IIPA 2022

Environmental Ecology, Bio-diversity & Climate Change

Short Answers

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Environmental Ecology

CHAPTER – 1

Environment

1. Environment

The word "environment" comes from the French word "environia," which means "to surround”. The environment refers to anything that surrounds or affects an organism during its lifetime. The environment can be defined as “the sum total of living, non-living components; influences and events, surrounding an organism”. All organisms (from virus to man) are obligatorily dependent on the other organisms and environment for food, energy, water, oxygen, shelter and for other needs.

1.1 Components of the environment

The interaction and relationship between organisms and environment is extremely complicated. Following are the components of the environment:

a) **Abiotic:** A non-living condition or thing, such as climate or habitat that influences or affects an ecosystem and the organisms in it.
b) **Biotic:** A living thing, such as an animal or plant that influences or affects an ecosystem.

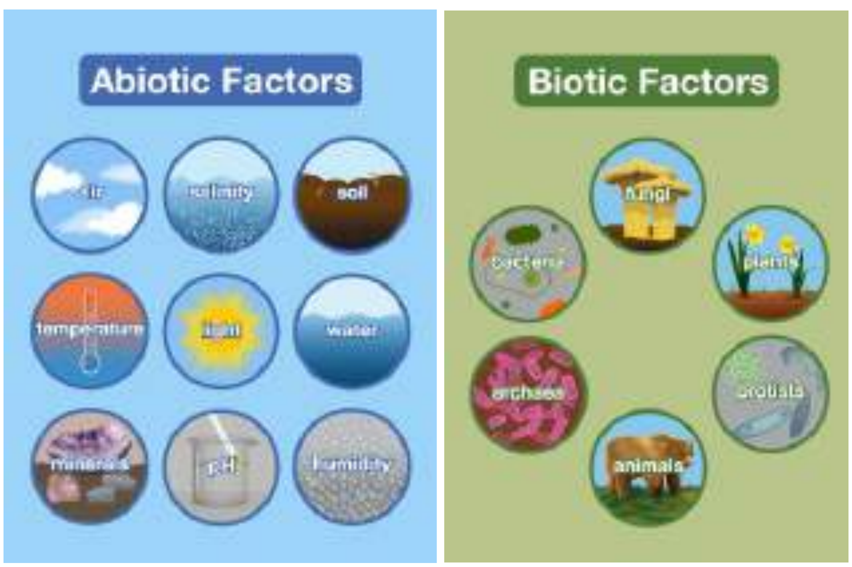

Fig 1. Components of environment

1.1.1 Abiotic Components

a) Light - Sunlight is a source of energy. Photosynthesis is the process through which green plants synthesize nourishment for themselves and all other living beings.

b) Rainfall - All living things require water to survive. In an aqueous medium, the majority of biological processes take place. Water aids in the regulation of body temperature. Further, water bodies form the habitat for many aquatic plants and animals.

c) Temperature - Temperature is a vital environmental component that has a significant impact on organism survival. Organisms can endure only a limited range of temperature and humidity.

d) Atmosphere - The atmosphere of the earth is made up of 21% oxygen, 78% nitrogen, and 0.038% carbon dioxide. The remaining are inert gases (0.93% Argon, Neon etc).

e) Substratum (soil, river/sea bed) - Organisms can be either terrestrial or aquatic in nature. Soil covers the land and is home to a broad range of microbes, protozoa, fungi, and tiny animals (invertebrates). Roots of plants pierce through the soil to tap water and nutrients. Terrestrial animals are those that dwell on land. Aquatic plants, animals, and bacteria may exist in both fresh and salt water. Microbes can even be found in hot water vents beneath the sea.

1.1.2 Biotic Components

a) Green Plants - Prepare food for all living organisms through photosynthesis.

b) Animals - Individuals of the same species are found in the same environment. They also coexist with other species. One species forms food for another. Micro-organisms and fungi decompose dead plants and animals releasing nutrients locked in bodies of dead organisms for reuse by the growing plants.

As a result, living organisms require both abiotic and biotic components of the environment to survive. A delicately balanced relationship between living organisms and their environment is critically important for their survival.

1.2 Salient Features

- Environment can be defined as the surroundings or conditions in which an organism lives or operates.
- Components of environment includes non-living (abiotic) and living (biotic) components.
- Abiotic Components – Light, air, temperature, soil, etc.
- Biotic Components – animals, plants, fungi, etc.

CHAPTER – 2

Ecology

2. Ecology

The term Ecology was first coined by a German zoologist **Ernst Haeckel**. It is derived from the Greek word ‘oikos’ meaning ‘house’, combined with the word ‘logy’ meaning the ‘science of’ or ‘the study of ’. Ecology can be defined as the study of organisms, the environment and how the organisms interact with each other and their environment.

2.1 The Earth

The "BIG BANG" theory is the most commonly accepted theory of the universe's genesis. According to this theory, the universe began with a massive explosion that filled the entire space with substance (dust and gases). The earth broke off about 4.5 billion years ago with an explosion. Our home planet is the third planet from the Sun and the only planet we know of where life exist. The name Earth has been around for at least 1,000 years. Except for Earth, all of the planets were named after Greek and Roman gods and goddesses. Earth, on the other hand, is a Germanic term that simply means "ground." Despite being the fifth biggest planet in the system, Earth is the only planet in our solar system containing liquid water on its surface.

Fig 2. Facts about home planet - Earth

2.2 Origin and Evolution of Life on Earth

To begin with, the earth's environment were hostile to life. Methane, ammonia, carbon dioxide, and hydrogen were the main gases in the early atmosphere. The atmosphere was loaded with water vapor, but there was no free oxygen. This resulted in a decreasing atmosphere in which no life could survive.

2.2.1 Biological evolution- From the simple organisms to complex organisms

Water vapor condensed into liquid water when the earth cooled. Rains poured down, forming water bodies on the surface of the planet. The molecules of life were formed in the water. Bacteria, the oldest and most simple organism, emerged from the molecules of life. The earliest fossils of bacteria, the world's first living species, have been discovered in 3-5 billion-year-old rocks. Bacteria of various types have existed on Earth for about two billion years. Chlorophyll, a green pigment, was developed by one of these bacteria's. These chlorophyll-containing bacteria utilized carbon dioxide and water to produce oxygen, which they then released into the atmosphere through photosynthesis.

Such bacteria's continued photosynthesis gradually increased the amount of oxygen in the atmosphere. As a result, the atmosphere began to shift from reducing to oxidizing. At one point in time, the oxygen concentration in the atmosphere reached 21%. These alterations acted as a major catalyst for biological evolution to begin and proceed, resulting in the invasion of land by living organisms.

2.3 Salient Features

- Ecology is the study of organisms and environment; and how the organisms interact with each other and with their environment.
- Earth is a Germanic term meaning "ground"; it is the only planet where life exists.
- Methane, ammonia, carbon dioxide, and hydrogen were the main gases in the early atmosphere.
- Earth's atmosphere was filled with water vapor and no free oxygen because of which no life could survive.
- Chlorophyll, a green pigment, was developed by bacteria which utilized carbon dioxide and water to produce oxygen, and released it into the atmosphere through photosynthesis.
- Continued photosynthesis increased the amount of oxygen resulting in reducing to oxidizing atmosphere.

CHAPTER – 3

Principles of Ecology

3. Principles of Ecology

Certain basic fundamental ecological principles which describe various aspects of living organisms e.g. evolution and distribution of plants and animals, different components of biological communities, ecological succession, adaptation among species, habitat and organism, and interactions and inter-relationships among the organisms and between organisms and physical environment, etc.

3.1 Ecological Levels of Organizations

a. **Individual -** An organism that has the capability of acting or functioning independently is known as an individual. It can be an animal, bacteria, fungi or a plant. It is the basic unit of study.

b. **Population -** It is defined as a group of freely interbreeding individuals of the same species present in a specific area at a given time.

c. **Community -** A group of organisms consisting of several different species that live in an area and interact with each other.

d. **Ecosystem -** A community of organisms and their physical environment interacting as an ecological unit. It acts as a functional unit of nature and varies from a small pond to a large forest or a sea.

e. **Biome -** A large community unit, characterized by a major vegetation type and associated fauna, found in a specific climatic region. Examples include tundra, taiga, grasslands, savannas, deserts, tropical forests, etc. Temperature, soil, and the amount of light and water help determine what life exists in a biome. No two biomes can be alike. There are more than a dozen ways to classify biomes. One of the simplest classification systems has only two biomes: terrestrial (land) and aquatic (water).

f. **Biosphere -** The biosphere refers to the portion of the planet that contains living beings. The biosphere encompasses the majority of the Earth's surface, as well as a portion of the oceans and atmosphere. In other words, the biosphere encompasses the sum of all living organisms and their surroundings. Thus the atmosphere, lithosphere and hydrosphere are all included in the biosphere.

3.2 Biosphere

Earth is the only planet that sustains life forms and the space accommodating these life forms is called Biosphere. Atmosphere, Lithosphere and Hydrosphere are the three main realms of Biosphere.

3.2.1 Atmosphere

Although atmosphere is approximately 1000kms in width, but the layer which comprises the study of ecosystem is only 10-15 km thick, which is known as Troposphere.

Plants and animals undergo photosynthesis and respiration with the help of gasses of the Troposphere. Moreover, it is the sunlight prevalent through atmosphere, which acts as catalyzing energy for living things of the earth. The green plants incorporate a variety of inorganic elements and compounds. For example, during the process of converting solar energy into chemical energy, atmosphere carbon dioxide enters the living world as the basic constituent of all organic compounds.

Carbon dioxide along with water is used by all plants in their photosynthetic process to produce organic substances such as, glucose a vital molecule in living things, and Oxygen similarly in respiration, the food (glucose) is broken to give the Carbon Dioxide to the environment. Carbon dioxide of the atmosphere is replenished not only through the process of respiration or biological oxidation but also through combustion of fuels and volcanic eruptions

The oxygen is another very important constituent of atmosphere, necessary for the survival of ecosystem. Oxygen enters the living world through respiration which is a familiar process in both plants and animals including through it. The level of Oxygen depicts the health of any ecosystem on this planet.

Nitrogen is also an essential component of living systems. It is required by organisms for the synthesis of proteins, nucleic acids, and other nitrogenous compounds. In nature, atmospheric nitrogen is fixed by specialized organisms. There are industrial processes to convert atmospheric nitrogen into fertilizers.

3.2.2 Lithosphere

Geologically, lithosphere refers to the combination of earth's crust and outer mantle. It provides the platform and habitat to the biotic elements of the ecosystem. Lithosphere has two main functions with reference to the biosphere to the biosphere:

1. It provides platform for terrestrial, transitionary and aquatic plants.
2. It is the source of nutrients and minerals vital for the growth and survival of ecosystem.

3.2.3 Hydrosphere

Water is the most important constituent of biotic elements. In fact, almost all of the organisms have more than half of their constituents as water. It is inevitably required for the metabolism of living things. Moreover, plants also require it for the distribution of nutrients throughout its body. Hydrosphere refers to the water bodies like Lakes, ponds, rivers, oceans etc. on the earth surface. The surface of planet earth is occupied by more than 71% water. On a large scale water is cycled through, elements is partially used for metabolic activities and is partially excreted as waste in the environment in various forms.

3.3 Biome

A biome is often referred to as a global-scale community of plants and animals and is the largest subdivision of the biosphere. It may contain many different kinds of smaller ecosystems. Biomes are typically distinguished on the basis of the characteristics of their vegetation because it makes up the largest portion of biomass.

3.3.1 Biomes of India

1. Tropical humid forests
2. Tropical dry or deciduous forests
3. Warm deserts and semi-deserts
4. Coniferous forests
5. Alpine meadows

3.4 Community

It is an aggregation of populations of different species living together (inter dependent) in a specific area. Communities in most instances are named after the dominant plant form (species).

For example- A grassland community is dominated by grasses, though it may contain herbs, shrubs, and trees, along with associated insects and animals of different species. A community is not fixed or rigid.

a) **Major Communities:** These are large sized and self-regulating, self-sustaining, and relatively independent unit. They depend only on the Sun's energy from outside. Example- Tropical evergreen forests.
b) **Minor Communities:** These are dependent on neighboring communities and are often called societies. They are secondary aggregations within a major community. Example- A mat of lichen on a cow dung pad.

3.5 Ecological Succession

Ecological Succession is the progressive series of changes that leads to an establishment of a relatively stable climax community.

It is characterized by increased productivity, the shift of nutrients from the reservoirs, increased diversity of organisms with increased niche development and a gradual increase in the complexity of food webs.

3.5.1 Types of Ecological Succession

1. Primary Succession
2. Secondary Succession

Primary Succession

- Succession which occurs in areas where no living organisms ever existed is called primary succession.
- The species that invade a bare area are called pioneer species.
- The establishment of a new biotic community is generally slow as it takes natural processes several hundred to several thousand years to produce fertile soil on bare rock.

Important Terms

Pioneer Community: first community to inhabit an area
Climax Community: last and stable community
Sere: entire series of communities
Seral stage: community stage between pioneer and climax community

- Examples of areas where primary succession occurs are newly cooled lava, bare rock, newly created pond or reservoir etc.

Secondary Succession

- Secondary succession occurs where vegetation was present previously but vegetation was destroyed due to natural or artificial causes such as forest fires, floods, droughts, sudden changes in climate, deforestation, overgrazing, etc.
- Since some soil or sediment is present, secondary succession is faster than primary succession.
- Succession would occur faster in area existing in the middle of the large continent. This is because, here all propagules or seeds of plants belonging to the different series would reach much faster, establish and ultimately result in climax community.

Table 3.1 Sere and place of occurrence

Place of Succession where it occurs	Name of Sere
Succession in fresh water	Hydrosere
Succession in salty water	Halosere
Succession in acidic water	Oxalosere
Succession in Rocks	Lithosere
Succession in Sand	Psammosere
Succession in Dry Region	Xerosere
Succession in Moistened Region	Mesosere

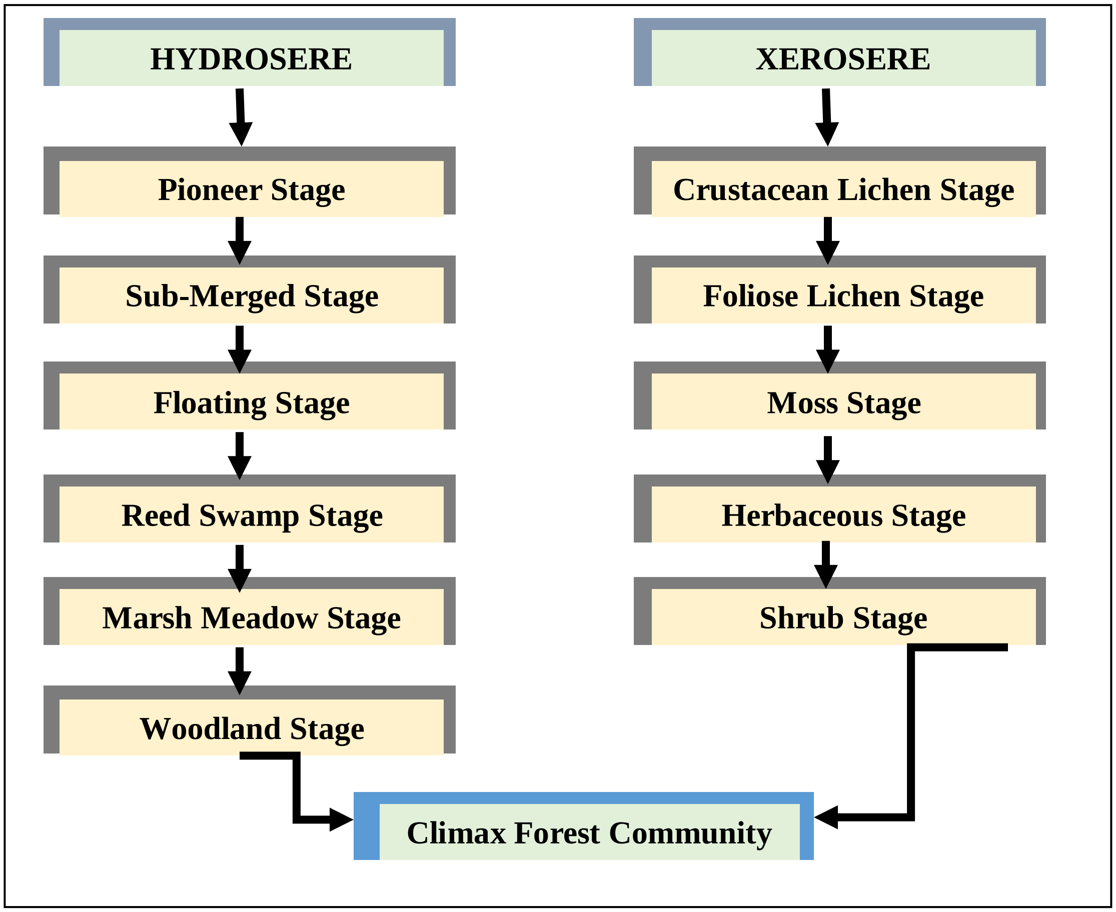

Fig 3.1 Successional stages involved in the succession of Hydrosere and Xerosere

3.6 Adaptation

Adaptation is the physical or behavioral characteristic of an organism that helps an organism to survive better in the surrounding environment.

Adaptation may be:

a) **Morphological** – It is a structural change which gives an organism a greater chance of survival in its habitat.
b) **Physiological** – It is an internal body process to regulate and maintain homeostasis for an organism to survive in the environment in which it exists.
c) **Behavioral** – This is the change that affects the behavior of an organism.

Examples of Adaptation:

- Many desert plants have a **thick cuticle** on their leaf surfaces and have their **stomata arranged in deep pits** to minimize water loss through transpiration.
- Some desert plants like Opuntia, **have no leaves – they are reduced to spines**, and the photosynthetic function is taken over by the flattened stems (few leaves mean less area is available for transpiration).
- Mammals from colder climates generally have **shorter ears and limbs to minimize heat loss**. This is called **Allen's Rule**.
- We need to breathe faster when we are on high mountains. After some days, our body adjusts to the changed conditions on the high mountain.
- Such small changes that take place in the body of a single organism over short periods, to overcome small problems due to changes in the surroundings, are called **acclimatization**.
- The body compensates low oxygen availability **by increasing red blood cell production, decreasing the binding capacity of hemoglobin** and by increasing breathing rate.
- A **hyperthermophile** is an organism that thrives in extremely hot environments — from 60°C. E.g. Archaebacteria flourish in hot springs and deep-sea hydrothermal vents.
- Some species are capable of burrowing into the soil to hide and escape from the above-ground heat.

3.7 Habitat and Organism

- Habitat is the physical environment in which an organism lives (address of an organism).
- Many habitats make up the environment.
- A single habitat may be common for more than one organism which have similar requirements.
- For example, a single aquatic habitat may support a fish, frog, crab, phytoplankton and many others.

3.8 Species

- Species is a group of living organisms consisting of similar individuals capable of exchanging genes or interbreeding considered as the basic unit of taxonomy.
- It is the smallest unit of biological classification **(To be continued in chapter-24)**

3.9 Evolution

- Evolution is the process of heritable changes in population of organisms over multiple generations. It happens in order to make the organism better suit to the present environment.
- Climate change, competition, adaptability, need, changing environment etc. are the major forces behind evolution.
- Evolution involves the processes of natural selection, adaptation, variation, etc.
- Evolution leads to speciation or formation of new species.
- A valid theory of evolution was propounded by Charles Darwin and Alfred Wallace in 1859. This theory has been extended in the light of progress in genetics and is known as **Neo-Darwinism.**

3.10 Salient Features

- The main levels of organization in ecology are Individual, Population, Community, Ecosystem, Biome and Biosphere.
- Biosphere is made up of the Atmosphere, Lithosphere and Hydrosphere.
- A biome is often referred to as a global-scale community of plants and animals and is the largest subdivision of the biosphere.
- Community is an aggregation of populations of different species living together (inter dependent) in a specific area.
- Succession is the progressive series of changes that leads to an establishment of a relatively stable climax community.
- Succession is of two types: Primary Succession and Secondary Succession.
- Adaptation is the physical or behavioral characteristic of an organism that helps an organism to survive better in the surrounding environment.
- Habitat is the physical environment in which an organism lives (address of an organism).
- Species is a group of closely related and interbreeding living things.
- Evolution is the process of heritable changes in population of organisms over multiple generations.
- Neo-Darwinism is an altered explanation of Darwin's theory with regards to modern synthesis of natural selection and Mendelian genetics.

CHAPTER – 4

Population Ecology

4. Population Ecology

Population ecology is the study of populations in relation to the environment. It includes environmental influences on population density and distribution, age structure, and population size.

The **population** is a group of individuals of a particular species, which potentially interbreed and live in a well-defined geographical area, and also share or compete for similar resources.

