the organic matter and subsequent conversion into stable compounds. Hydrolysis of complex organic matter takes place under anaerobic conditions and as a result gases like CH_4, CO_2, H_2S, etc. are evolved and also simpler water soluble organic acids are formed which diffuse through the soil. For better biological degradation the moisture content should be less than 60%.

The refuse gets stabilized, generally, within a period of 2 to 12 months, and settles down by 20 to 40% of its original height. Unequal

settlement and odour may be there for the first few years. But after that the land can be used for developing parks or other recreational use.

Advantages :

- Simple and economical.
- No costly plant and equipment is required.
- Skilled labour is not required.
- Separation of different kinds of solid-wastes is not required.
- No residue or by-product ; hence no further disposal.
- Low-lying areas can be reclaimed and put to better use.

Disadvantages :

- Large land area requirement.
- Continuous evolution of foul smell near the site of disposal.
- Use of insecticides is required.
- Covering good earth required for top layer may sometimes be difficult to obtain.
- The biggest disadvantage is formation of 'leachate'. It is a coloured liquid formed due to seepage of rainy water into the land fill. This water may dissolve the harmful and carcinogenic compounds present in the refuse. When such a polluted water contaminates the ground water, it may lead to diseases like cholera, typhoid, polio, etc.

Sometimes 'trenching' is also adopted, when low lying areas are not available. Trenches of size 4 to 10 m long, 2 to 3 m wide, and 1 to 2 m deep are excavated with a clear spacing of 2 m or so. These trenches are then used for the disposal of solid-wastes in the same manner as the low lying areas.

2. Incineration

Incineration means burning of the solid-wastes in properly constructed hearth of furnaces. This method is generally used when suitable dumping land areas are not available and disposal in sea is not possible. When solid-waste is collected together, it is better to separate the non-combustible and inert material like earth, broken glass, chinaware, metals, etc., so as to reduce the load on the hearth. The combustible garbage, rubbish and dead animals are only burnt. The minimum temperature in the combustion chamber should be greater than 670°C to incinerate all the organic matter and oxidize the foul smelling gases. If steam is to be generated then a temperature of about 1000°C is to be produced in the combustion chamber. Each batch of solid-wastes entering the furnace should be well-mixed and the proportion of the fuel in the charge be adjusted to provide complete combustion and proper

temperature. When the moisture contents of the solid-wastes is high, auxiliary fuels like wood, coal or oil may be used.

The final products will be ashes and clinkers. The ashes are dispersed by dumping in low lying areas, while the clinkers can be used as aggregate for low grade concrete or as road material.

Advantages :

- The method is sanitary, as all the pathogens and insects are destroyed.
- No odour and dust nuisance.
- Same revenue can be generated by raising steam power and selling of the clinkers.

Disadvantages :

- Relatively high initial cost.
- Nuisance of smoke, odour and ash during the improper functioning of incinerators.

3. Pulverization

In this method, the solid-waste is pulverized in grinding machines so as to reduce its volume and change its physical character. By doing so it becomes practically odourless and unattractive to insects. Although it contains fertilizing elements, but it cannot be suitably used as a manure. It has to be further disposed of by land filling. The method is quite costly, and hence not commonly used, particularly in India.

4. Composting

In this method the putrescible organic material in solid-wastes is digested anaerobically and converted into humus and stable mineral compounds. Its volume is also considerably reduced and is made free of most of the pathogenic organisms so that is can be easily and safely handled. It is a hygienic method which converts the solid-wastes into manure through anaerobic bacterial action. This method is best suited to Indian conditions, especially for small and medium size towns ; since it solves three problems simultaneously—disposal of solid-wastes, disposal of night soil (where there is no water carriage system of sanitation), and production of valuable manure for crops.