4.1 Characteristics of any Population

4.1.1 Population Size

In population genetics and ecology, population size (N) is defined as the number of individual organisms in a population. The factors that govern population size are:

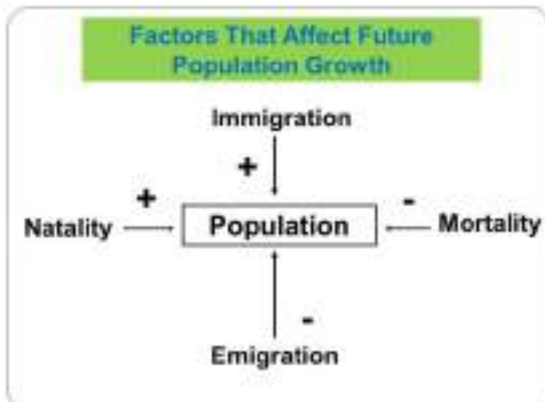

Fig 4.1 Factors affecting population size

a) **Natality (Birth Rate):** The rate at which new individuals are born and added to a population under given environmental conditions is called natality.

b) **Mortality (Death Rate):** Loss of individuals from a population due to death under given environmental conditions is called mortality**.**

c) **Immigration:** The numbers of organisms moving into an area occupied by the population is called as Immigration.

d) **Emigration:** The numbers of organisms moving out of the area occupied by the population is called as Emigration.

4.1.2 Population Density

The number of individuals per unit area at a given time is termed population density which may vary from time to time and place to place.

$$\textit{Density} = \textit{Population}/\textit{Area}$$

4.1.3 Population Dispersion

The dispersion of a population is the pattern of spacing among individuals within the geographic boundaries.

Population Dispersion is of three types:

a) **Clumped Dispersion:** It is a pattern when individuals are aggregated in patches. It is the most frequent pattern of dispersion in a population. A clumped dispersion may be seen in plants that drop their seeds straight to the ground, such as oak trees or animals that live in groups /schools of fish or herds of elephants.

b) **Uniform Dispersion:** Evenly spaced distribution, in which members of the population maintain a minimum distance from one another. One example of uniform dispersion comes from plants that secrete toxins to inhibit growth of nearby individuals, a phenomenon called allelopathy.

c) **Random Dispersion:** It is a spacing pattern based on total unpredictability. It is the least common pattern of distribution. An example of random dispersion comes from dandelions and other plants that have wind-dispersed seeds.

Fig 4.2 Types of population dispersion

4.1.4 Demography

The statistical study of any population, human or otherwise, is known as Demography.

4.1.5 Sex Ratio

It is defined as the number of females per 1000 males in the population. Thus, a sex ratio of 1000 implies complete parity between the two sexes. Ratios above 1000 indicate excess of females over males; those below 1000 indicate a deficit of females.

Example: According to the recently released Economic Survey, India has more females as compared to males. The number of females per 1,000 males has increased from 991 in 2015-16 to 1,020 in 2019-21.

4.1.6 Age Distribution

Age distribution refers to the proportion of individuals of different age groups in a population.
The population may be broadly divided into three age groups:

a) Pre-reproductive age group (0 – 14 years): Comprising of juvenile individuals or children.

b) Reproductive age group (15 – 60 years): Consisting of individuals capable of reproduction.

c) Post-reproductive age group (>60years): Contains aged individuals who are incapable of reproduction.

4.1.7 Population Pyramids

A population pyramid is a graphical representation of the **age and sex** composition of a specific population. The **age-sex structure** of a population refers to the number of females and males in different age groups. The male and female populations are represented on the **horizontal axis**, with the male population on one side and the female population on the other. The **vertical axis** is divided into equal divisions to represent various age groups, so that the entire population of the country/region is represented. The shape of the population pyramid reflects the characteristics of the population.

There are three types of age distribution pyramids/ population pyramids:

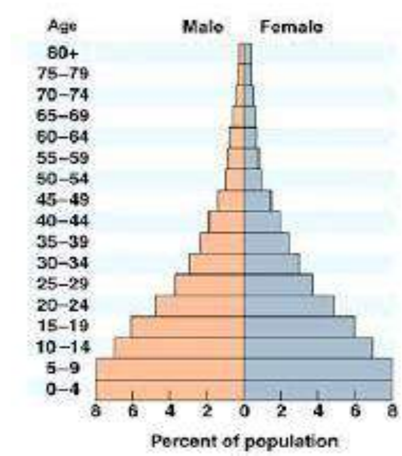

Fig 4.3 Expanding population pyramid

4.1.7.1 Triangular Pyramid

It indicates expanding population with high growth rate. These have larger populations in lower age groups due to high birth rates. Examples: India (northern states except Punjab and Himachal Pradesh), Nigeria, Bangladesh, Mexico.

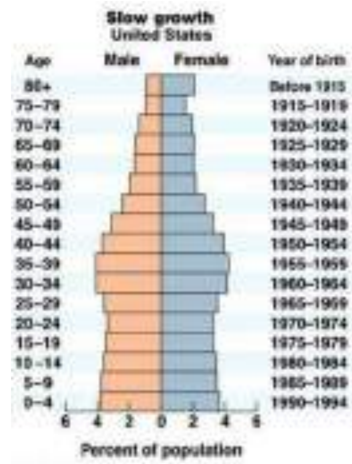

Fig 4.4 Constant population pyramid

4.1.7.2 Bell shaped Pyramid

The age-sex pyramid is **bell-shaped and tapered towards the top.** It indicates stable population with slow growth rates.

Examples: U.S, Australia, India (southern states except Kerala).

4.1.7.3 Urn Shaped Pyramid

It indicates declining population with zero growth rate. The pyramid has a **narrow base and a tapered top** showing low birth and death rates.

Examples: Japan and other developed countries, Kerala state and Mizoram.

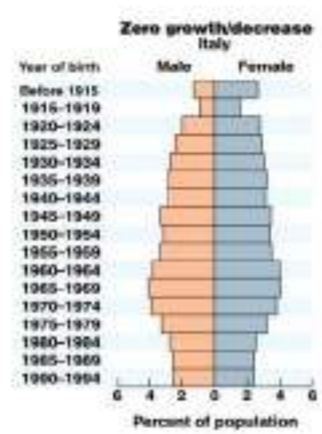

Fig 4.5 Declining population pyramid

4.2 Population Growth Models

Population Growth Rate is the percentage variation between the numbers of individuals in a population at two different times. It can be positive due to birth and/or immigration or negative due to death and/or emigration.

There are two types of population growth patterns may occur depending on specific environmental conditions:

4.2.1 Exponential growth

- In an ideal condition where there is an unlimited supply of food and resources, the population growth will follow an exponential order.
- In such an environment there will be no competition to place limits on a geometric rate of growth.

- Initially population growth will be slow as there is a shortage of reproducing individuals that may be widely dispersed.
- As population numbers increase the rate of growth similarly increases, resulting in an **exponential (J-shaped) curve.**
- This maximal growth rate for a given population is known as its **biotic potential.**
- Exponential growth can be seen in populations that are very small or in regions that are newly colonized by a species.

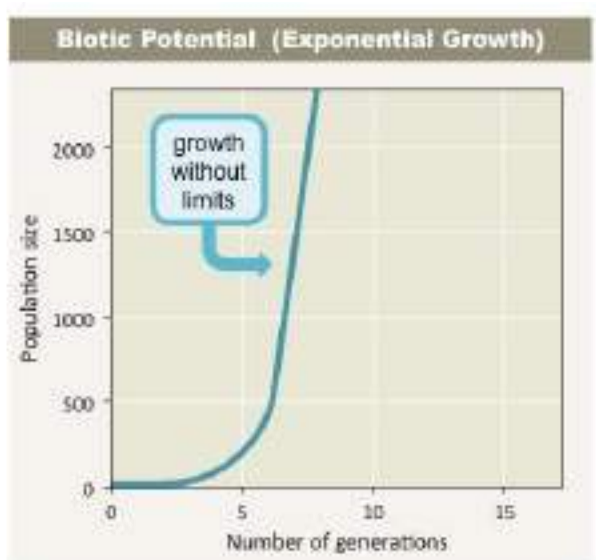

Fig 4.6 Population Growth Curves: Exponential Curve

Consider a population of size N and birth rate be represented as *b*, death rate as d, Rate of change of N can be given by the equation:

$$dN/dt = (b-d) \times N$$

If, $(b - d) = r$,

$$dN/dt = rN$$

Where, r = intrinsic rate of natural increase

This equation can be represented with a graph which has a J shaped curve. According to calculus,

$$N_t = N_0 e^{rt}$$

Where, N_t = Population density at time t

N_0 = Population density at time zero

r = intrinsic rate of natural increase

e = base of natural logarithms

4.2.2 Logistic growth

- This model defines the concept of **'survival of the fittest'**. Thus, it considers the fact that resources in nature are exhaustible.

- **'Carrying capacity'** defines the limit of the resources beyond which it cannot support any number of organisms.
- As a population approaches the carrying capacity, environmental resistance occurs, slowing the rate of growth.
- This results in a **sigmoidal (S-shaped) growth curve.**
- Logistic growth will eventually be seen in any stable population occupying a fixed geographic space.

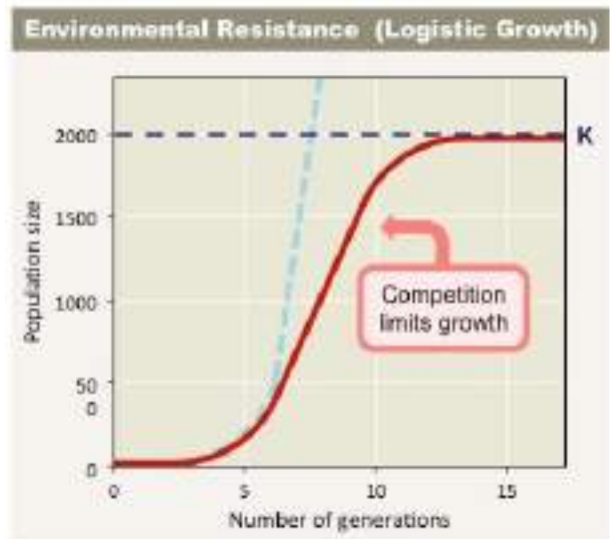

Fig 4.7 Population Growth Curves: Logistic Curve

Let this carrying capacity be represented as K.

The availability of limited resources cannot show exponential growth. As a result, the graph will have a lag phase, followed by an exponential phase, then a declining phase and ultimately an asymptote. This is known as Verhulst-Pearl Logistic Growth and is represented using the equation:

$dN/dt = rN((K-N) /K$

4.3 Biotic Interaction

- The activities of living organisms which may cause the marked effect on the survival of others are called Biotic Interaction. The interactions may be intra-specific or inter-specific interaction.
- The interaction that occurs among different individuals of the same species is called **Intra-specific Interaction.**
- The interaction among individuals of different species in a community is termed as **Inter-specific Interaction.**
- All the interactions are divided into three types, they are:
- **Positive Interaction-** Member of one or both the interacting species are benefited but neither is harmed. Example: Mutualism and Commensalism.

- **Negative Interaction-** One or both interacting species is harmed. Example: Predation, Parasitism, Competition and Ammensalism.
- **Neutral Interaction-** Interacting species are neither benefited nor do they suffer. They may have the same shelter but do not have any effect on each other. Examples: Birds and squirrel living in the same tree.

Table 4.1 Types of Biotic Interaction

S. No	Type of Biotic Interaction	
1.	**Mutualism/ Symbiosis** **(+ +)**	• This is a close association between two species in which both the species depends on each other for growth and survival. They basically benefit each other. • It is the obligatory relationship. • Example: Lichens are mutualistic relationship between algae and fungi • Mycorrhizae are associations between fungi and the roots of higher plants
2.	**Commensalism** **(+ 0)**	• In this relationship one of the species benefits while the other is neither harmed nor benefited. • Example: Sucker fish (Remora) often attaches to a shark by means of its sucker which is present on the top side of its head
3.	**Parasitism** **(+ -)**	• In this type of interaction, one species is harmed and the other is benefited. • The parasite gets the nourishment from the host but it does not kill the host. • Type of Parasites: • **Ecto-parasite:** lives on the body of host Example- Lice, leech, etc

S. No	Type of Biotic Interaction	
		• **Endo-parasite:** lives in the body of host Example: Tapeworm(lives in intestine) and Plasmodium (lives in RBC of human)
4.	**Predation** **(+ -)**	• A free living organism which catches and kills another species for food. • Lion, snakes and buffalo
5.	**Ammensalism** **(- 0)**	• In this interaction one species is inhibited by toxic secretion of another species. Inhibitor species is neither benefited nor harmed. • Example, the bread mould fungi *Pencillium* produce penicillin, an antibiotic substance which inhibits the growth of a variety of bacteria
6.	**Competition** **(- -)**	• Process in which the fitness of one species is significantly lower in the presence of another species. • This is an interaction between two populations in which both species are harmed to some extent. • **Inter-specific competition:** occurring between individuals of two different species in a habitat for the same resources. For example, sharks, dolphins, and seabirds often eat the same type of fish in ocean ecosystems. • **Intra-specific competition:** occurs between individuals of same species. An example among protozoa involves *Paramecium aurelia* and *Paramecium caudatum* competing for the same resources.

4.4 Limiting Factors

Limiting factors are environmental conditions that control the rate at which a process (e.g. population growth) can occur.

Population growth can be determined by **density-dependent** or **density-independent factors:**

a) **Density dependent environmental factors** are influenced by the relative size of a population. These factors include predator numbers, availability of food and other resources and the spread of pathogenic diseases.

b) **Density independent environmental factors** are **not** influenced by the relative size of a population. These factors include weather and climate conditions, as well as the occurrence of natural disasters (e.g. earthquakes).

4.5 Salient Features

- Population ecology is the study of populations in relation to the environment.
- A population is defined as a group of individuals of the same species living and interbreeding within a given area.
- Population size is defined as the number of individuals present in a subjectively designated geographic range.
- Population size is governed by 4 factors: Natality, Mortality, Immigration and Emigration.
- The number of individuals per unit area at a given time is termed population density which may vary from time to time and place to place.
- The dispersion of a population is the pattern of spacing among individuals within the geographic boundaries. It is of three types: Clumped, Uniform and Random Dispersion.
- Age distribution refers to the proportion of individuals of different age groups in a population. Triangular, Bell shaped and Urn shaped are the types of Population pyramids.
- There are two types of population growth patterns may occur depending on specific environmental conditions: Exponential (J-shaped) and Logistic (S-shaped) Growth Curves.
- Biotic potential is the maximum reproductive capacity of an organism under optimum environmental conditions.
- The carrying capacity is the maximum number of a species that can be sustainably supported by the environment.

- The activities of living organisms which may cause the marked effect on the survival of others are called Biotic Interaction.
- There are two types of biotic interaction i.e. Intra-specific and Inter-specific Interaction.
- The interaction that occurs among different individuals of the same species is called Intra-specific Interaction.
- The interaction among individuals of different species in a community is termed as Inter-specific Interaction.
- Limiting factors are environmental conditions that control the rate at which a process (e.g. population growth) can occur. Population growth can be determined by density-dependent or density-independent factors.

CHAPTER – 5

Ecosystem

5. Ecosystem

An ecosystem is a structural and functional unit of the biosphere that consists of a community of living beings and their physical environment, which interact and exchange materials. Plants, trees, animals, fish, birds, microorganisms, water, soil, and people are all part of it. Ecosystems vary in size and composition, but they are all functional parts of nature. Everything that lives in an ecosystem is dependent on the other species and elements that are also part of that ecological community. When one portion of an ecosystem is destroyed, it affects the rest of the ecosystem. When an ecosystem is healthy (i.e., sustainable), all of the elements live in harmony and are capable of self-reproduction. Ecosystems may vary in size from a single tree to a whole forest.

5.1 Components of an Ecosystem

The components of the environment and ecosystem are same (i.e., abiotic and biotic components). These abiotic and biotic components create and exchange materials on a constant basis. The interaction between them involves input, transfer and storage of energy and nutrients. However, as a result of these complex processes, the components of an ecosystem tend to attain a state of equilibrium, thereby becoming self-sustaining and controlled by limiting factors.

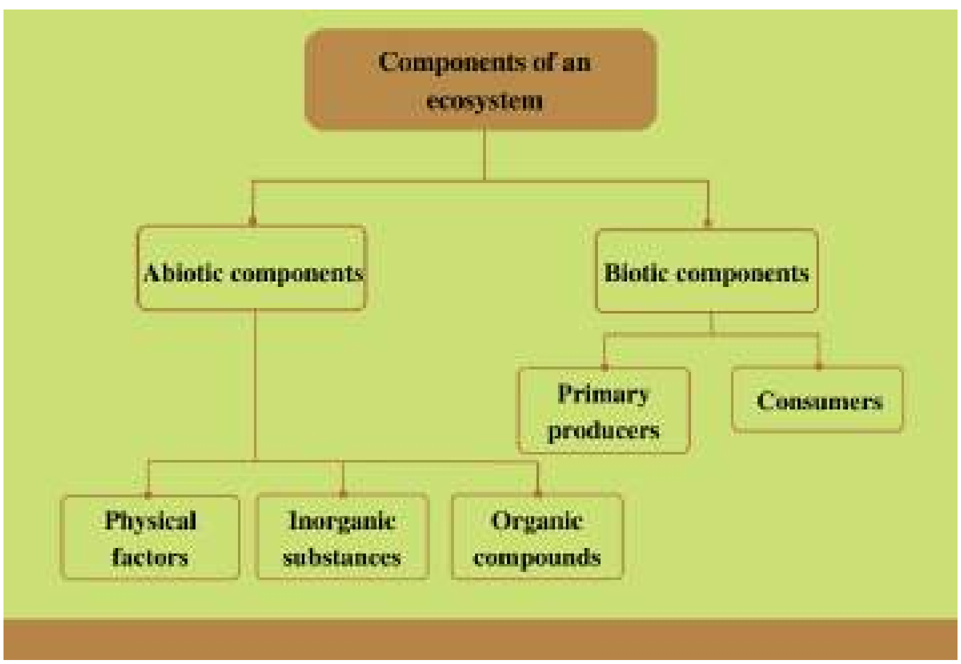

Fig 5.1 Components of ecosystem

1. **Abiotic Components:** Abiotic components are the inorganic and non-living parts of the world. They are the most essential factors of where an organism lives and how well it survives in its surroundings. Despite the fact that various factors interact, a single component might limit an organism's range. The abiotic component can be grouped into the following three categories:
   a. **Physical factors:** Sunlight, temperature, rainfall, humidity and pressure. They sustain and limit the growth of organisms in an ecosystem.
   b. **Inorganic substances:** Carbon dioxide, nitrogen, oxygen, phosphorus, sulphur, water, rock, soil and other minerals.
   c. **Organic compounds:** Carbohydrates, protein, lipids and humic substances. They are the building blocks of living systems and therefore, link the abiotic and biotic compounds.

2. **Biotic Components:** Biotic components include living organisms comprising of plants, animals and microbes and are classified according to their functional attributes into producers and consumers.
   a. **Primary producers - Autotrophs (self-nourishing)**
   - Primary producers are basically green plants (and certain bacteria and algae).
   - They synthesize carbohydrates from simple inorganic raw materials like carbon dioxide and water in the presence of sunlight by the process of photosynthesis for themselves, and supply indirectly to other non-producers.

   b. **Consumers – Heterotrophs or phagotrophs (other nourishing)**
   - Consumers are incapable of producing their own food (photosynthesis).
   - They depend on organic food derived from plants, animals or both.
   - Consumers can be divided into two broad groups namely micro and macro consumers.

   i. *Macro Consumers*
   - They feed on plants or animals or both and are categorized on the basis of their food sources.
   - Herbivores are primary consumers which feed mainly on plants e.g. cow, rabbit.
   - Secondary consumers feed on primary consumers e.g. wolves.
   - Carnivores which feed on secondary consumers are called tertiary consumers e.g. lions which can eat wolves.

- Omnivores are organisms which consume both plants and animals e.g. man, monkey.

ii. *Micro consumers – Saprotrophs (decomposers or osmotrophs)*

- They are bacteria and fungi which obtain energy and nutrients by decomposing dead organic substances (detritus) of plant and animal origin.
- The products of decomposition such as inorganic nutrients which are released in the ecosystem are reused by producers and thus recycled.
- Earthworms and certain soil organisms (such as nematodes and arthropods) are detritus feeders and help in the decomposition of organic matter and are called **detrivores**.

> **Example**
>
> A pond is an excellent example of an ecosystem. It includes physical factors like temperature, pressure, humidity; inorganic aspects like Oxygen, Nitrogen, Water; organic compounds like Protein, Carbohydrates, Lipids; Producers; Micro-consumers and so on.

5.2 Types of ecosystems

Ecosystem can be classified into following categories:

i) **Natural Ecosystems:** The interaction between the environment and the species that live in it is referred to as a natural ecosystem. It occurs naturally in nature and requires no human activity for its survival. Examples of natural ecosystems include ponds, rivers, forests, etc. It can be classified into terrestrial and aquatic ecosystem.

ii) **Man-made / artificial ecosystems:** Artificial ecosystems are structures created by humans that require biotic and abiotic components to interact in order to survive. It is not self-sustaining and will perish if not assisted by humans. Examples of artificial ecosystems include aquariums, agriculture fields, zoos, etc.

5.3 Ecosystem services

Following are some of the services provided by an ecosystem:

1. **Provisioning services:** The material benefits that people get from ecosystems for e.g. supply of food, water, fibers, wood and fuels.
2. **Regulating services:** These are the benefits obtained from the regulation of ecosystem processes e.g. the regulation of air quality and soil fertility, control of floods or crop pollination.
3. **Supporting services:** These are necessary for the production of all other ecosystem services, for e.g. by providing plants and animals with living spaces, allowing for diversity of species, and maintaining genetic diversity.
4. **Cultural services:** These are non-material benefits people gain from ecosystems, for e.g. educational, aesthetic and engineering inspiration, cultural identity and spiritual well-being.

Fig. 5.2 Ecosystem Services

5.4 Salient features

- An ecosystem is a unit of nature, where living organisms interact among themselves and also with the surrounding physical environment.
- Components of ecosystem includes:

1. Abiotic components which are non-living parts of the world such as physical factors (sunlight, rainfall, etc.), inorganic substances (nitrogen, carbon dioxide, etc.) and organic compounds (carbohydrates, protein, etc.)
2. Biotic components which comprise of living organisms (plants, animals, etc.); they are further classified into producers and consumer based on their functional attributes.

« Consumers are further classified into macro consumers (feed on plants or animals or both) and micro consumers (bacteria and fungi which obtain energy and nutrients by decomposing dead organic substances of plant and animal origin).

« Earthworms and certain soil organisms (such as nematodes and arthropods) are micro consumers which help in the decomposition of organic matter and are called **detrivores.**

- There are two types of ecosystems : Natural and manmade/artificial ecosystems
- Some services provided by an ecosystems include provisioning, regulating, supporting and cultural services.

CHAPTER – 6

Terrestrial Ecosystem

6. Terrestrial Ecosystem

A terrestrial ecosystem is a land-based community of organisms and the interactions of biotic and abiotic components in a given area. Examples of terrestrial ecosystems include the tundra, grasslands, deserts, etc. The temperature range, average quantity of precipitation, soil type and amount of light received determine the kind of terrestrial ecosystem present in a given location. Terrestrial ecosystems encompass roughly 140 to 150 million km^2, or about 25 to 30 percent of the earth's total surface area. The following four ecosystems make up the terrestrial ecosystem:

- **a)** Forest Ecosystems
- **b)** Grassland Ecosystems
- **c)** Desert Ecosystem
- **d)** Tundra Ecosystem

6.1 Forest Ecosystems

A diverse assembly of many sorts of biotic communities makes up the forest ecosystem. The formation of forest communities is dependent on ideal circumstances such as temperature and ground moisture. The distribution of trees and their quantity in the forest vegetation is determined by the type of the soil, climate and local terrain. Forests cover over one-third of the Earth's surface area and contain roughly 70% of all carbon found in living things. They are a significant carbon sink and a substantial source of food and resources. Coniferous forest, temperate forest, and tropical forest are the three basic kinds of forest ecosystems.

6.1.1 Coniferous forest (boreal forest)

The boreal coniferous forest is found in cold places with considerable rainfall, strong seasonal climates with long winters and short summers. Evergreen plant species such as Spruce, fir and pine trees, as well as animals such as the lynx, wolf, bear, red fox, porcupine, squirrel and amphibians such as Hyla, Rana and others, characterize this region. Thin podzols define boreal forest soils, which are often poor. Both because rocks weather slowly in cold environments and because conifer needle (leaf) litter decomposes slowly and is deficient in nutrients. These soils are acidic and low in minerals. This is due to the passage of huge amounts of water through the soil without a considerable counter-upward movement of evaporation, which leaches essential soluble elements like calcium, nitrogen and potassium beyond the reach of roots. This procedure ensures that no alkaline-oriented cations come into contact with the organic acids in the litter. A boreal forest's productivity and community stability are lower than those of any other forest environment.

6.1.2 Temperate deciduous forest

Temperate forests have a mild temperature and broad-leafed deciduous trees that shed their leaves in the fall, remain bare in the winter and sprout new foliage in the spring. The precipitation is generally consistent throughout the temperate deciduous forest. Temperate forest soils are podzolic and quite deep.

6.1.3 Temperate evergreen forest

Warm, dry summers and cold, damp winters define Mediterranean climatic zones across the world. Low broad leafed evergreen trees are typically seen here. Fire is a significant concern in this habitat and the plants' adaptations allow them to regrow swiftly after being burned.

6.1.4 Temperate rain forests

The temperate rain forests have distinct seasons in terms of temperature and rainfall. Rainfall is expected to be heavy and fog is possible. It is a more significant source of water than rainfall. In comparison to other temperate forests, temperate rain forests have a high biotic diversity. However, when compared to the tropical rainforest, the diversity of flora and animals is far lower.

6.1.5 Tropical rain forests

Tropical rain forests can be found near the equator. They are one of the world's most diversified and wealthy communities. The temperature and humidity are both high and rather consistent. The yearly rainfall is around 200 cm and falls evenly throughout the year. The flora is quite diverse. The tropical rain forests' thick vegetation remains vertically stratified, with tall trees frequently covered with vines, creepers, lianas, epiphytic orchids and bromeliads. The understory consists of trees, bushes and plants such as ferns and palms. Tropical rainforest soil is red latosol, which is quite thick. These soils are largely unusable for agricultural uses due to the high rate of leaching, but if left undisturbed, the quick cycling of nutrients within the litter layer generated by decomposition can compensate for the natural poverty of the soil. The absence of sunshine at ground level limits undergrowth in many regions.

6.1.6 Tropical seasonal forests

Tropical seasonal forests, often known as monsoon forests, are found in areas with high total annual rainfall but distinct wet and dry seasons. South East Asia, central and south America, northern Australia, western Africa and tropical islands of the pacific as well as India are the regions where this kind of forests are found.

6.1.7 Subtropical rain forests

Broad-leaved evergreen subtropical rain forests are found in areas with moderate rainfall but little seasonal temperature variation. Epiphytes are abundant in this area. Subtropical forest animals are quite similar to those seen in tropical rainforests.

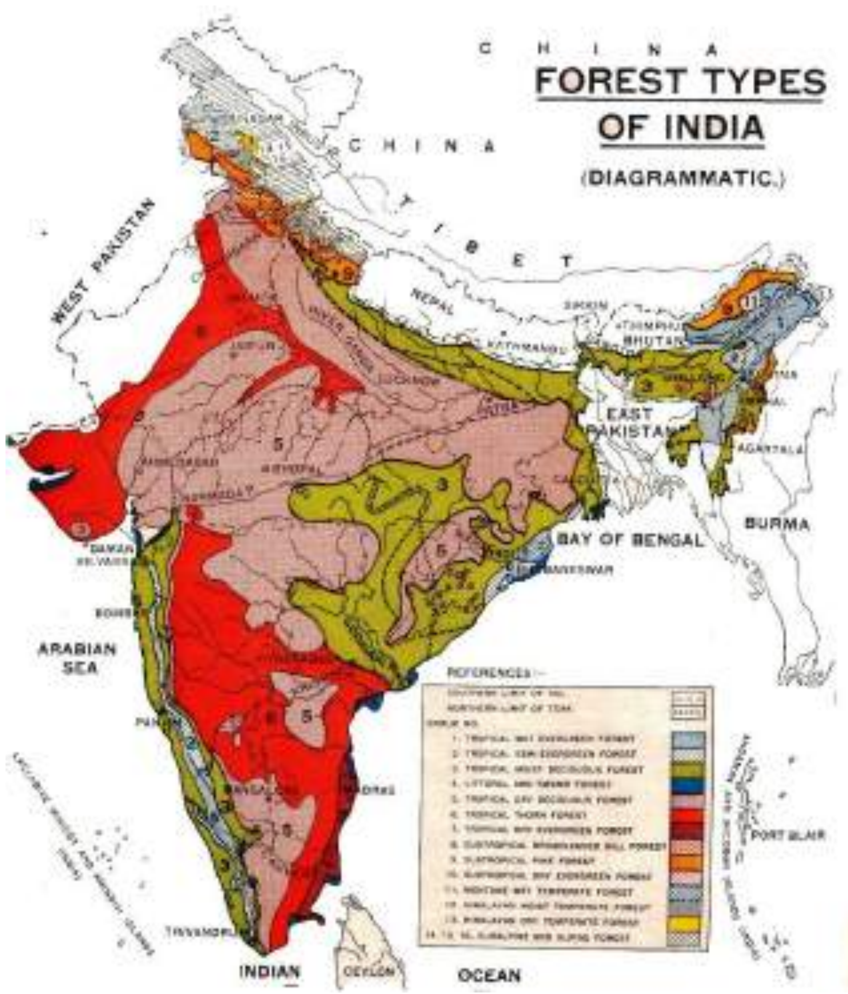

Fig. 6 Indian forest types

6.2 Indian Forest Types

From the rainforests of Kerala in the south to the alpine meadows of Ladakh in the north, from the deserts of Rajasthan in the west to the evergreen forests of the north-east, India boasts a broad variety of forests. The key criteria that affect the kind of forest are climate, soil type, topography and elevation. Forests differ in terms of their nature and composition, the sort of climate they flourish in and their connection with the environment. Forest types in India are classified by Champion and Seth into sixteen types.

6.2.1 Tropical Wet evergreen forests

The Western Ghats, the Andaman and Nicobar Islands and the northeastern area all have wet evergreen forests. Tall, straight evergreen trees dominate the landscape. The jackfruit, betel nut palm, jamun, mango and hollock are some of the most frequent trees found here. The trees in this forest are arranged in a tier pattern, with bushes covering the layer closest to the ground, then short structured trees and finally tall trees. On the trunks of the trees, beautiful ferns of various hues and orchids of numerous sorts thrive.

6.2.2 Tropical Semi-evergreen forests

The Western Ghats, the Andaman and Nicobar Islands and the Eastern Himalayas all have semi-evergreen forests. The damp evergreen trees and moist deciduous trees coexist in such forests. The forest is dense and is filled with a large variety of trees of both types.

6.2.3 Tropical Moist deciduous forests

Except in the western and north-western parts of the country, India is covered with moist deciduous forests. These have tall trees with wide trunks, branching trunks and roots that anchor them to the earth. During the dry season, some of the taller trees lose their leaves. In the undergrowth, there is a layer of shorter trees and evergreen plants. Sal and teak, as well as mango, bamboo and rosewood, dominate these forests.

6.2.4 Littoral and swamp

The Andaman and Nicobar Islands as well as the Ganga and Brahmaputra delta areas have littoral and swamp forests. They feature soft tissue roots that allow the plant to breathe while in the water.

6.2.5 Tropical Dry deciduous forest

Except in the north-east, dry deciduous forests may be found across the northern section of the country. Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu all have it. Normally, the canopy of the trees does not surpass 25 meters. The sal, a kind of acacia and bamboo are common trees.

6.2.6 Tropical Thorn forests

This kind may be found in locations with black soil in India's north, west, central and southern region. The trees don't get much taller than 10 meters. This area is known for spurge, caper and cactus.

6.2.7 Tropical Dry evergreen forest

The coasts of Tamil Nadu, Andhra Pradesh and Karnataka are covered in dry evergreens. There are mostly hard-leaved evergreen trees with aromatic blossoms as well as a few deciduous trees.

6.2.8 Sub-tropical Broad-leaved forests

Broad-leaved forests can be found in the Silent Valley in the Eastern Himalayas and Western Ghats. There is a significant variation in the plant types between the two places. Poonspar, cinnamon, rhododendron and fragrant grass are common in the Silent Valley. The flora of the Eastern Himalayas has been severely impacted by shifting cultivation and forest fires. The majority of the trees in these wet forests are evergreen with a few deciduous trees. Oak, alder, chestnut, birch and cherry trees can be found here. Orchids, bamboo and creepers come in a wide variety in these forests.

6.2.9 Sub-tropical Pine forests

Pine woods can be found on the Shivalik Hills, Western and Central Himalayas, Khasi, Naga and Manipur Hills' high dry slopes. Chir, oak, rhododendron and pine are the most common trees in these areas with sal, amla and laburnum growing in the lower sections.

6.2.10 Sub-tropical Dry evergreen forests

Dry evergreen forests normally have a prolonged hot and dry season and a cold winter. It is characterized by evergreen trees with gleaming, glossy foliage. These forests may be found up to 1000 meters in the Shivalik Hills and Himalayan foothills.

6.2.11 Montane Wet temperate forests

Montane wet temperate forests can be found in the north stretching from Nepal to Arunachal Pradesh and receive a minimum of 2000 mm of rainfall. The forest in the north is divided into three layers: the upper layer is mostly coniferous, the middle layer is deciduous trees like oak and the lowest layer is covered with rhododendron and champa. It may be found in areas of the Nilgiri Hills in Kerala's upper elevations in the south. Northern regions are thicker than those in the south. Rhododendrons and other ground plants can be found here.

6.2.12 Himalayan Moist temperate Forest

From the Western to the Eastern Himalayas, this kind may be found. Broad-leaved oak, brown oak, walnut, rhododendron and other trees may be found in the western portion. Rainfall is substantially greater in the Eastern Himalayas, therefore the vegetation is much more lush and thick. There are many different types of broad-leaved trees, ferns and bamboo to choose from. Coniferous trees may also be found here, with certain types differing from those in the south.

6.2.13 Himalayan Dry temperate Forest

This kind may be found in Lahul, Kinnaur, Sikkim and other Himalayan regions. There are predominantly coniferous trees, along with broad-leaved trees such as the oak, maple and ash. Fir, juniper, deodar and chilgoza are found at higher elevations.

6.2.14 Sub alpine forest

Between 2900 and 3500 meters, sub alpine forests stretch from Kashmir to Arunachal Pradesh. Juniper, rhododendron, willow and black currant make up the majority of the flora of the Western Himalayas. Red fir, black juniper, birch and larch are abundant trees in the eastern regions. The timberline in this area is higher than in the West because of considerable rainfall and high humidity. Many types of Rhododendron cover the slopes in this area.

6.2.15 Moist Alpine scrub

The Himalayan foothills and the higher slopes near the Myanmar border are covered with moist alpines. It features a thick evergreen forest with low scrub, primarily rhododendron and birch. Patches of mosses and ferns cover the ground. Snowfall is common in this area.

6.2.16 Dry alpine scrub

Dry alpines may be found at elevations ranging from 3000 to 4900 meters. The black juniper, drooping juniper, honeysuckle and willow are the most common dwarf plants.

6.3 Importance of forests

We rely on forests directly or indirectly for everything, from the air we breathe to the food we eat to the paper and wood we use. Without forests most of the areas would have been deserts.

- Forests are commonly referred to as lungs of the earth. It is mostly due to the existence of a diverse range of plants, which create huge amounts of oxygen due to their high density, allowing other organisms to breathe.
- Forests are home to a wide range of animal and plant species that not only contribute to Earth's biodiversity, but also play a crucial role in the ecosystem.
- About 25% of all the medicines that are produced, originate from rainforest plants. Quinine, for example, comes from the "Cinchona Tree," which is used to cure Malaria.
- Forests offer timber, which is used to construct houses, furniture and other structures.
- Forests prevents soil erosion, maintains water cycle, etc.
- Wildlife tourism generates lots of capital, which in turn increases the revenue of the government.
- Forests harbor various species of living organisms which are still being discovered. Protecting the forests not only preserves a process of life that started billions of years ago but it also gives us missing clues to various riddled aspects of life.

6.4 Deforestation

The deliberate clearance of forested terrain is known as deforestation. Forests have been severely depleted as a consequence of indiscriminate tree cutting as a result of urbanization, industrialization, mining activities and the usage of wood for home and other reasons.

6.4.1 Cause of deforestation

a) **Shifting cultivation:** This method involves clearing a section of land, burning plants and mixing the ash with the soil to add nutrients. This plot of land is used to grow crops for two to three years, with a small output. After that, the region is abandoned and permitted to regain its fertility and the process is repeated on a new piece of land. This method of cultivation just requires a few simple instruments and does not require a high level of automation.

b) **Development project:** The human population has grown significantly, as have their needs. Hydroelectric projects, big dams and reservoirs and the construction of railway lines and highways are all tremendously helpful, but they are also tied to a number of environmental issues. Many of these initiatives necessitate significant deforestation.

c) **Fuel Requirements:** With an ever-increasing population, the need for firewood grows putting more pressure on the forests, resulting in higher intensity of deforestation.

d) **Raw Material Requirements:** Various businesses utilize wood as a raw material to make paper, plywood, furniture, match sticks, boxes, crates, packing cases, etc. Drugs, scents and perfumes, resin, gums, waxes, turpentine, latex and rubber, alkaloids and bees wax are all raw ingredients obtained from plants. This exerted tremendous pressure on forest ecosystem and their unrestricted exploitation for various other raw materials is the main cause of degradation of the forest ecosystem.

e) **Other Causes:** Deforestation also results from overgrazing, agriculture, mining, urbanization, flood, fire, pest, diseases, defence and communication activities.

6.4.2 Effects of deforestation

- Closed forests (based on canopy level) have being diminished due to deforestation leading to increase in degraded forests.
- Forests recycle moisture from soil into their immediate atmosphere by transpiration where it again precipitates as rain.
- Deforestation results in an immediate lowering of ground water level and in long-term reduction of precipitation.
- Due to deforestation, this natural reuse cycle is broken and water is lost through rapid run off.
- Much of the mining activity in India is being carried out in forest regions. The obvious result is deforestation and soil erosion.
- Underground mining has also significantly denuded forests, as timber is used for supporting the roofs of mine galleries.
- A large number of abandoned mines are lying in bad shape and are under extensive gully erosion leading to degradation of the habitat.
- Deforestation affects the biota and neighboring ecosystems, soil erosion, land degradation, alteration of ground water channels, pollution and scarce.

6.5 Forest Fires

Forest fires are uncontrollable flames that consume trees, animals, meadows and brushlands in their path. The fire spreads quickly due to the wind, resulting in substantial air pollution. Climate change is usually the cause of flames that last longer or are very flammable. Human-caused forest fires, lightning and extreme drought have also occurred. Forest fires have become a global problem, with many nations suffering considerable losses in terms of lives and property. Furthermore, forest fires emit carbon dioxide into the air, which causes lung and skin infections in humans. There are three conditions that need to be present in order for a wildfire to burn: fuel, oxygen and a heat source.

6.5.1 Cause of Forest Fires

- Forest fires can be caused by many natural causes; according to the study, many major fires in India start mainly from human activities. At present, the incidence of forestry is continuously increasing in the whole world, especially in Brazil and Australia, for which climate change can be considered responsible.
- In India, Forest fires is most commonly recorded during March and April, when the ground contains large amounts of dry wood, logs, dead leaves, stumps, hay and weeds. Under natural conditions, excessive heat and dryness, the friction created by rubbing of branches with each other is also known to start a fire.
- In Uttarakhand, soil moisture deficiency is also being seen as an important factor. In two consecutive monsoon seasons (2019 and 2020), there has been a deficit of rainfall at seasonal averages of 18% and 20% respectively.
- According to forest officials the maximum number of fires in India are man-made. Even a small spark from the butt of a cigarette or a carelessly lit matchstick fire can turn into a terrible forest fire.

6.5.2 Effects of Forest Fire

- Forest fires can impact the economy as many families and communities depend on the forest for food, fodder and fuel.
- It burns down the small shrubs and grasses, leading to landslides and soil erosion.

- Burning of forests causes smoke and poisonous gas emissions that result in significant health issues in humans.
- Loss of trees can disrupt the climatic conditions and break down the carbon chain.
- Wildfires damage the habitat of animals, causing them to wander in cities. Many die in the fires, unable to escape.
- These fires destroy the vegetation, soil quality and overall flora and fauna.

6.6 Indian State of Forest Report, 2021

- State of Forests Report is published by the Forest Survey of India (FSI) on a biennial basis since 1987. The India State of Forest Report 2021 is the 17th report in the series.
- It has for the first time assessed forest cover in tiger reserves, tiger corridors and the Gir forest which houses the Asiatic lion.
- It states that there has been an increase of 2,261 sq. km in the total forest and tree cover of the country in last two years.
- Area-wise Madhya Pradesh has the largest forest cover in the country.
- Maximum increase in forest cover witnessed in Andhra Pradesh (647 sq. km) followed by Telangana (632 sq. km) and Odisha (537 sq. km).
- 17 states/UTs have above 33 percent of the geographical area under forest cover.
- Total carbon stock in country's forest is estimated to be 7,204 million tonnes, an increase of 79.4 million.
- Total mangrove cover in the country is 4,992 sq. km, an increase of 17 sq. Km observed.