There are three methods of composting, as explained below :

Composting by Trenching. In this method, trenches 4 to 10 m long, 2 to 3 m wide and 0.7 to 1.0 m deep are excavated at a clear spacing of 2 m. Solid-waste is disposed of into these trenches in layers of 15 cm and by sandwiching 5 cm layers of night soil or animal dung in semi-liquid form, till the heaps so formed rise about 30 cm above the original ground

5. Pyrolysis

In pyrolysis, the chemical constituents and chemical energy of some organic wastes is recovered by destructive distillation of the solid waste. In pyrolysis, the combustible constituents of the solid-waste are heated in a specially designed retort like chamber, known as pyrolysis reactor at 650 to 1000°C in an oxygen-free (or low-oxygen) environment. Pyrolysis is an endothermic process and thus differs from the conventional incineration. Its merits and demerits are same as that of incineration process discussed earlier.

6. Disposal into Sea

This method of solid-wastes disposal can be used in coastal areas having deep sea water (> 30 m) at a reasonable distance (< 16 to 20 km), and with strong forward currents. This is quite a simple and cheap method, but it has following disadvantages :

- The bulky and lighter components of solid-wastes float, spread, and tend to return to the shores during high tides.
- During monsoons or stormy weather, solid-waste has to be either stored or disposed of by some other methods.
- Some portion of the solid-wastes may return and spoil the beaches, despite all the necessary precautions.

5.9.5 Choice of Method of Disposal

Initial cost, availability of land trained personnel for operation and maintenance of the plant and equipment are some of the important considerations for selecting a particular method for the disposal of solid-wastes. The advantages/feasibility of various methods of disposal are discussed under :

(*i*) Uncontrolled dumping is the cheapest method of solid-wastes disposal ; but it is neither hygienic, nor free from nuisance.

(*ii*) Manual composting is cheap and can pay for its cost by selling the manure produced ; but it requires large land areas. Therefore, it can be suitably used for smaller towns, where land is easily and cheaply available.

(*iii*) Land filling can be adopted when large areas of low lying waste-land are available. These areas can be reclaimed for further growth and development of the city.

(*iv*) Mechanical composting requires less land area, and can compete in cost with sanitary land fill by selling the compost.

(*v*) Incineration is very costly process, about 3 to 4 times (even if heat generated is utilized for power generation) costlier than other methods. Though it requires small area, its initial cost is quite high and again skilled supervision is required.

(*vi*) Disposal into sea is confined to very few coastal cities which are favourably located.

5.9.6 Solid Waste Management

Indiscriminate disposal of solid wastes causes adverse environmental effects. The main objective of solid waste management is to minimize these adverse effects before it becomes too difficult to rectify in the future. The principle objectives of solid waste management include collection, processing and disposal of solid wastes in an economical manner consistent with the protection of public health.

Solid waste management may, thus, be defined as the application of techniques that will ensure the orderly execution of the functions of collection, processing and disposal of solid waste. These functions are called the 'three basic functional elements of solid waste management'.

1 Collection is the first fundamental function of solid waste management. It refers to the gathering of solid wastes from places such as residences, commercial, institutional and industrial establishments, and other public places. Generally, there are two methods of collection—*hauled-container system* and *stationary-container system*. In the hauled-container system, the container is hauled from the collection point to the final point of disposal, processing facility, or transfer station. In the stationary-container system, the container is emptied into collection vehicles at the point of collection.

2 Processing is the second fundamental function of solid waste management. It refers to the activity applied to solid waste to prepare it for subsequent operation. Processing improves the efficiency of solid waste disposal and prepares solid waste for subsequent recycling and recovery of materials.

3 Disposal is the third fundamental function of solid waste management. It refers to the placing of solid waste in its ultimate resting place. The various methods of solid waste disposal have already been discussed earlier.

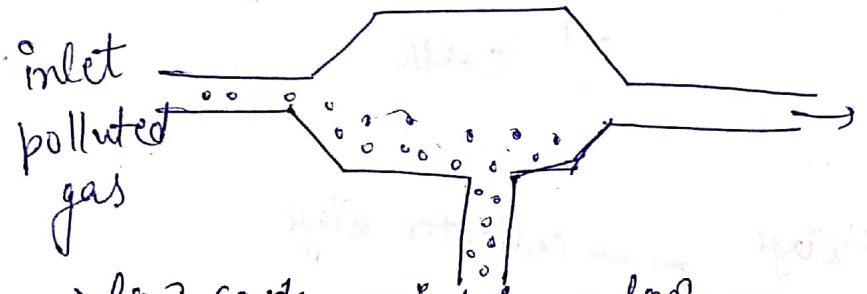
5.9.7 Recycling of Solid Waste and Its Management