6.7 Grassland Ecosystem

The grasslands are found where rainfall is not enough to support a forest, but more than that of a true desert. In fact, grasslands often lie between forests and deserts. Grasslands cover about 20% to 40% of the world's land area, depending on how they're characterized. The quantity of precipitation received by the grassland environment affects its vegetation. There are two types of grassland ecosystems:

6.7.1 Tropical Grasslands

Tropical Grasslands receive 50 to 130 cm of rain annually. They also have both rainy and dry days. As a result, they are warm all year. Savanna is another name for tropical grasslands. These grasslands are characterized by dry plants and little trees. Also, the tropical grasslands contain quite short plants which makes it an excellent hunting ground. For instance, the African savanna is one of the tropical grasslands. In conclusion, the tropical grassland is a home for elephants, giraffes, lions, cheetahs, zebras and other spectacular species.

6.7.2 Temperate Grasslands

Temperate grasslands receive rainfall of the range 25 cm and 75 cm. Furthermore, the climate in the temperate grasslands makes it both dormant and growing. Moreover, these grasslands suffer extreme climates. In the cold season, the temperature can reach up Flooded Grasslands to 0 degrees Fahrenheit. While in the summer season it reaches up to 90 degrees in some areas. The precipitation in these grasslands is mostly in the form of dew and snow. For instance, some vegetation that grows here are, cacti, sagebrush, perennial grasses, buffalo grass clovers and wild indigos, etc.

6.8 Desert Ecosystem

Deserts cover about one-fifth of our planet and witness extremely low rainfall over an area. The most defining feature of this ecosystem is the amount of precipitation it receives, which is the least as compared to any ecosystem. Soils often have abundant nutrients because they need only water to become very productive and have little or no organic matter. There are relatively few large mammals in deserts because most are not capable of storing sufficient water and withstanding the heat. There are two major types of deserts:

6.8.1 Hot and Arid Desert

These generally occur at low latitudes and can be found in Sahara, South-America, North America, Australia and Middle East. Seasons in the arid desert are generally dry and hot with few occurrences of rain during the winter. When it rains, it is common for the rain to evaporate before hitting the ground. The soil is usually either sand or coarse and rocky. Vegetation consists mainly of shrubs and small trees of which the leaves have evolved to retain water. Animal species being mostly active at night (nocturnal).

6.8.2 Cold Desert

There is moderately high amount of snow during the wintertime. The soil is too heavy and alkaline. Cold desert offers less than ideal conditions for sustaining delicate plants and animals. Most of the animals in the cold desert are burrowers, even the carnivores and reptiles, which even though are cold blooded have made their homes in the cold desert.

6.9 Desertification

Desertification refers to the persistent degradation of dry land ecosystems by climatic variations and human activities. It occurs on all continents (except Antarctica) and affects the livelihoods of millions of people, including a large proportion of the poor in drylands. In arid and semiarid regions, the restoration of the fragile ecosystem is very slow and issues like deforestation and mining enhances the desertification. Desertification is a main problem faced by desert adjoining areas, which stretches across parts of Rajasthan, Gujarat, Punjab and Haryana.

6.9.1 Factors leading to desertification

There are two main factors which leads to desertification:

a) **Climatic Variations:** Climate change, drought, moisture loss on a global level.
b) **Human activities:** These includes overgrazing, deforestation and removal of the natural vegetation cover (by taking too much fuel, wood, etc.), agricultural activities in the vulnerable ecosystems of arid and semi-arid areas, which are thus sustained beyond their capacity. These activities are triggered by population growth, the impact of the market economy and poverty.

6.9.2 Consequences of desertification

Desertification reduces the ability of the land to support life, affecting wild species, domestic animals, agricultural crops and people. The reduction in plant cover that accompanies desertification leads to accelerated soil erosion by wind and water.

6.10 Tundra Ecosystem

Tundra means a “barren land” since they are found where environmental conditions are very severe. The ecosystem, which is devoid of trees and covered with snow for most of the year is called the tundra ecosystems. These types of ecosystems are mainly found in cold climates and in those regions with limited or scarce rainfall. Polar Regions are some examples of the tundra ecosystem. There are two types of tundra ecosystems - arctic and alpine.

6.10.1 Arctic Tundra

The arctic tundra occupies the earth's northern hemisphere. The soil in arctic tundra is poor in nutrients which accounts for low amount of vegetation. There is an under-layer of soil called permafrost which remains completely frozen at all times, allowing little room for deep rooting plants and trees. The plants that do not survive the frozen landscape are extremely resilient and their roots are close to the surface of the hard soil, as to intake what little water falls upon the ground. Most of the artic tundra's plant life consists of shrubbery, lichen, moss and flowers. Birds of the tundra migrate south during the winter months, causing constant change in the animal population.

6.10.2 Alpine Tundra

The alpine tundra ecosystem exists on rocky mountaintops and is very similar to the Arctic Tundra except for a conspicuous lack of trees. Because tree cannot grow at this high altitude, most of the alpine tundra's plant life consists of shrubbery and small leafy plants such as alpine bluegrass which is consumed by a variety of grazing animals such as bighorn sheep and mountain goats.

6.11 Salient Features

- A terrestrial ecosystem is a land-based community of organisms and the interactions of biotic and abiotic components in a given area.
- Terrestrial ecosystems cover approximately 140 to 150 million km^2, which is about 25 to 30 percent of the total earth surface area.
- Terrestrial ecosystem comprises of the four ecosystems: Forest, Grassland, Desert and Tundra.
- A forest ecosystem is a functional unit or a system which comprises of soil, trees, insects, animals, birds and man as its interacting units.
- Forest ecosystem can be classified into three major categories: coniferous forest (trees that grow needles instead of leaves and cones instead of flowers), temperate forest (composed of

both broad-leaved and coniferous trees) and tropical forest (broad-leaved trees that form a dense upper canopy).

- According to Champion and Seth, Indian forest types are classified into sixteen types; Tropical Wet evergreen forests, Tropical Semi-evergreen forests, Tropical Moist deciduous forests, Littoral and swamp, Tropical Dry deciduous forest, Tropical Thorn forests, Tropical Dry evergreen forest, Sub-tropical Broad-leaved forests, Sub-tropical Pine forests, Sub-tropical Dry evergreen forests, Montane Wet temperate forests, Himalayan Moist temperate Forest, Himalayan Dry temperate Forest, Sub alpine forest, Moist Alpine scrub, Dry alpine scrub.
- Forests are important because they keep up the natural balance, purify the air, prevent soil erosion, provide medicinal properties, provide us fuel and timber and provide raw materials for industries.
- Deforestation is the purposeful clearing of forested land. Shifting cultivation, development project, fuel requirements, raw material requirements and other causes such as overgrazing, agriculture, mining, etc. are some of the causes of deforestation.
- Loss of habitat, increased greenhouse gases, less water in the atmosphere, soil erosion and flooding are some of the effects of deforestation.
- Forest fires are wildfires that spread uncontrollably, burning plants, animals, grasslands and brushlands that fall in their path.
- Human activities, excessive heat and dryness, the friction created by rubbing of branches with each other are some of the causes of forest fires.
- Landslides, soil erosion, change in climatic conditions, damage in the habitat of animals, vegetation, soil quality and overall flora and fauna are major effects of forest fires.
- For the first time, Indian State of Forest Report (2021) assessed forest cover in tiger reserves, tiger corridors and the Gir forest which houses the Asiatic lion.
- According to Indian State of Forest Report (2021), there’s an increase of 2,261 sq. km in the total forest and tree cover; Madhya Pradesh has the largest forest cover in the country; 17 states/UTs have above 33 percent of the geographical area under forest cover; total carbon stock in country’s forest is estimated to be 7,204 million tonnes; total mangrove cover in the country is 4,992 sq. km.

- Grasslands are found where rainfall is not enough to support a forest, but more than that of a true desert. There are two types of grassland ecosystems: Tropical Grasslands (which receive 50 cm to 130 cm rain) and Temperate Grasslands (which receive rainfall of the range 25 cm and 75 cm).
- Desert ecosystems are regions with very little rainfall. There are two major types of deserts hot & arid desert and cold desert.
- Desertification refers to the persistent degradation of dry land ecosystems by climatic variations and human activities. Factors leading to desertification are climatic variations and human activities such as overgrazing, deforestation etc.
- Reduction in the ability of the land to support life, affecting wild species, domestic animals, agricultural crops and people along with soil erosion are some consequences of desertification.
- The ecosystem, which is devoid of trees and covered with snow for most of the year is called the tundra ecosystems. There are two types of tundra ecosystems - arctic and alpine.

CHAPTER – 7

Aquatic Ecosystem

7. Aquatic Ecosystem

An ecosystem in a water body is called as Aquatic Ecosystem. Aquatic Ecosystems are classified based on their salt content are:

a) Freshwater Ecosystem

b) Marine Ecosystem

c) Estuary Ecosystem

7.1 Aquatic Organism

The aquatic organisms are classified on the basis of their zone of occurrence and their ability to cross these zones. The organisms (both flora and fauna) in the aquatic ecosystem are unevenly distributed but can be classified on the basis of their life form or location into five groups. They are as follows:

7.1.1 Classification of Aquatic Organism

7.1.1.1 Neuston

These are unattached organisms which live at the air water interface such as floating plants, etc. Some organisms spend most of their lives on top of the air-water interface such as water striders, while others spend most of their time just beneath the air-water interface and obtain most of their food within the water. Example: beetles and backswimmers.

7.1.1.2 Periphyton

These are organisms which remain attached to stems and leaves of rooted plants or substances emerging above the bottom mud such as sessile algae and their associated group of animals.

7.1.1.3 Plankton

This group includes both microscopic plants like algae (phytoplankton) and animals like crustaceans and protozoan's (zooplankton) found in all aquatic ecosystems, except certain swift moving waters. The locomotory power of the planktons is limited so that their distribution is controlled, largely, by currents in the aquatic ecosystems.

7.1.1.4 Nekton

This group contains animals which are swimmers. The nektons are relatively large and powerful as they have to overcome the water currents. The animals range in size from the swimming insects (about 2 mm long) to the largest animals, the blue whale.

7.1.1.5 Benthos

The benthic organisms are those found living in the bottom of the water mass. Practically, every aquatic ecosystem contains well developed benthos. Clams, worms, oysters, shrimp-like crustaceans and mussels are all examples of benthic organisms.

7.1.2 Factors limiting productivity of Aquatic Habitats

7.1.2.1 Sunlight

It is the most important factor of productivity in aquatic ecosystem. The penetration of light and distribution of plant is classified into two zone i.e. Photic and Aphotic zone.

a) **Photic zone:** This is the upper layer of the aquatic ecosystem up to which light penetrates and within which photosynthetic and respiration activity takes place. The depth of this zone depends on the transparency of water.

b) **Aphotic zone:** It is the lower layer of aquatic ecosystem where the light penetration and plant growth is restricted, so only respiration activity is limited to this zone. This zone is positioned below the littoral and photic zone.

7.1.2.2 Dissolved Oxygen

Dissolved oxygen (DO) is one of the most important indicators of water quality. It is essential for the survival of fish and other aquatic organisms. Oxygen dissolves in surface water due to the aerating action of winds. Oxygen is also introduced into the water as a byproduct of aquatic plant photosynthesis. The colder water is, the more oxygen it can hold. As the water becomes warmer, less oxygen can be dissolved in the water. Many aquatic creatures die when the dissolved oxygen content goes below 3-5 ppm.

7.1.2.3 Temperature

Aquatic creatures have a narrow temperature tolerance limit because water temperatures are less susceptible to change.

7.2 Freshwater Ecosystem

Freshwater ecosystems are made up of water on land that is constantly cycling and has a low salt content (always less than 5 ppt). Freshwater ecosystems are divided into two categories:

7.2.1 Lentic Ecosystem

- They include all ecosystems with static or still water.
- Lakes and ponds are among the most common examples of the Lentic Ecosystem.
- Algae, crabs, shrimp, and amphibians like frogs and salamanders also live in these habitats.
- It is also called the **lacustrine ecosystem** or the **still water ecosystem.**

7.2.2 Lotic Ecosystem

- These primarily relate to fast-moving water bodies that run in one direction, such as rivers and streams.
- Furthermore, these settings support a diverse range of organisms, including beetles, mayflies, stoneflies, and a variety of fish species, including trout, eel, and minnow.
- It is also called the **riverine ecosystem**.

7.3 Marine Ecosystem

- Marine ecosystems are defined as bodies of water with a salt concentration equal to or greater than that of seawater (i.e. 35 ppt or above).
- Marine ecosystems are the largest of the Earth's aquatic ecosystems, and they exist in salty waters.

7.3.1 Coral Reefs

- Coral reefs are built by and made up of thousands of tiny animals—**coral "polyps"**—that are related to **anemones and jellyfish.**
- Polyps are **shallow water organisms** which have a soft body covered by a **calcareous skeleton**. The polyps extract calcium salts from sea water to form these hard skeletons.
- The polyps live in colonies fastened to the rocky sea floor.
- The tubular skeletons grow upwards and outwards as a cemented calcareous rocky mass, collectively called **corals.**
- When the coral polyps die, they shed their skeleton (coral) on which new polyps grow.

- The cycle is repeated for over millions of years leading to accumulation of layers of corals (shallow rock created by these depositions is called **reef**).
- These layers at different stages give rise to various marine landforms. One such important landform is called **coral reef.**
- Coral reefs over a period of time transform or evolve into **coral islands (Lakshadweep).**
- The corals occur in different forms and colors, depending upon the **nature of salts** or constituents they are made of.
- Small marine plants **(algae)** also deposit calcium carbonate contributing to coral growth.

7.3.1.1 Ideal growth conditions for Coral reefs

- **Sunlight and temperature**: Corals need to grow in shallow water as sunlight is important for growth. Corals depend on the zooxanthellae (algae) that need sunlight to survive.
- **Clean Water**: Corals need clear water as clean water lets sunlight through. They don't thrive well in opaque water. Also, Sediment and plankton can cloud water, decreasing sunlight exposure.
- **Warm water temperature**: Reef-building corals need warm water to survive. Different corals living in different regions can withstand various temperatures fluctuations.
- **Saltwater**: Corals need saltwater and a certain balance in the ratio of salt to water to survive. This is why corals don't live in areas of estuaries. Corals cannot tolerate turbid and freshwaters. They also cannot tolerate excessive salinity.
- **Stable climatic conditions** are conducive for the growth of corals.
- **Narrow diurnal and annual temperature ranges**
- **Abundant sunlight available:** The ideal depths for coral growth are 45 m to 55 m below sea surface, where there is abundant sunlight available.
- Corals are highly fragile and are **vulnerable to climate change and pollution** and even a minute increase in marine pollution can be catastrophic.

7.3.1.2 Types of coral reefs

a) Fringing reefs

Fringing reefs evolve and develop near the continent and remain close to the coastline. These reefs are separated from the coastline by small, shallow lagoons. They are the most commonly found reefs in the world. Fringing reefs can be seen at the New Hebrides Society islands off Australia and off the southern coast of Florida.

b) Barrier reefs

Barrier reefs are found offshore on the continental shelf. They usually run parallel to the coastline at some distance. A deep and wide lagoon is located between the coastline and the barrier reef. The **1200-mile long Great Barrier Reef** off the NE coast of Australia is the world's largest example of this reef type.

c) Atolls

Atolls are formed on mid-oceanic ridges. They are shaped circularly or elliptically and are surrounded by seas on all four sides and have shallow waters in the center called a lagoon. In the South Pacific, most atolls occur in mid-ocean. Examples of this reef type are common in **French Polynesia, the Caroline and Marshall Islands, Micronesia,** and **the Cook Islands**. The Indian Ocean also contains numerous atoll formations. Examples are found in the **Maldives** and **Chagos island groups**, **the Seychelles**, and in **the Cocos Island group.**

d) Patch reefs

Patch reefs are small and isolated reefs usually occur between fringing reefs and barrier reefs and grow from the open bottom of the island or continental shelf. They rarely reach to the surface. These reefs are quite common in the Caribbean and Pacific Islands.

7.3.1.3 Importance of Coral Reefs

a) **Coastal protection**: Healthy reefs act as natural barriers, protecting coastal areas and beaches from strong ocean waves. Without coral reefs, many beaches and buildings become vulnerable to wave and storm damage. With more frequent storms due to climate change, these coastal protection services will become even more important.
b) Example: In the tsunami of December 2004, some coastlines were protected from severe damage because of healthy reefs.
c) **Food**: Reef fish are a source of protein for a billion people, especially for those living near reefs.
d) **Medicine**: Coral reefs are called the medicine chests of the sea. Some creatures found on reefs produce compounds that have been used for human applications.

e) Example: Coral's unique skeletal structure has been used for making bone-grafting materials.

f) **Tourism**: Healthy reefs support local and global economies. The tourism industry and fisheries, coral reefs generate billions and provide jobs for millions around the world.

g) **Economic Benefits:** Countries with coral reef industries get most of the gross national product from them. A study estimated the value of coral reefs at $10 billion and direct economic benefits of $360 million per year.

h) **Meteorology**: corals found in the North Indian Ocean had the potential to provide new insights into the onset and withdrawal of the Indian Monsoon until a few hundred years ago.

7.3.1.4 Threats to the coral ecosystem

a) **Global Warming:** As the global warming increases leads to melting of glaciers and decreases the Salinity of Ocean as influx of River Water increases and hence threats to coral reefs are increasing.

b) **Coral Bleaching**: Most corals have a narrow temperature tolerance. Coral bleaching when corals are stressed due to warmer ocean waters. Corals eject the symbiotic algae that live inside them when stressed. When corals lose their algae, they lose their built-in food source. Outbreaks of coral disease follow bleaching events as the stressed corals are susceptible to infection.

c) **Rising sea-surface temperature**: As glaciers melt due to global warming, they cause sea levels to rise. Consequently, corals end up in deeper underwater, receive less sunlight and grow more slowly.

d) **Natural Disaster:** Stronger, more frequent storms, hurricanes, cyclones can break coral branches and overturn coral colonies.

e) **Ocean Acidification**: As the oceans absorb CO2, they become more acidic. With increased acidity in the water, coral may form weaker skeletons, be more vulnerable to disease and destruction by storms.

f) **Ozone Depletion**: Corals have a natural sunscreen for protection from UV rays radiation but if UV rays level increases, this radiation can damage corals in shallow waters.

g) **Unsustainable fishing**: Overfishing is a threat affecting around 55 percent of the world's coral reefs.

h) **Water Pollution**: An overabundance of nutrients in marine environments upsets the balance of reef ecosystems. Excess nutrients promote the growth of algae, which can kill corals by smothering, blocking sunlight, and promoting the growth of harmful bacteria.

i) **Habitat Destruction**: Coral reefs are living structures that can take years to regenerate once destroyed. Many activities such as Coral mining, construction, Coral collecting, destructive fishing methods, unsustainable tourism affect the habitat and impact coral reefs adversely.

7.3.1.5 Coral reefs in India

India has four coral reef areas:

1. Gulf of Mannar
2. Andaman and Nicobar Islands
3. Lakshadweep islands
4. The Gulf of Kutch

7.3.1.6 Coral Bleaching

- When corals face stress by changes in conditions such as temperature, light, or nutrients, they expel the symbiotic algae zooxanthellae living in their tissues, causing them to turn completely white. This phenomenon is called coral bleaching.
- The pale white color is of the translucent tissues of calcium carbonate which are visible due to the loss of pigment producing zooxanthellae.
- Corals can recover if the stress-caused bleaching is not severe.
- Coral bleaching has occurred in the Caribbean, Indian, and Pacific oceans on a regular basis.

7.3.1.7 Causes of Coral Bleaching

a) **Rise in Sea Temperature:** Most coral species live in waters close to the warmest temperature they can tolerate i.e., a slight increase in ocean temperature can harm corals. El Nino elevates the sea temperature and destroys coral reefs.

b) **Ocean Acidification:** Due to rise in carbon dioxide levels, oceans absorb more carbon dioxide. This increases the acidity of ocean water and inhibits the corals ability to create calcareous skeletons, which is essential for their survival.

c) **Solar radiation and ultraviolet radiation:** Changes in tropical weather patterns result in less cloud cover and more radiations which induce coral bleaching.

d) **Infectious Diseases:** Penetration of bacterium like vibrio shiloi inhibits photosynthesis of zooxanthellae. These bacteria become more potent with elevated sea temperatures.

e) **Chemical Pollution:** Increased nutrient concentrations affect corals by promoting phytoplankton growth, which in turn supports increased numbers of organisms that compete with coral for space.

f) **Increased Sedimentation:** Land clearing and coastal construction result in high rates of erosion and a higher density of suspended silt particles which can:

   1. Smother corals when particles settle out (sedimentation),
   2. Reducing light availability (turbidity) and
   3. Potentially reducing coral photosynthesis and growth.

g) **Human Induced Threats:** Over-fishing, pollution from agricultural and industrial runoff, coral mining, development of industrial areas near coral ecosystems also adversely impact corals.

7.4 Estuary Ecosystem

- An estuary is a place where a river or a stream opens into the sea (mouth of the river).
- It is partially enclosed coastal area of brackish water (salinity varies between 0 – 35 ppt) with one or more river or streams flowing into it, and with a free connection to the open sea.
- At the estuaries, freshwater carrying fertile silt and runoff from the land mixes with the salty sea water.
- Estuaries form a transition zone (ecotone) between river environments and maritime environments.
- Estuaries are formed due to rise in sea level, movement of sand and sandbars, glacial processes and tectonic processes.
- All the plants and animals I the estuaries are subjected to variations in salinity to which they are adapted (osmoregulation).
- Estuaries are generally influenced by tidal action. They are periodically washed by sea water once or twice a day based on the number of tides.
- Estuaries are usually biologically highly productive zones.

- They also act as a filter for some dissolved constituents in river water; these precipitate in the zone where river water meets seawater.
- In general, the phytoplanktons of estuaries are diatoms, dinoflagellates, green algae, blue-green algae.
- Towards the sea coast of the estuaries, there are large algae and sea grass. Near the mouth of the rivers and deltas, there are mangrove forests.
- Examples of estuaries are river mouths, coastal bays, tidal marshes, lagoons and deltas.

7.4.1 Mangroves

- Mangroves are the characteristic littoral plant formation and subtropical coastlines.
- Mangroves are trees and bushes growing below the high water level of spring tides which exhibits remarkable capacity of salt water tolerance.
- The best locations are where abundant silt is brought down by rivers on the backshore of accreting sandy beaches.
- Mangroves are highly productive ecosystems and the trees may vary in height from 8 – 20m. They protect the shoreline form the effect of cyclone sands tsunamis.
- They are breeding and spawning ground for many commercially important fishes.
- Since mangroves are located between the land and the sea, they represent the best example of ecotone.
- Mangroves are shrubs or small trees that grow in coastal saline or brackish water.
- Mangroves are salt tolerant trees, also called halophytes, and are adapted harsh coastal conditions.
- Mangrove vegetation facilitates more water loss. Leaves are thick and contain salt secreting gland .Some block absorption of slat at their roots itself.
- They contain a complex slat filtration system and complex root system to cope with salt water immersion and wave action.
- They are adapted to the low oxygen (anoxic) conditions of waterlogged mud.
- They produce pneumatophores (blind roots) to overcome the respiration problem in the anaerobic soil.
- Mangroves occur worldwide in the tropics and subtropics, mainly between latitudes 25° N and 25° S.

- They require high solar radiation to filter saline water through their roots. This explains why mangroves confined to only tropical and subtropical coastal waters.

7.4.1.1 Mangroves in India

- Mangroves of **Sundarbans** are the largest single block of tidal halophytic mangroves of the world. This mangrove forest is famous for the **Royal Bengal tiger** and crocodiles.
- The mangroves of **Bhitarkanika** (Orissa), which is the second largest in the Indian sub-continent, harbor high concentration of typical mangrove species and high genetic diversity.
- Mangrove swamps occur in profusion in the intertidal mudflats on both side of the creeks in the Godavari-Krishna deltaic regions of Andhra Pradesh.

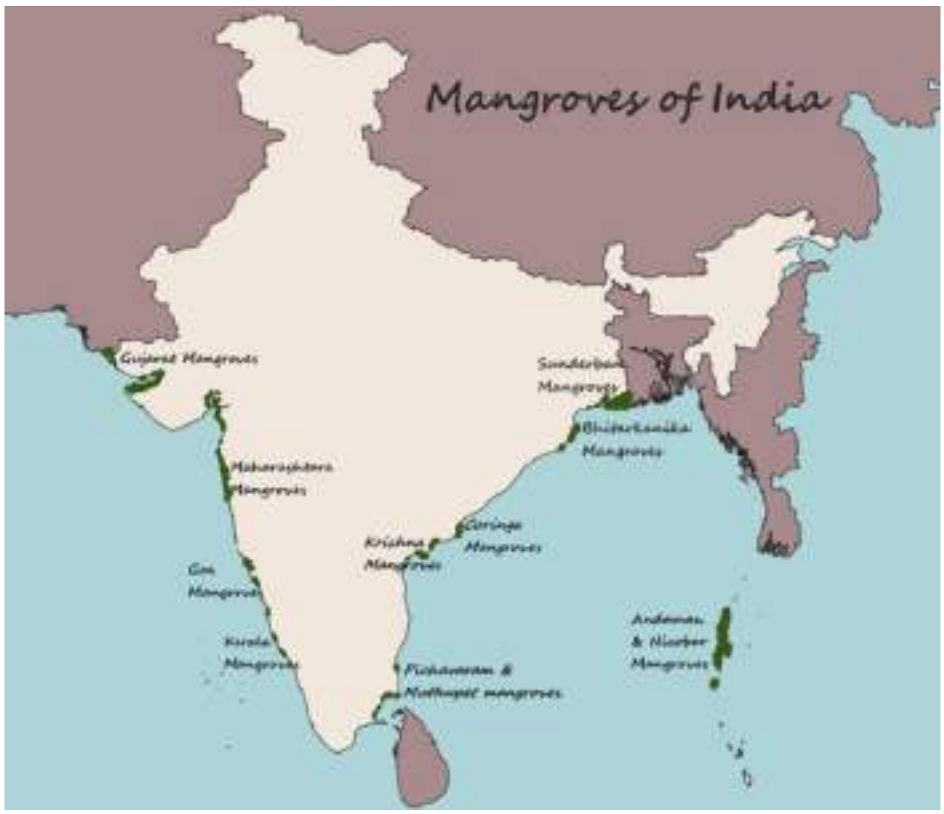

Fig 7.1 Mangrove map of India

- Mangroves of **Pichavarm** and **Vedaranyam** are degraded mainly due to the construction of aquaculture ponds and salt pans.

7.4.1.2 Threat to Mangroves

Mangroves are destroyed for conversion of the area for agricultural purpose, fuel, fodder and salinisation, mining, oil spills, aquaculture farming, use of pesticides and fertilizers and industrial purposes.

7.5 Wetlands

- Wetlands are defined as: "lands transitional between terrestrial and aquatic eco-systems where the water table is usually at or near the surface or the land is covered by shallow water".
- Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land, or where the land is covered by water.
- Wetlands are **transition zones (ecotone)** between terrestrial and aquatic ecosystems.
- Example: Mangroves lake littorals (marginal areas between highest and lowest water level of the lakes), floodplains (areas lying adjacent to the river channels beyond the natural levees and periodically flooded during high discharge in the river) and other marshy or swampy areas.

7.5.1 Classification of Wetlands

There are several ways in which the wetland classification is done. According to Ramsar Convention, three major classes are identified:

1. Marine/Coastal Wetlands
2. Inland Wetlands
3. Human-made Wetlands

These are subdivided by the type of water: fresh / saline / brackish / alkaline; further may be subdivided based on whether they are permanent or temporary.

7.5.2 Four Major Types of Wetlands

7.5.2.1 Marshes

These are periodically saturated or flooded with water and characterized by herbaceous (non-woody) vegetation adapted to wet soil conditions. Marshes are further characterized as **tidal marshes** and **non-tidal marshes**.

7.5.2.2 Swamps

These are fed primarily by surface water inputs and are dominated by trees and shrubs. Swamps occur in either freshwater or saltwater floodplains. Some of the world's largest swamps are found along major rivers such as the Amazon, the Mississippi and the Congo.

7.5.2.3 Bogs

A Bog is a mire that accumulates peat. A Bog is dome shaped landform, is higher than the surrounding landscape, and obtains most of its water from rainfall. The gradual accumulation of decayed plant material in a bog functions as a carbon sink. The characteristic is acidic surface water, low in nutrients. These are the features of cold, temperate boreal climate of Northern Hemisphere.

7.5.2.4 Fen

The difference with Bog is that a Fen is served by both groundwater and rainfall and is therefore, is slightly acidic, neutral or alkaline. It is relatively rich in minerals. It is located on a slope, flat or a depression. They are also features of cold climates such as in Western Europe.

7.5.3 Functions of Wetland

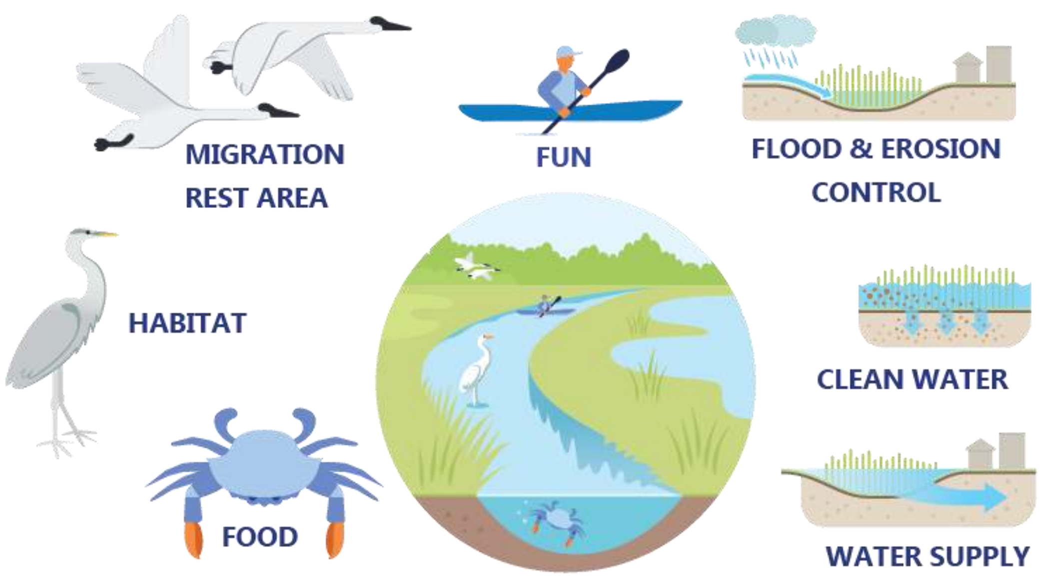

Fig 7.2 Functions and Benefits of Wetland

7.5.4 Threats to Wetlands

- Dense human population in catchment areas.
- Rapid urbanization
- Drainage of wetlands for agricultural and construction activities causes harm to wetlands.
- The introduction of invasive species to wetlands damages the wetland ecosystems.
- Pollution of wetlands due to human activities such as the dumping of factory wastes is harming the flora and fauna of wetland ecosystems.
- Climate change
- The construction of dams alters the flow of water to wetlands thus altering the healthy status of wetlands.
- Weed choking is another cause of concern for wetlands.
- Sand and shell removal is harming the wetlands.
- Wastes from intensive aquaculture are another threat.
- Upstream human activities exert pressure on the downstream area in coastal backwaters.

7.5.5 Ramsar Convention on Wetlands

- The Convention came in to force in 1975.
- The Convention's mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world" **(to be continued in chapter-38).**

7.6 Challenges of Aquatic Ecosystem

7.6.1 Eutrophication

- Lakes receive their water from surface runoff and along with its various chemical substances and minerals.
- Over periods spanning millennia, ageing occurs as the lakes accumulate mineral and organic matter and gradually, get filled up.
- The nutrient-enrichment of the lakes promotes the growth of algae, aquatic plants and various fauna. This process is known as natural **eutrophication**.

- Similar nutrient enrichment of lakes at an accelerated rate is caused by human activities and the consequent ageing phenomenon is known as **cultural eutrophication**.
- On the basis of their nutrient content, lakes are categorized as **Oligotrophic (very low nutrients)**, **Mesotrophic (moderate nutrients)** and **Eutrophic (highly nutrient rich)**.
- A vast majority of lakes in India are either **eutrophic or mesotrophic** because of the nutrients derived from their surroundings or organic wastes entering them.

7.6.1.1 Effects of Eutrophication

- **Loss of freshwater lakes:** Eutrophication eventually creates **detritus layer** in lakes and produces successively **shallower** depth of surface water.
- Eventually, the water body is reduced into marsh whose plant community is **transformed** from an aquatic environment to a recognizable **terrestrial** environment.
- Algal Blooms restrict the penetration of sunlight resulting in the **death of aquatic plants** and hence restricts the replenishment of oxygen.
- **New species invasion:** Eutrophication may cause the ecosystem competitive by transforming the normal limiting nutrient to abundant level. This cause shifting in species composition of the ecosystem.
- **Loss of coral reefs:** Occurs due to decrease in water transparency (increased turbidity).

7.6.2 Algal Bloom

An algal bloom or marine bloom or water bloom is a rapid increase in the population of algae in an aquatic system. Algal blooms may occur in freshwater as well as marine environments.

7.6.2.1 Harmful Algal Bloom (HABs)

- Harmful algal blooms are overgrowths of algae in water. Some produce dangerous toxins in fresh or marine water but even nontoxic blooms hurt the environment and local economies.
- Most algal blooms are not harmful, but some produce toxins. These are known as Harmful Algal Blooms (HABs).
- Some algal blooms when died or eaten, release **neuro & hepatotoxins** which can kill aquatic organism & pose a threat to humans. E.g. **Shellfish poisoning**.

- HAB events adversely affect commercial and recreational fishing, tourism, and valued habitats, creating a significant impact on local economies and the livelihood of coastal residents.

7.6.2.2 Causes of Algal Bloom

1. **Nutrients:** Nutrients promote and support the growth of algae and cyanobacteria. The **Eutrophication** (nutrient enrichment) of waterways is considered as a major factor.
2. **Temperature:** Blooms are more likely to happen in summer or fall but can occur any time of year.
3. **Turbidity:** Turbidity is caused by the presence of suspended particles and organic matter in the water column. When turbidity is low, more light can penetrate through the water column. This creates optimal conditions for algal growth.

7.6.2.3 Effects of Algal Bloom

- Produce extremely dangerous toxins that can sicken or kill people and animals.
- There have also been complaints of respiratory distress in humans due to red tide.
- Algal Blooms deprive aquatic organisms of Sunlight and oxygen and negatively impact a variety of species that live below the water surface.
- Create **Dead Zones** in the water.
- Raise treatment costs for drinking water. Hurt industries that depend on clean water.

7.6.2.4 Mitigation

- **Multiple treatment of effluent:** Simple treatment options are not effective; multiple treatment steps are typically needed to remove algae toxins. Using tertiary sewage treatment methods to remove phosphate and nitrate before discharging the effluent into rivers and lakes.
- **Nitrogen testing & modelling:** N-Testing is a technique to find the optimum amount of fertilizer required for crop plants. It will reduce the amount of nitrogen lost to the surrounding area.

Important term

"Dead zone" is a more common term for hypoxia, which refers to a reduced level of oxygen in the water.

- **Encouraging organic farming:** Reducing the overuse of fertilizers in agriculture and encouraging organic farming can reduce the bulk flow of runoff and can be effective for reducing severe algal blooms.
- **Reduction in nitrogen emission** from vehicles and power plants.
- **Reducing the use of phosphates** as builders in detergents.

7.7 Salient Features

- An ecosystem in a water body is called as Aquatic Ecosystem. It comprises of three ecosystem i.e. freshwater, marine and estuary ecosystem.
- Neuston, Periphyton, Plankton, Nekton and Benthos are the different types of aquatic organism classified on the basis of their zone of occurrence and their ability to cross these zones.
- Freshwater ecosystems are made up of water on land that is constantly cycling and has a low salt content (always less than 5 ppt). It is divided into the two types of ecosystem: lotic (flowing) and lentic (standing) fresh water ecosystem.
- Marine ecosystems are defined as bodies of water with a salt concentration equal to or greater than that of seawater (i.e. 35 ppt or above).
- Coral reefs are built by and made up of thousands of tiny animals—coral “polyps”—that are related to anemones and jellyfish.
- There are 4 types of coral reefs: Fringing, barrier, atolls and patch reefs.
- When corals face stress by changes in conditions such as temperature, light, or nutrients, they expel the symbiotic algae zooxanthellae living in their tissues, causing them to turn completely white. This phenomenon is called coral bleaching.
- Estuary is partially enclosed coastal area of brackish water (salinity varies between 0 – 35 ppt) with one or more river or streams flowing into it, and with a free connection to the open sea.
- Mangroves are a group of trees and shrubs that live in the coastal intertidal zone.
- Wetlands are defined as: "lands transitional between terrestrial and aquatic eco-systems where the water table is usually at or near the surface or the land is covered by shallow water".
- Marshes, swamps, bogs and fen are the four major types of wetland.

- The Ramsar Convention's mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world",
- Eutrophication is the process in which a water body becomes overly enriched with nutrients, leading to plentiful growth of simple plant life.
- An algal bloom or marine bloom or water bloom is a rapid increase in the population of algae in an aquatic system.
- Harmful algal blooms (HABs) are the rapid growth of algae or cyanobacteria that can cause harm to people, animals, or the local ecology.

CHAPTER – 8

Functions of an ecosystem

8. Functions of an Ecosystem

An ecosystem is a wide, complex, and integrated dynamic system. It may be studied in the context of energy flow and food chains. They connect the biotic and abiotic components of an ecosystem.

8.1 Energy Flow

Energy is the fundamental factor that drives all metabolic processes. Energy flow is the unidirectional movement of energy from the producer to the top consumers. The study of trophic level interaction in an ecosystem provides insight into the ecosystem's energy flow.

8.2 Trophic level interaction

Trophic level interaction deals with how the members of an ecosystem are connected based on nutritional needs.

Table 8.1 Trophic levels

Trophic levels (Trophe = nourishment)		
I	Autotrophs	Green plants (producers)
II	Heterotrophs	Herbivore (primary consumers)
III	Heterotrophs	Carnivores (secondary consumers)
IV	Heterotrophs	Carnivore (tertiary consumers)
V	Heterotrophs	Top carnivores (quaternary consumers)

Energy flows through the trophic levels: from producers to subsequent trophic levels. This energy always flows from lower (producer) to higher (herbivore, carnivore etc.) trophic level. It never flows in the reverse direction that is from carnivores to herbivores to producers. Each trophic level loses some energy in the form of useless heat, hence the energy level drops from the first trophic level upwards.

As a result, there are normally four or five trophic levels, and seldom more than six, as there is insufficient energy to support any organism beyond that. Trophic levels are numbered according to the steps an organism is away from the source of food or energy that is the producer. The trophic level interaction involves three concepts namely:

1. Food Chain
2. Food Web
3. Ecological Pyramids

8.2.1 Food Chain

The ecosystem's organisms are linked via trophic levels or feeding mechanisms, in which one creature becomes food for another. A food chain is a series of organisms that feed on one another. Producers are at the beginning of the food chain, while top carnivores are at the end. The food chain is the sequence of eating and being eaten that results in the transfer of food energy. The plant converts solar energy into chemical energy by photosynthesis. Plant matter is consumed by small herbivores, who then transform it to animal matter. Large carnivores consume these herbivores.

8.2.1.1 Types of Food Chain

i. **Grazing food chain:** The grazing food chain is made up of the consumers who start the food chain by eating the plant or plant portion. The food chain starts with green plants at the bottom, and herbivores are the primary consumers.

For example, in terrestrial ecosystem, grass is eaten up by caterpillar, which is eaten by lizard and lizard is eaten by snake. In Aquatic ecosystem phytoplankton (primary producers) is eaten by zoo plankton which is eaten by fishes and fishes are eaten by pelicans.

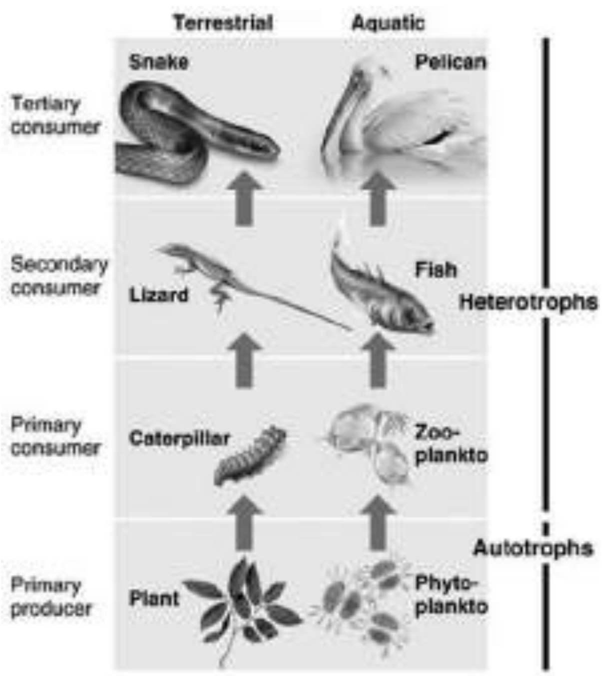

Fig. 8.1 Grazing food chain

ii. **Detritus food chain:** It begins with microorganisms consuming the dead organic matter of decaying animals and plant bodies, followed by detritus-feeding creatures known as detrivores or decomposers, and to other predators.