The recovery of solid waste components for possible use as raw materials is called recycling or salvaging. It involves separating materials (such as scrap metal, glass, paper, plastic, etc.) from refuse and reprocessing them for reuse. Processing to segregate solid waste components may be done at the point of generation (on-site processing) or at a central processing facility. In on-site processing, wastes are segregated into different types at the point of generation. For example, paper is put in one container, metal scrap in another, and so on. The on-site processing, thus, needs the cooperation of the waste producer

AIR Pollution Control

To Control Particulate Matter :—

① Horizontal / Gravitational Settling Chamber :→



$$V_s = \frac{g \cdot \rho \cdot d^2}{18 \mu}$$

imp. → low cost, maintainace low.

imp. → works on principle of gravity

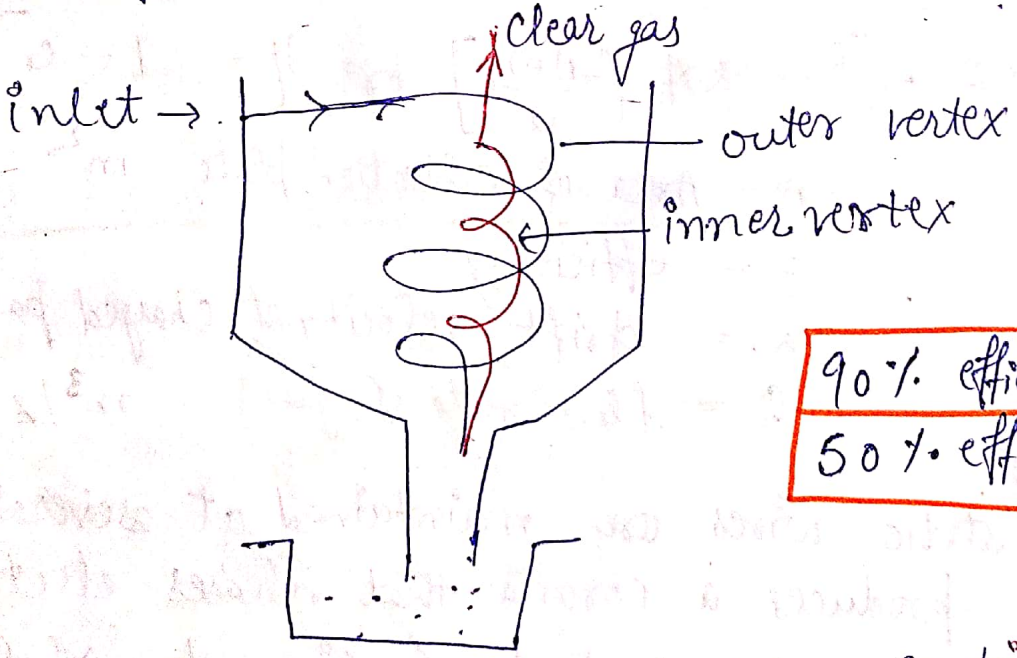
imp. → effective particles > 40 um.

→ eff. ↑es by settling a series of these chambers.

② Centrifugal Collector / precipitator / seperator :→

Cyclone

P 5.10 Deshmukh



90% efficiency ≥ 40 um
50% eff. ≤ 8 um.