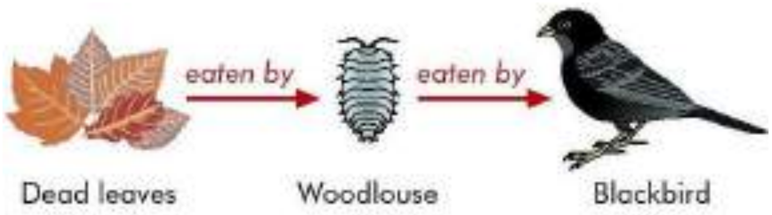

Fig. 8.2 Detritus food chain

The source of energy for the first level consumers distinguishes these two food chains. The major source of energy in the grazing food chain is live plant biomass, whereas the primary source of energy in the detritus food chain is dead organic matter or detritus. Both food chains are interconnected. The waste materials and dead organic matter from the grazing food chain provide the first energy source for the detritus food chain.

8.2.2 Food Web

A food chain is just one aspect of the food or energy flow across an ecosystem and it implies a simple, isolated relationship that is seldom found in ecosystems. Several interconnected food chains can make up an ecosystem. More typically, the same food supply is found in many food chains, especially at lower trophic levels. "A food web depicts all possible energy and nutrition exchanges among organisms in an ecosystem, whereas a food chain follows only one food pathway".

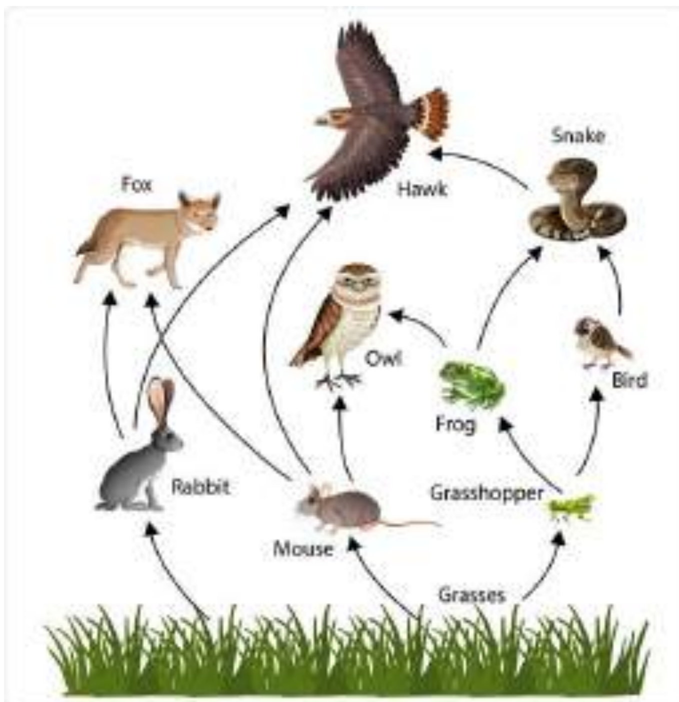

Fig. 8.3 Food Wed

If any link in the intermediate food chain is eliminated, the chain's subsequent links will be severely impacted. Most organisms in an environment have more than one food source due to the food web and therefore it increases their chance of survival. For example, grasses may serve food for rabbit or grasshopper or goat or cow. Similarly, a herbivore may be food source for many carnivorous species.

Also, food availability and preferences of food of the organisms may shift seasonally e.g. we eat watermelon in summer and peaches in the winter. Thus, there are interconnected networks of feeding relationships that take the form of food webs.

8.2.3 Ecological Pyramids

Ecological pyramids are diagrammatic representations of the stages of trophic levels. The base of the pyramid is the food producer, and the apex is the top carnivore. Other trophic levels of consumer are in the middle. The pyramid is made up of a series of horizontal bars that represent different trophic levels, grouped in order from primary producer through herbivore to carnivore. The total number of individuals at each trophic level in an ecosystem is represented by the length of each bar. With each step from the producer to the consumer level, the number, biomass, and energy of organisms decreases, and the diagrammatic depiction takes on a pyramid form. There are three types of ecological pyramids.

1. Pyramid of numbers,
2. Pyramid of biomass,
3. Pyramid of energy or productivity.

Do you know?

Charles Elton developed the concept of the ecological pyramids. These pyramids are also known as Eltonian pyramids.

8.2.3.1 Pyramid of Numbers

The link between the number of primary producers and different levels of consumers. It is a graphical depiction of the total number of individuals belonging to various species at each trophic level in an ecosystem. The pyramid of number may not always be upright, and may even be totally inverted, depending on the size and biomass of the organism.

a) Pyramid of numbers – upright

- In this pyramid, the number of individuals is decreased from lower level to higher trophic level.
- This type of pyramid can be seen in grassland ecosystem.
- The grasses occupy the lowest trophic level (base) because of their abundance.
- The next higher trophic level is primary consumer - herbivore (example – grasshopper).
- The individual number of grasshopper is less than that of grass. The next energy level is primary carnivore (example – rat).

- The number of rats are less than grasshopper, because, they feed on grasshopper. The next higher trophic level is secondary carnivore (example – snakes). They feed on rats.
- The next higher trophic level is the top carnivore. (Ex. Hawk).

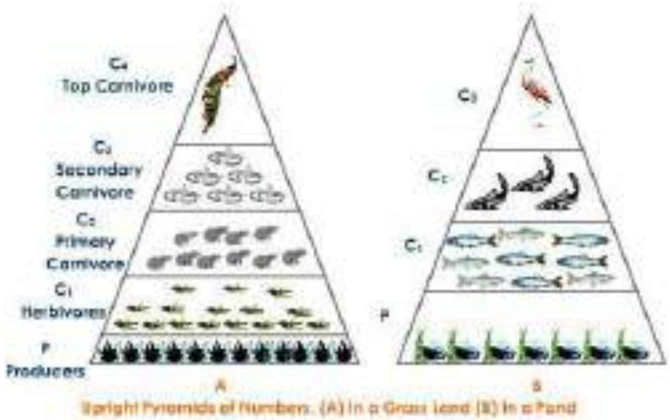

Fig. 8.4 Upright pyramid of numbers

- With each higher trophic level, the number of individual decreases.

b) Pyramid of numbers – inverted

- In this pyramid, the number of individuals is increased from lower level to higher trophic level.
- A count in a forest would have a small number of large producers, for e.g. few number of big trees.
- This is because the tree (primary producer) being few in number and would represent the base of the pyramid and the dependent herbivores (Example - Birds) in the next higher trophic level and it is followed by parasites in the next trophic level. Hyper parasites being at higher trophic level represents higher in number.
- And the resulting pyramid is in inverted shape. A pyramid of numbers does not take into account the fact that the size of organisms being counted in each trophic level can vary.
- It is very difficult to count all the organisms, in a pyramid of numbers and so the pyramid of number does not completely define the trophic structure for an ecosystem.

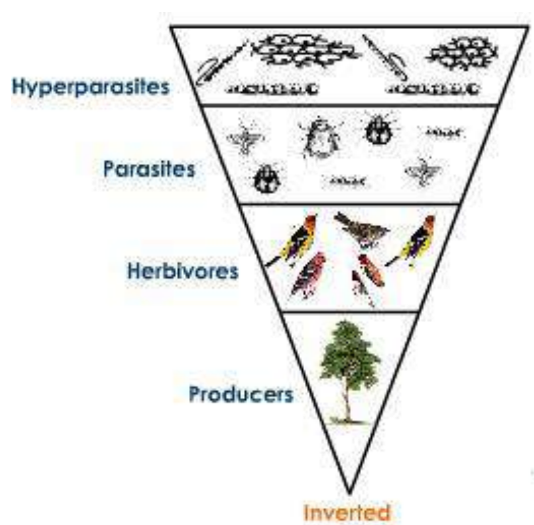

Fig. 8.5 Inverted pyramid of numbers

8.2.3.2 Pyramid of Biomass

The pyramid of biomass is used to overcome the drawbacks of the pyramid of numbers. Individuals at each trophic level are weighed rather than counted in this method. This results in a biomass pyramid, which represents the total dry weight of all organisms at each trophic level at any given moment. Pyramid of biomass is usually determined by collecting all organisms occupying each trophic level separately and measuring their dry weight. This overcomes the size difference problem because all kinds of organisms at a trophic level are weighed. Biomass is measured in g/m^2.

a) Upward pyramid

For most ecosystems on land, the pyramid of biomass has a large base of primary producers with a smaller trophic level perched on top. The biomass of producers (autotrophs) is at the maximum. Primary consumers have less biomass than producers at the following trophic level. The biomass of secondary consumers i.e., the next higher trophic level, is lower than that of primary consumers. There is relatively little biomass at the top i.e., high trophic level.

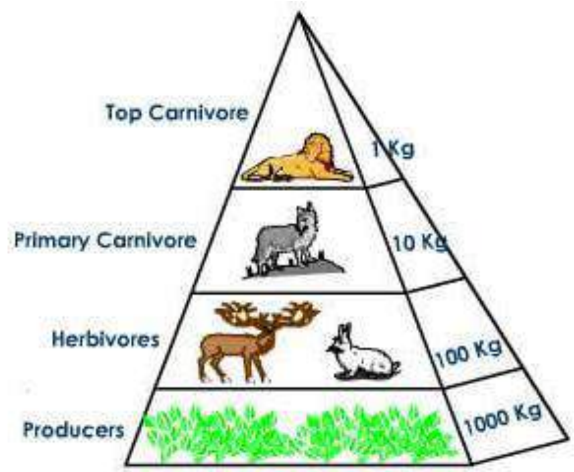

Fig. 8.6 Upward pyramid of Biomass

b) Inverted pyramid

In contrast, in many aquatic ecosystems, the pyramid of biomass may assume an inverted form. This is because the producers are tiny phytoplanktons that grow and reproduce rapidly. Here, the pyramid of biomass has a small base, with the consumer biomass at any instant actually exceeding the producer biomass and the pyramid assumes inverted shape.

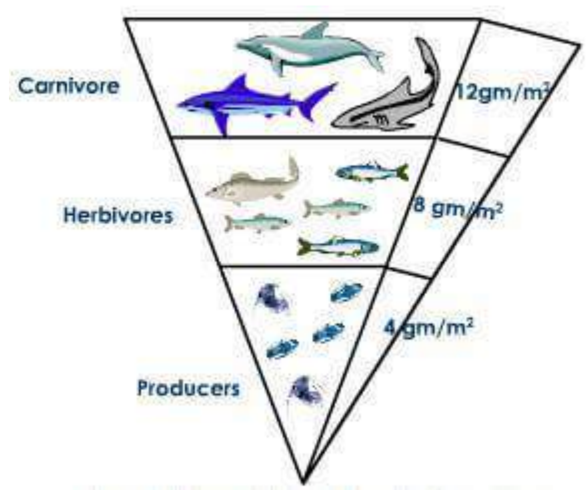

Fig. 8.7 Upward pyramid of Biomass

8.2.3.3 Pyramid of Energy

An energy pyramid is the best way to compare the functional roles of the trophic levels in an ecosystem. An energy pyramid, reflects the laws of thermodynamics, with conversion of solar energy to chemical energy and heat energy at each trophic level and with loss of energy being depicted at each transfer to another trophic level. Hence the pyramid is always upward, with a large energy base at the bottom.

This can be explained with the help of an example, suppose an ecosystem receives 1000 calories of light energy in a given day. Most of the energy is not absorbed; some is reflected back to space; of the energy absorbed only a small portion is utilized by green plants, out of which the plant uses up some for respiration and of the 1000 calories, therefore only 100 calories are stored as energy rich materials.

Now suppose an animal, say a deer, eats the plant containing 100 Cal of food energy. The deer uses some of it for its own metabolism and stores only 10 Cal as food energy. A lion that eats the deer gets an even smaller amount of energy. Thus usable energy decreases from sunlight to producer to herbivore to carnivore. Therefore, the energy pyramid will always be upright.

Fig. 8.8 Upward pyramid of Biomass

Energy pyramid concept helps to explain the phenomenon of biological magnification-the tendency for toxic substances to increase in concentration progressively at higher levels of the food chain.

8.3 Pollutants and Trophic Level

Pollutants especially non-degradable ones move through the various trophic levels in an ecosystem. Non-degradable pollutants mean materials, which cannot be metabolized by the living organisms. Example: chlorinated hydrocarbons.

We are concerned about these phenomena because, together they enable even small concentrations of chemicals in the environment to find their way into organisms in high enough dosages to cause problems. Movement of these pollutants involves two main processes:

i. Bioaccumulation

ii. Bio-magnification

8.3.1 Bioaccumulation

- It refers to how pollutants enter a food chain.
- In bioaccumulation there is an increase in concentration of a pollutant from the environment to the first organism in a food chain. For example, pesticides such as DDT (Dichlorodiphenyltrichloroethane), is non-biodegradable. It gets incorporated in the food chain and gets deposited on the tissues of the organisms. When DDT enters aquatic bodies, it gets build up in the body of fishes and this is known as bioaccumulation.

8.3.2 Bio-magnification

- Bio-magnification refers to the tendency of pollutants to concentrate as they move from one trophic level to the next.
- Thus in bio-magnification there is an increase in concentration of a pollutant from one link in a food chain to another.

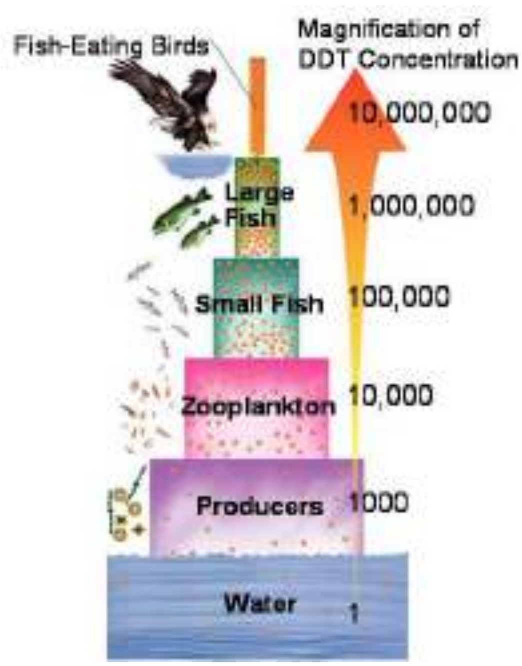

Fig. 8.9 Bio-magnification

The pollutant must be long-lived, mobile, soluble in fats, and biologically active in order for bio-magnification to occur. If a pollutant is short-lived, it will be broken down before it can become dangerous. If it is not mobile, it will remain static and will not be consumed by organisms. The organism will excrete the pollutant if it is soluble in water. Pollutants that dissolve in fats, however, may be retained for a long time. It is traditional to measure the amount of pollutants in fatty tissues of organisms such as fish. In mammals, we often test the milk produced by females, since the milk has a lot of fat in it are often more susceptible to damage from toxins (poisons). If a pollutant is not active biologically, it may bio-magnify, but we really don't worry about it much, since it probably won't cause any problems.

8.4 Salient features

- The flow of energy from producer to top consumers is called energy flow and it is **unidirectional**.
- Trophic level interaction deals with how the members of an ecosystem are connected based on nutritional needs.
- A sequence of organisms that feed on one another, form **food chain**. The sequence of eaten and being eaten, produces transfer of food energy and it is known as food chain.
- There are two types of food chain: Grazing (source of energy is live plant biomass) and detritus (primary source of energy is dead organic matter or **detritus**).
- A **food web** illustrates, all possible transfers of energy and nutrients among the organisms in an ecosystem.
- The steps of trophic levels expressed in a diagrammatic way are referred as ecological pyramids. The ecological pyramids are of three categories: **Pyramid of numbers, Pyramid of biomass and Pyramid of energy or productivity**.
- **Pyramid of numbers** deals with the relationship between the numbers of primary producers and consumers of different levels. These are of two types: Upright (the number of individuals is decreased from lower level to higher trophic level) and Inverted (the number of individuals is increased from lower level to higher trophic level).
- **Pyramid of biomass** shows the total weight and another suitable measures of the total amount of living matter. These are of two types: Upright (has a large base of primary producers with a smaller trophic level perched on top) and Inverted (in aquatic ecosystems, the producers are tiny phytoplanktons that grow and reproduce rapidly thus it is inverted).
- **Pyramid of energy** shows the rate of energy flow and/or productivity at successive trophic levels.
- Pollutants especially non-degradable ones move through the various trophic levels. Movement of these pollutants involves two main processes: Bioaccumulation (how pollutants enter a food chain) and Bio-magnification (the tendency of pollutants to concentrate as they move from one trophic level to the next).

CHAPTER – 9

Biogeochemical cycles

9. Biogeochemical Cycles

Any of the natural pathways by which essential elements of living matter are circulated can be called as the biogeochemical cycle. The term biogeochemical is a contraction that refers to the consideration of the biological, geological, and chemical aspects of each cycle. Elements within biogeochemical cycles flow in various forms from the nonliving (abiotic) components of the biosphere to the living (biotic) components and back. Each biogeochemical cycle can be considered as having a reservoir pool, a larger (slow-moving, usually abiotic portion), and an exchange (cycling) pool (a smaller but more active portion) concerned with the rapid exchange between the biotic and abiotic aspects of an ecosystem. Energy and nutrient circulation are the major functions of the ecosystem. Energy is lost as heat whereas nutrients are recycled indefinitely.

9.1 Types of biogeochemical cycles

Based on the pathways or reservoir, biogeochemical cycles can be divided into following two categories:

a) **Gaseous cycles:** These involve the transportation of matter through the atmosphere.
b) **Sedimentary cycles:** These cycles involve the transportation of matter through the ground to water; that is to say from lithosphere to the hydrosphere.

9.2 Gaseous Cycles

Gaseous cycle can be categorized into carbon cycle, nitrogen cycle and hydrological cycle (water cycle).

9.2.1 Carbon Cycle

Carbon is found in the atmosphere, mostly as carbon dioxide (CO_2). A constant flow of carbon between the atmosphere and organisms is known as the carbon cycle. Photosynthesis transports carbon from the atmosphere to green plants and eventually to organisms. It returns to the atmosphere through the processes of respiration and decomposition of dead organic matter. It is usually a short term cycle.

Some carbon also enters a long term cycle. It builds up as undecomposed organic matter in peaty layers of marshy soil or as insoluble carbonates in bottom sediments of aquatic systems, taking a long time to disintegrate. Such carbon can be buried for millions of years in deep waters until geological action lifts the rocks above sea level. When these rocks are subjected to erosion, carbon dioxide, carbonates, and bicarbonates are released into streams and rivers.

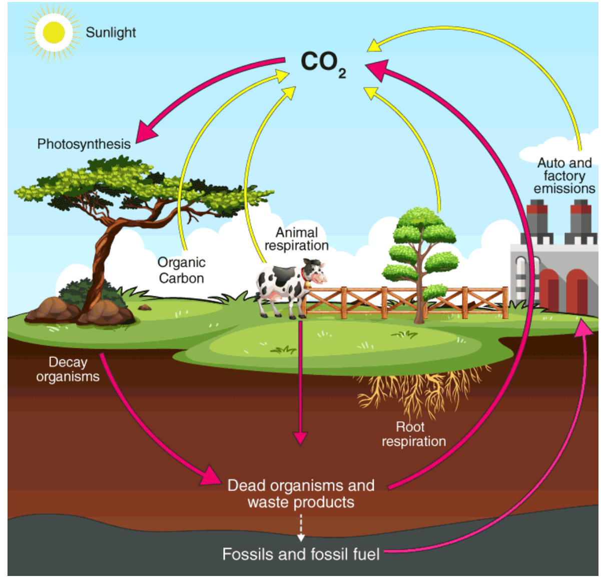

Fig. 9.1 Carbon Cycle

Fossil fuels such as coal, oil and natural gas, are organic substances that were buried before they could disintegrate and were subsequently changed into fossil fuels by time and geological processes. The carbon stored in them is released back into the atmosphere as carbon dioxide when they are burnt.

9.2.2 Nitrogen Cycle

All living organisms require nitrogen to make a variety of complex organic compounds such as amino acids which are the building blocks of proteins, and nucleic acids which include DNA and RNA. The ultimate store of nitrogen is nitrogen gas (N_2), which exists in the atmosphere. Organic materials in soil and the oceans are two other main sources of nitrogen. Following are the five main processes that are essential for nitrogen cycle:

a) Nitrogen fixation: This process involves conversion of gaseous nitrogen into ammonia, a form in which it can be used by plants. Atmospheric nitrogen can be fixed by the following three methods:

1. *Atmospheric fixation:* Lightening, combustion and volcanic activity help in the fixation of nitrogen.
2. *Industrial fixation:* At high temperature (400^{o}C) and high pressure (200 atm.), molecular nitrogen is broken into atomic nitrogen which then combines with hydrogen to form ammonia.
3. *Bacterial fixation:* There are two types of bacteria:

- Symbiotic bacteria e.g. Rhizobium in the root nodules of leguminous plants.
- Free living e.g. Nostoc, Azobacter and Cyanobacteria.

These can combine atmospheric or dissolved nitrogen with hydrogen to form ammonia.

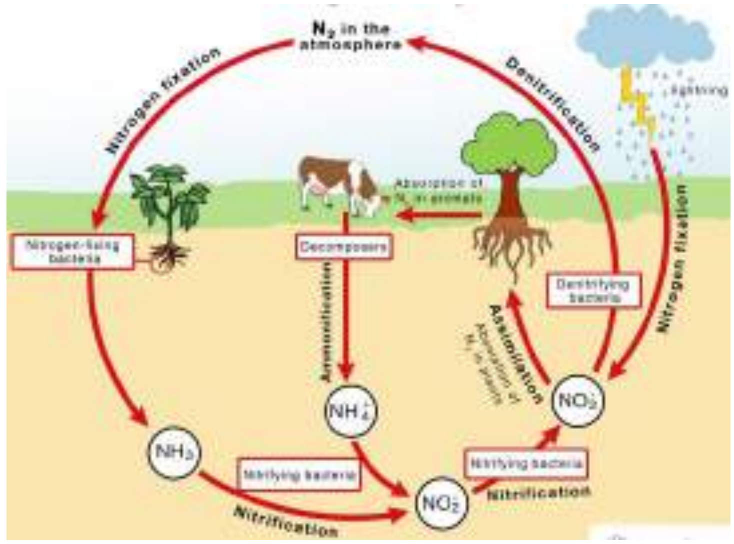

Fig. 9.2 Nitrogen Cycle

b) Nitrification: Nitrosomonas and nitrococcus bacteria convert ammonia to nitrates or nitrites, respectively, in this process. Another soil bacteria, Nitrobacter has the ability to convert nitrate to nitrite.

c) Assimilation: In this process, nitrogen fixed by plants is converted into organic molecules such as proteins, DNA, RNA, etc. These molecules make the plant and animal tissue.

d) Ammonification: Urea and uric acid are nitrogenous waste products produced by living organisms. These waste products as well as dead remains of organisms are converted back into inorganic ammonia by the bacteria. This process is called ammonification.

e) Denitrification: Denitrification is the process of converting nitrates back into gaseous nitrogen. Denitrifying bacteria like to live in an oxygen-free environment, thus they reside deep in the soil near the water table. Denitrification is reverse of nitrogen fixation.

9.2.3 Hydrological Cycle (water cycle)

The hydrologic cycle is the solar-energy-driven continuous circulation of water in the Earth-atmosphere system. Major sources of water on our planet include the atmosphere, oceans, lakes, rivers, soils, glaciers, snowfields and groundwater. Water moves from one reservoir to another by the processes of evaporation, transpiration, condensation, precipitation, deposition, runoff, infiltration, and groundwater flow.

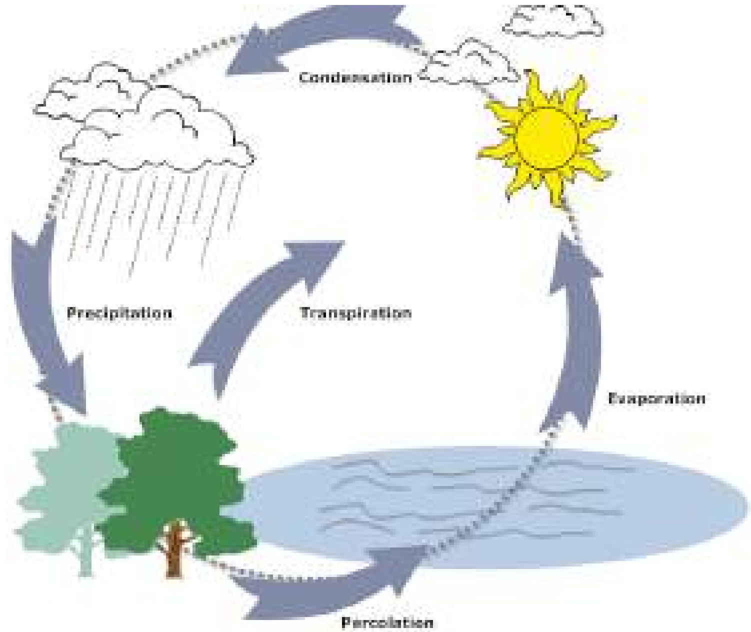

Fig. 9.3 Hydrological Cycle

9.3 Sedimentary Cycle

The sedimentary cycle circulates phosphorus, calcium and magnesium. The element involved in the sedimentary cycle does not generally cycle via the atmosphere, but rather follows a basic flow pattern through erosion, sedimentation, mountain building, volcanic activity and biological movement via marine bird excreta.

9.3.1 Phosphorus Cycle

In aquatic ecosystems and water quality, phosphorus is essential. Unlike carbon and nitrogen which are predominantly derived from the atmosphere, phosphorus is abundant as a mineral in phosphate rocks and enters the cycle through erosion and mining. This nutrient is thought to be the primary source of excessive rooted and free-floating microscopic plant growth in lakes.

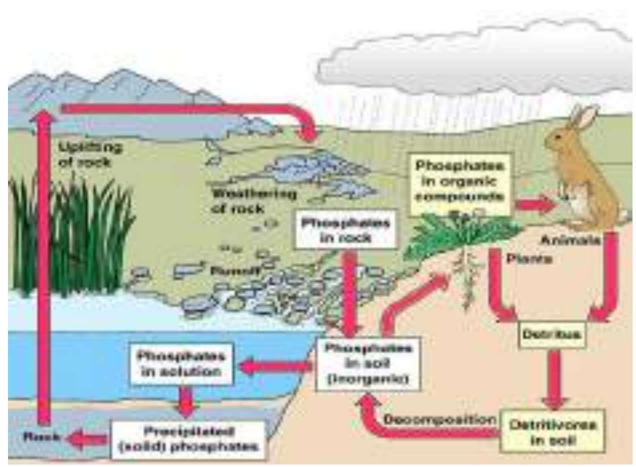

Fig. 9.4 Phosphorus Cycle

Phosphorus is mostly stored in the earth's crust. Phosphates are the most common type of phosphorus found on land. Phosphates enter rivers and streams through weathering and erosion, where they are transported to the ocean. Phosphorus accumulates on continental shelves in the form of insoluble deposits in the ocean. The crustal plates rise from the sea floor after millions of years, exposing the phosphates on land. Weathering will eventually release them from the rock, and the cycle's geochemical phase will begin again.

9.3.2 Sulphur Cycle

The sulphur reservoir is in the soil and sediments where it is locked in organic (coal, oil and peat) and inorganic deposits (pyrite rock and sulphur rock) in the form of sulphates, sulphides and organic sulphur. Weathering of rocks, erosional runoff and decomposition of organic materials releases it, which is then carried in salt solution to terrestrial and aquatic ecosystems. The sulphur cycle is mostly sedimentary except two of its compounds hydrogen sulphide (H_2S) and sulphur dioxide (SO_2) add a gaseous component to its normal sedimentary cycle. Sulphur enters the atmosphere from several sources like volcanic eruptions, combustion of fossil fuels, from surface of ocean and from gases released by decomposition. Atmospheric hydrogen sulphide also gets oxidized into sulphur dioxide. After being dissolved in rainfall as weak sulphuric acid, atmospheric sulphur dioxide is carried back to the soil.

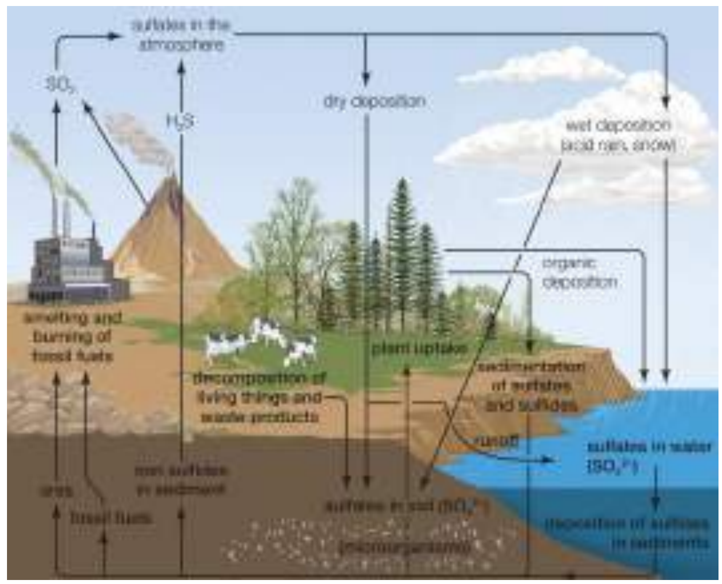

Fig. 9.5 Sulphur Cycle

Sulphur in the form of sulphates is taken up by the plants and is converted into sulphur carrying amino acids, which are integrated in the proteins of autotroph tissues through a number of metabolic processes. Then it passes through the grazing food chain. Through excretion and decomposition of dead organic material, sulphur bound in live organisms is transferred back to the soil, the bottom of ponds, lakes and seas. The bio-geochemical cycles mentioned here are just a handful of the many in the ecosystem. These cycles usually do not operate independently but interact with each other at some point or the other.

9.4 Salient Features

- Any of the natural pathways by which essential elements of living matter are circulated can be called as the biogeochemical cycle. The term biogeochemical is a contraction that refers to the consideration of the biological, geological, and chemical aspects of each cycle.
- There are two types of biogeochemical cycles: Gaseous (transportation of matter through the atmosphere) and sedimentary (transportation of matter through the ground to water).
- Further gaseous cycle can be categorized into carbon cycle, nitrogen cycle and hydrological cycle.
- Carbon cycle is the continuous exchange of carbon between the atmosphere and organisms.
- Nitrogen cycle includes five process: nitrogen fixation (conversion of gaseous nitrogen into ammonia), nitrification (conversion of ammonia into nitrates or nitrites), assimilation (nitrogen fixed by plants is converted into organic molecules), ammonification (conversion of dead remains of organisms into inorganic ammonia) and Denitrification (conversion of nitrates back into gaseous nitrogen).
- Hydrological cycle is the continuous circulation of water in the Earth-atmosphere system which is driven by solar energy.
- Sedimentary cycle is categorized into two cycles: Phosphorous cycle (movement of phosphorus through the lithosphere, hydrosphere, and biosphere) and Sulphur cycle (circulation of sulfur in various forms through nature).

CHAPTER – 10

Environmental Pollution and Degradation

10. Environmental Pollution and Degradation

Pollution is any undesirable change in physical, chemical or biological characteristics of air, land, water or soil. Agents that bring about such an undesirable change are called as pollutants.

10.1 Pollutants

- Pollutants can be solid, liquid or gaseous substances present in greater concentration than in natural abundance and are produced due to natural or human activities.
- For example, smoke from industries and automobiles, chemicals from factories, radioactive substances from nuclear plants, sewage of houses and discarded household articles are the common pollutants.

10.1.1 Classification of Pollutants

a) According to the form in which they persist after the release into the environment

- **Primary Pollutants:** These are the pollutants that are formed and emitted directly from particular sources. Example: plastic, DDT (Dichlorodiphenyltrichloroethane).
- **Secondary Pollutants:** These are formed by interaction among the primary pollutants. Example: PAN (Peroxy Acetyl Nitrate) is formed by the interaction of nitrogen oxides and hydrocarbons.

b) According to their existence in nature

- **Quantitative Pollutants:** These occur in nature and become pollutant when their concentration reaches beyond a threshold level. Example: carbon dioxide, nitrogen dioxide.
- **Qualitative Pollutants:** They do not occur in nature and are man-made. Example: fungicides, herbicides, DDT, etc.

c) According to their nature of disposal

- **Biodegradable Pollutants:** Waste products, which are degraded by microbial action. Example: sewage waste.
- **Non-biodegradable Pollutants:** Pollutants which are not decomposed by microbial action. Example: Plastics, glass, DDT, salts of heavy metals.

10.2 Types of Pollution

- Air Pollution
- Water Pollution
- Noise Pollution
- Soil Pollution
- Thermal Pollution
- Light Pollution
- Radioactive Pollution

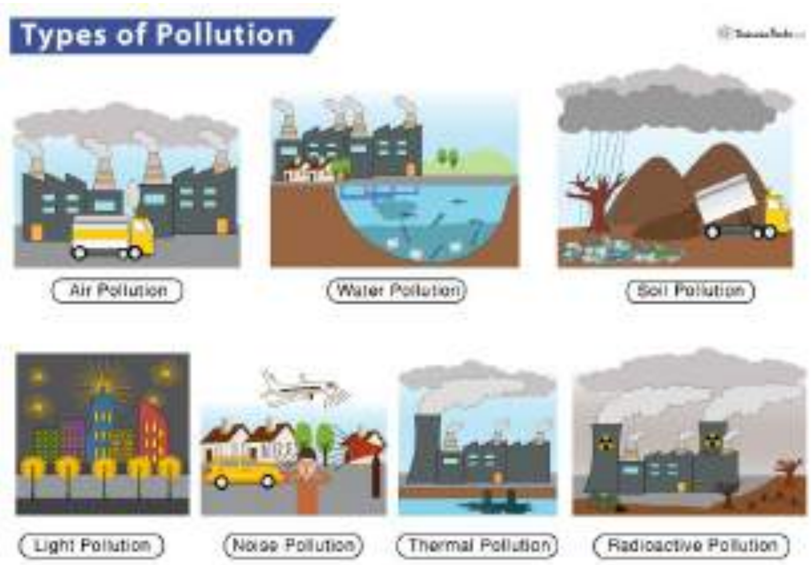

Fig 10.1 Types of Pollution

10.3 Impacts of Pollution

Pollution currently poses one of the greatest public health and human rights challenges, disproportionately affecting the poor and the vulnerable.

- Pollution is not just an environmental issue, but affects the health and well-being of entire societies.
- Despite the huge impacts on human health and the global economy, and the opportunity to apply simple and affordable solutions, pollution has been undercounted and insufficiently addressed in national policies and international development agendas.
- Pollution of all kinds can have negative effects on the environment and wildlife and often impacts human health and well-being.

10.4 Environment Protection Act, 1986

The **Environment Protection Act (EPA)** was enacted in 1986 with the objective of providing the protection and improvement of the environment.

- It **empowers the Central Government** to establish authorities charged with the mandate of preventing environmental pollution in all its forms and to tackle specific environmental problems that are peculiar to different parts of the country.
- The Act is **one of the most comprehensive legislations** with a pretext to protection and improvement of the environment. **(to be continued in Chapter-40)**

10.5 Salient Features

- Pollution is any undesirable change in physical, chemical or biological characteristics of air, land, water or soil.
- Pollutants are the materials or factors, which cause adverse effect on the natural quality of any component of the environment.
- There are different types of pollutants i.e. air pollution, water pollution, soil pollution, thermal pollution, noise pollution, light pollution and radioactive pollution.
- The Environment Protection Act (EPA) was enacted in 1986 with the objective of providing the protection and improvement of the environment.

CHAPTER – 11

Air Pollution

11. Air Pollution

Air pollution is defined as the presence of pollutants in the atmosphere that are harmful to human and other living beings' health, as well as to the environment and materials.

Gases (such as ammonia, carbon monoxide, sulphur dioxide, nitrous oxides, methane, carbon dioxide, and chlorofluorocarbons), particles (both organic and inorganic), and living molecules are all examples of air pollution.

11.1 Primary Pollutants

These are directly emitted into the atmosphere from the processes such as fossil fuel consumption, volcanic eruption, etc. Oxides of Sulphur, Oxides of Nitrogen, Oxides of Carbon, Particulate Matter, Methane, Ammonia, Chlorofluorocarbons, Toxic metals etc. are the major primary pollutants.

11.1.1 Particulate Matter

Particulate matter is the sum of all solid and liquid particles suspended in air many of which are hazardous. It includes soot, smoke, fly ash, dust of various types, pollen grains, spores, hair, fur etc. These particles vary greatly in size, composition, and origin.
Based on size, particulate matter is often divided into two main groups:

- The **coarse** fraction contains the larger particles with a size ranging from 2.5 to 10 µm **(PM_{10})**.
- The **fine** fraction contains the smaller ones with a size up to 2.5 µm **($PM_{2.5}$)**. The particles in the fine fraction which are smaller than 0.1 µm are called **ultrafine** particles.

Small size particles are much dangerous than the larger size particles because large size particles when inhaled get filtered from the nasal tract. While the smaller particles escapes the natural filtering and settle down deep into the lungs.

11.1.2 Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless gas. It results from the incomplete combustion of carbon-containing fuels such as natural gas, gasoline, or wood, and is emitted by a wide variety of combustion sources, including motor vehicles, power plants, wildfires, and incinerators. Its natural source is paddy fields. Carbon monoxide is dangerous because it binds to hemoglobin in the blood, limiting blood's ability to transport oxygen.

11.1.3 Sulphur Oxides

Volcanic eruption is a major natural source. Manmade sources are smelting of metallic ores (iron, copper, zinc, lead, nickel), burning of coal and petroleum in industries, thermal plants, motor vehicles and manufacture of chemicals. **Garden pea** is a pollution indicator for **SO_2**.

11.1.3.1 Effects of SO_2

- It is highly corrosive in nature and thus causes weight loss of materials, leaf injury or discoloration.
- Addition of SO_2 in aerosol produces London Smog or Classical Smog.
- It is highly water soluble so it gets absorbed in the moist passage of upper respiratory tract where it causes long term damage.
- SO_2 also contributes as the main component of **acid rain**.

11.1.4 Nitrogen Oxides

NO and NO_2 are the two major air pollutants. They originate naturally from forest fires electric storms, high energy radiations and solar flares. Human activities responsible for their production are combustion process of industries, automobiles, incinerators and nitrogen fertilizers. Nitrogen oxides produced **brown air** or reddish brown **haze** and give rise to **photochemical smog.** They form peroxy acetyl nitrates (PAN) (secondary pollutant) with hydrocarbons and part of acid rain.

They have mutagenic and carcinogenic properties in biological systems. It causes chlorosis in plants.

11.1.5 Volatile Organic Compounds (VOC's)

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. It can cause irritation in eyes, skin, nose, and throat. Long-term exposure can cause serious damage to the liver and other organs.

11.2 Secondary Air Pollutants

These are not directly emitted into the atmosphere. The secondary pollutants formed from the reaction among the primary pollutants or with the other components. Tropospheric ozone and PAN (Peroxy Acetyl Nitrates) are the example of secondary pollutants.

11.2.1 Tropospheric ozone

It is formed from NOx and VOCs. Ozone (O_3) is a secondary pollutant and a key constituent formed in the troposphere. Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and by night. Ozone is a powerful and aggressive oxidizing agent, elevated levels of which cause respiratory and cardiovascular health problems and leads to premature mortality. High levels of O_3 (ozone) can also damage plants, leading to reduced agricultural crop yields and decreased forest growth.

11.2.2 PAN (Peroxy Acetyl Nitrates)

It is formed by the interaction of **nitrogen oxides** and **hydrocarbons**. PANs are a component of photochemical smog, produced in the atmosphere when oxidized volatile organic compounds combine with nitrogen dioxide. PANs are a secondary pollutant since they form in the atmosphere after the emission of primary pollutants. Sources of the pollutants required to create PANs include motor vehicles, tobacco smoke, and the burning of fossil fuels. PANs have many adverse effects in the human body such as reduced respiratory function (including emphysema and impaired breathing) and eye irritation. Human exposure to PANs typically occurs in urban centers where automobile and industrial emissions are high.

11.3 Other Atmospheric Pollutants

- **Hydrogen sulfide (H_2S)** is produced during the processing of ores, refineries, chemical plants and bitumen fuels and it smells like rotten eggs. It can cause eye and throat irritation and nausea in humans; and problems like mottled chlorosis (deficiency of potassium in plants) and defoliation in plants.
- **Mercury (Hg)** is produced by burning of coal and smelting. It causes infant deformity, loss of appetite, mouth and skin lesions, and damage of eyes; liver and nervous system.