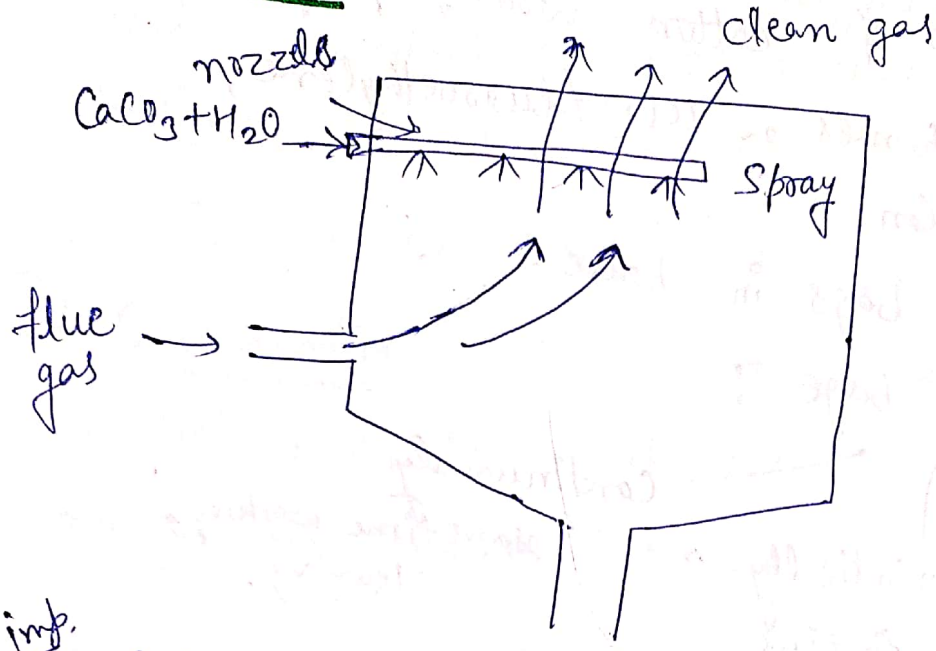
< 5–10 um

→ particles from gas, seperated by centrifugal force. and collected from bottom.

→ inexpensive, easy maintainance, 90% eff. for > 5 um particle but low efficiency for small size particles.

→ ... bag house and ESP.

Scrubber :-



particles size > 10 um washed out

imp.

$$CaCO_3 + 2H_2O + SO_x \rightarrow \underline{CaCO_3 \cdot 2H_2O} + CO_2$$

← Rid of SO_x

→ if we use $CaCO_3$ slurry, sulphur can be removed as $CaSO_4$ or Calcium Sulphate (gypsum).

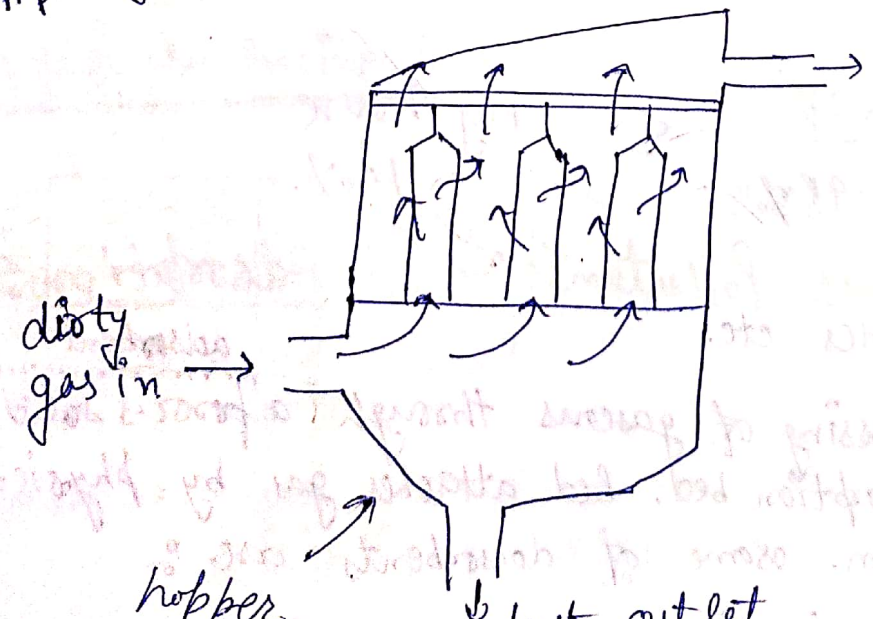
→ effective of submicron particles.

→ most sufficient for 0.5 – 5 um.

→ expensive system for gaseous particles than P.M.

(5) Bag House / Fabric filter :→

V. imp.



by centrifugal action