- **Ammonia (NH_3)** is produced from fertilizer, lacquer and dye industries. It causes irritation and inflammation of respiratory tract.

- **Lead (Pb)** comes from auto mobile exhausts and it may damage liver, kidneys, reproductive system, causes anemia, neurological disorders, behavioral disorders, muscle paralysis, hypertension, etc.

11.4 Smog

Smog is a form of air pollution caused by tiny particles in the air. The term smog was first coined in 1905 by Dr. Henry Antoine Des Voeux to describe combination of smoke and fog. It is a hazy mixture of heavily polluted air that can form in cities due to the emissions of sulfur dioxide and aerosols from the burning of fossil fuels.

11.4.1 Types of Smog

11.4.1.1 Classical Smog

It is also called London smog/Reducing smog/Industrial smog/Sulfurous smog as it occurred in 1952 in London. It contains SO_2 and particulate matter. It forms in areas with high water vapor and high levels of sulfur emissions. Sulfur particles dissolve into water droplets to form sulfuric acid in the atmosphere, while coal soot darkens the skies. The main constituent of London smog is soot and it also contains large quantities of fly ash, sulfur dioxide, sodium chloride and calcium sulfate particles.

11.4.1.2 Photochemical Smog

It is called as the Los Angeles smog/ Oxidizing smog. It contains VOC's (Volatile Organic Compound), NO_x, Tropospheric ozone, PAN, Aldehyde.

- Photochemical smog is created when sunlight reacts with nitrogen oxides and at least one volatile organic compound (VOC) in the atmosphere. This kind of smog requires neither smoke nor fog.
- Nitrogen oxides are emitted in the atmosphere from automobiles, power plants, factory emissions.
- Volatile organic compounds are released in the atmosphere due to paints, gasoline, and cleaning solvents.

11.4.2 Effects of smog

- It can cause deaths due to bronchial diseases.
- Irritation of nose and eyes.
- It affects the visibility and harms the environment.
- It causes respiratory health problems such as coughing, shortening of breath, etc.

11.5 Acid Rain

Acid rain is caused by a chemical reaction that begins when compounds like sulfur dioxide and nitrogen oxides are released into the air. These substances can rise very high into the atmosphere, where they mix and react with water, oxygen, and other chemicals to form more acidic pollutants, known as acid rain. Example: **Taj Mahal**, one of the 7 wonders of the world, is largely affected by acid rain and **Statue of Liberty** which is made up of copper has also been damaged by the cumulative action of acid rain and oxidation for over 30 years and is, therefore, becoming green.

11.5.1 Types of Acid Deposition

"Acid rain" is a broad term referring to a mixture of wet and dry deposition (a form of deposition material) from the atmosphere.

11.5.1.1 Wet Deposition

- If the acid chemicals in the air are blown into areas where the weather is wet, the acids can fall to the ground in the form of rain, snow, fog, or mist.
- As this acidic water flows over and through the ground, it affects a variety of plants and animals.

11.5.1.2 Dry Deposition

- In areas where the weather is dry, the acid chemicals may become incorporated into dust or smoke and fall to the ground through dry deposition, **sticking to the ground, buildings, vegetation, cars,** etc.
- Dry deposited gases and particles can be washed from these surfaces by rainstorms, through runoff. This runoff water makes the resulting mixture more acidic.
- About half of the acidity in the atmosphere falls back to earth through **dry deposition**.

11.5.2 Effects of Acid Rain

- Acid rains damage standing crops and forests.
- It has adverse impact on freshwater life, other aquatic life forms, insects etc.
- Acid rain can cause the ocean's pH to fall. This phenomenon is known as '**ocean acidification**'. Though acid rain does not have huge impacts on oceans, they significantly affect shallower coastal waters.
- Excess nitrogen inputs from the atmosphere in the oceans promote increased growth of marine plants and phytoplankton which may result in more frequent harmful algal blooms and eutrophication.
- Limestone skeleton in Corals is sensitive to decrease in pH levels, as calcium carbonate which is the core component of the limestone skeleton – dissolves in low pH/acidic solutions.

Do You Know?

"Marble cancer" refers to the gradual deterioration (or eating away) of a monument's marble caused by acid rain. The suspended particulate matter, such as soot particles, released in the smoke from the Mathura Oil Refinery discolors the Taj Mahal's pristine white marble, making it yellowish.

- Some microbes in the soil cannot tolerate changes to low pH and get killed. The enzymes of these microbes are denatured by the acid.
- It corrodes structures as well as buildings. Example: Acid rains have turned the Taj Mahal's marble yellow.
- Acid rain also causes the corrosion of water pipes which further results in leaching of heavy metals such as iron, lead and copper into drinking water.
- Acid rain does not harm humans immediately. The sulfur dioxide creates various health problems. It can cause lung inflammation including asthma, bronchitis and emphysema.

11.5.3 Acid Rain Control

- Use of low sulphur fuel or natural gas or washed coal (chemical washing of pulverised coal) in thermal plants can reduce incidences of acid rain.

- Buffering: the practice of adding a neutralizing agent to the acidified water to increase the pH. Usually, lime in the form of **calcium oxide and calcium carbonate** is used.

11.6 Ocean Acidification

- Ocean acidification has been called the "**evil twin of global warming"** and "**the other CO_2 problem**".
- Ocean acidification is the ongoing decrease in the pH of the Earth's oceans, caused by the uptake of **carbon dioxide (CO_2)** from the atmosphere.
- An estimated 30–40% of the carbon dioxide from human activity released into the atmosphere dissolves into oceans, rivers and lakes.
- To achieve chemical equilibrium, some of it reacts with the water to form **carbonic acid**.
- Some of these extra carbonic acid molecules react with a water molecule to give a **bicarbonate ion** and a **hydronium ion**, thus **increasing ocean acidity (H^+ ion concentration)**.
- Checking CO and CO_2 emissions and controlling pollution are the only means to reduce ocean acidification.

11.6.1 Effects of Ocean Acidification

- Oceans are an important reservoir for CO_2, absorbing a significant quantity of it (one-third) produced by anthropogenic activities and effectively buffering climate change.
- The uptake of atmospheric carbon dioxide is occurring at a rate exceeding the natural buffering capacity of the oceans.
- Increasing acidity depresses metabolic rates and immune responses in some organisms.
- Seawater absorbs CO_2 to produce carbonic acid, bicarbonate and carbonate ions.
- However, the increase in atmospheric CO_2 levels lead to a decrease in pH level, an increase in the concentration of carbonic acid and bicarbonate ions, causing a decrease in the concentration of carbonate ions.
- The decrease in the amount of carbonate ions available makes it more difficult for marine calcifying organisms, such as coral (calcareous corals) and some plankton (calcareous plankton), to form biogenic calcium carbonate.

- Commercial fisheries are threatened because acidification harms calcifying organisms which form the base of the Arctic food webs.
- Increasing acidity accentuates coral bleaching as corals are very sensitive to changes in water composition.

11.7 Indoor Air Pollution

It refers to the physical, chemical, and biological characteristics of air in the indoor environment within a home, building, or an institution or commercial facility. Different conditions are responsible for indoor air pollution in the rural areas and the urban areas. Poor ventilation due to faulty design of buildings leads to pollution of the confined space. In congested areas, slums and rural areas, the burning of firewood and biomass results in lot of smoke.

> **Do You Know?**
>
> Air pollution kills 7 million people every year, 4 million of whom die from indoor air pollution.

11.7.1 Major Indoor Air Pollutants

- **Volatile Organic Compounds:** They are mainly originates from solvents and chemicals. Perfumes, hair sprays, furniture polish, glues, air fresheners, moth repellents, wood preservatives, etc., are the main indoor sources. It can cause irritation of the eye, nose and throat. In more severe cases there may be headaches, nausea and loss of coordination.
- **Tobacco Smoke:** It generates a wide range of harmful chemicals and is known to cause cancer. They cause a wide range of problems to the passive smokers from burning eyes, nose, and throat irritation to cancer, bronchitis, severe asthma, and a decrease in lung function.
- **Pesticides:** Pesticides are used to control insects, pests, microbes, termites, and rodents. As a result, they are inherently toxic. Pesticides are common household products such as insecticides and disinfectants. Exposure to pesticides can have a variety of short-term and long-term effects, including skin, eye, nose, and throat irritation, increased risk of cancer, and damage to the central nervous system.
- **Biological Pollutants:** They include pollen from plants, mite, hair from pets, fungi, parasites, and some bacteria. Most of them are allergens and can cause asthma, hay fever, and other allergic diseases.

- **Formaldehyde:** It is a gas that comes mainly from carpets, particle boards, and insulation foam. It causes irritation to the eyes and nose and may cause allergies in some people.
- **Asbestos:** Asbestos is a mineral fiber. It occurs naturally in rock and soil. Because of its strength and heat resistance, it has been utilized in a variety of construction materials, including insulation, roofing shingles, and as a fire retardant. Asbestos exposure can increase one's risk of developing lung disease, mesothelioma, or asbestosis.
- **Radon:** It is a gas that is emitted naturally by the soil. It has no taste, color, or smell, making it very difficult to detect without specific radon testing. Due to modern houses having poor ventilation, it is confined inside the house causing harm to the dwellers. Long-term radon exposure can increase one's risk of developing lung cancer.

11.7.2 Prevention and Control of Indoor Air pollution

- Use of wood and dung cakes should be replaced by cleaner fuels such as biogas, kerosene or electricity.
- Improved stoves for looking like smokeless chullahs have high thermal efficiency and reduced emission of pollutants including smoke.
- The house designs should incorporate a well-ventilated kitchen. The use of biogas and CNG (Compressed Natural Gas) need to be encouraged.

11.8 Air Pollution Control Devices

11.8.1 Electrostatic Precipitators (ESP)

The emanating dust is charged with ions and the ionized particulate matter is collected on an oppositely charged surface. The particles are removed from the collection surface by occasional shaking or by rapping the surface. ESPs are used in boilers, furnaces, and many other units of thermal power plants, cement factories, steel plants, etc. Electrostatic precipitation can remove over 99 per cent particulate matter present in the exhaust.

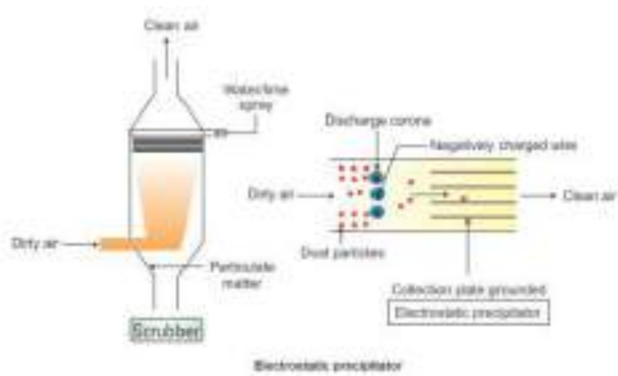

Fig 11.1 Electrostatic Precipitator

11.8.1.1 Working

- An electrostatic precipitator has electrode wires that are maintained at several thousand volts, which produce a **corona** that releases **electrons**.
- These electrons attach to dust particles giving them a net negative charge. The collecting plates are grounded (relatively positive charge) and attract the charged dust particles.
- The velocity of air between the plates must be low enough to allow the dust to fall.
- The particles are removed from the collection surface by occasional shaking or by rapping the surface.
- ESPs are used in boilers, furnaces, and many other units of **thermal power plants, cement factories, steel plants,** etc.

11.8.2 Scrubbers

Scrubbers are wet collectors. They remove aerosols from a stream of gas either by collecting wet particles on a surface followed by their removal, or else the particles are wetted by a scrubbing liquid. The particles get trapped as they travel from supporting gaseous medium across the interface to the liquid scrubbing medium. Scrubber is more suitable to remove gaseous pollutant than particulates. A scrubber can remove gases like **sulphur dioxide**.

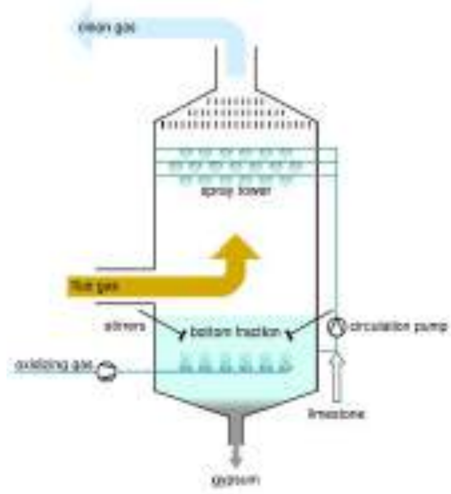

Fig 11.2 Wet Scrubbers

11.8.3 Gravity Settling Chambers

Gravity settling chambers are the oldest and simplest means of removing large diameter suspended particles from a gas. It works on the principle of gravity. It is effective for larger size particles. This is the simplest device in which exhaust gas velocity is slow down sufficiently to allow large particles to settle down by gravity.

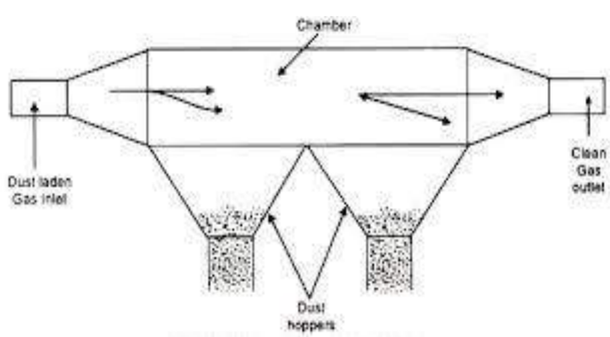

Fig 11.3 Gravity Settling Chamber

11.8.4 Cyclone Separators

The articles then drop out at bottom while the cleaner gas exists at top. In this separator, the gas is the separator forcing the particles against the outer wall of separator by centrifugal force.

Fig 11.4 Cyclonic Separator

11.8.5 Bag House Filters

Filters remove particulate matter from the gas stream. Bag house filtration system is the most common one and is made of cotton or synthetic fibres (for low temperatures) or glass cloth fabrics (for higher temperature up to 290^0 C).

11.8.6 Catalytic Converter

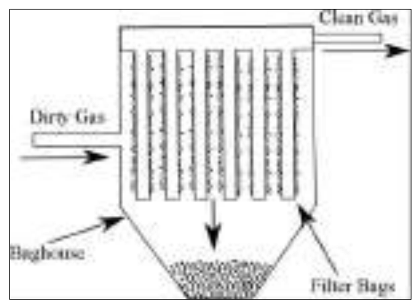

Fig 11.5 Bag House Filter

- Catalytic converters, having expensive metals namely **platinum-palladium** and **rhodium** as the catalysts, are fitted into automobiles for reducing the emission of poisonous gases.
- As the exhaust passes through the catalytic converter, unburnt hydrocarbons are converted into **carbon dioxide and water**, and **carbon monoxide and nitric oxide are changed to carbon dioxide and nitrogen gas**, respectively.
- Motor vehicles equipped with catalytic converter should use **unleaded petrol** because the lead in the petrol inactivates the catalyst.

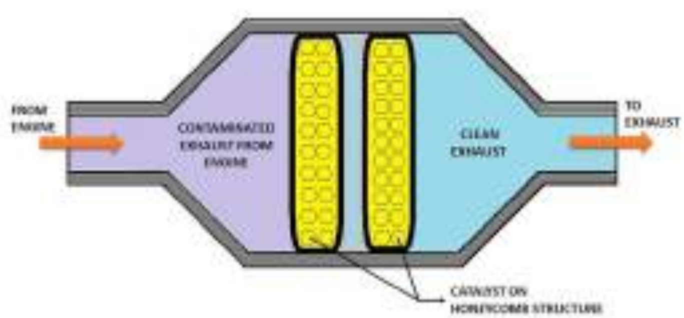

Fig 11.6 Catalytic Converter

11.9 Initiatives of Government of India to control Air Pollution

11.9.1 National Air Quality Monitoring Programme (NAMP)

The Central Pollution Control Board is executing a nationwide programme of ambient air quality monitoring known as National Air Quality Monitoring Programme (NAMP). Central Pollution Control Board initiated National Ambient Air Quality Monitoring (NAAQM) programme in the year 1984 with 7 stations at Agra and Anpara. Subsequently the programme was renamed as National Air Quality Monitoring Programme (NAMP). Steadily the air quality monitoring network got strengthened, in year 2019 the number of stations was raised to 804 covering 344 cities/towns/villages in 28 states and 6 Union Territories as on 31st December 2019.

11.9.1.1 Parameters monitored under NAMP

To check air quality of the country, Central Pollution Control Board initiated National Air Quality Monitoring Programme (NAMP) under which three air pollutants viz., Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and Particulate Matter size equal to or less than 10 micron (PM_{10}), have been monitored regularly at all the locations. Other parameters like PM2.5 (Particulate Matter having an aerodynamic diameter less than or equal to 2.5 µm), Carbon monoxide (CO), Ammonia (NH_3), Lead (Pb), Ozone (O_3), Benzene (C_6H_6), Benzo(a)pyrene (BaP), Arsenic (As) and Nickel (Ni) are being monitored at selected locations and are slowly being added to the monitoring network under NAMP. The monitoring of meteorological parameters such as wind speed and direction, relative humidity and temperature were also integrated with the monitoring of air quality and are monitored at selected locations. The monitoring of regular parameters is carried out for 24 hours (4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter) with a frequency of twice a week, to have 104 observations in a year.

11.9.2 National Ambient Air Quality Standards (NAAQS)

NAAQS set by CPCB (Central Pollution Control Board) applies nationwide. CPCB draws this power from the **1981** Air **(Pollution Prevention** and **Control) Act.** The first ambient air quality standards were developed in 1982 pursuant to the Air Act. Later, in 1994 and 1998, these standards were revised. The latest revision to the **NAAQS** was done in 2009 and this is the latest version being followed. The 2009 standards further lowered the maximum permissible limits for pollutants and made the standards uniform across the nation. Previously, industrial zones had less stringent standards as compared to residential areas. The compliance of the NAAQS is monitored under the National Air Quality Monitoring Programme (NAMP). NAMP is implemented by the CPCB.

11.9.2.1 Objectives of air quality standards

- To indicate the levels of air quality necessary with an adequate margin of safety to protect the public health, vegetation and property;
- To assist in establishing priorities for abatement and control of pollutant level;
- To provide uniform yardstick for assessing air quality at national level.

11.9.3 National Air Quality Index

On April 6, 2015, India had launched its first ever National Air Quality Index (NAQI) and acknowledged the problem of its incessantly rising air pollution. This index was launched by Prime Minister Narendra Modi in New Delhi, starting with 10 cities in the first phase. The cities include Delhi, Agra, Kanpur, Faridabad, Lucknow, Varanasi, Ahmedabad, Chennai, Bangalore and Hyderabad. NAQI is tool that uses numbers to simplify air quality data by classifying pollution levels into 6 categories—good, satisfactory, moderate, poor, very poor and severe, and denotes a color code on the basis of how harmful the pollution in a specific area is. Each of the pollutants—$PM_{2.5}$, PM_{10}, NO_2, CO and Ozone—are assigned an air quality index (AQI) and thereafter an overall AQI is given daily indicating the value of the worst pollutant value for that area. This makes it easier for people to know how bad the pollution in their area is and which places they should avoid on that day.

11.9.4 National Clean Air Programme

The MoEF&CC launched National Clean Air Programme (NCAP) as a long-term, time-bound, national level strategy to tackle the air pollution problem across the country in a comprehensive manner with targets to achieve 20% to 30% reduction in Particulate Matter concentrations by 2024 keeping 2017 as the base year for the comparison of concentration. It is India's flagship program for better air quality in 122 cities. The plan includes 102 non-attainment cities, across 23 states and Union territories, which were identified by the Central Pollution Control Board (CPCB) on the basis of their ambient air quality data between 2011 and 2015.

Non-attainment cities: These are those that have fallen short of the National Ambient Air Quality Standards (NAAQS) for over five years.

11.10 Bharat Stage Emission Standards

The Bharat Stage (BS) is emission standards instituted by the Government of India to regulate the output of air pollutants from motor vehicles. The Environment Ministry is responsible for deciding the fuel standard in the country. The Central Pollution Control Board implements these standards. The BS regulations are based on the European emission standards. Companies can come up with new vehicles with BS VI fuel standards even before the April 2020 deadline. But after the deadline, vehicles that do not comply with BS VI standards will not be registered. With the implementation of new norms, pollution levels are expected to come down significantly as the particulate matter (PM) will decrease. About one-third of the air pollution is caused by cars and motor vehicles.

> **Do You Know?**
>
> **World Health Organization (WHO)** has released **Air Quality Database 2022,** which shows that Almost the entire global population (99%) breathes air **that exceeds WHO's air quality limits.**

11.10.1 BS-VI Emission Norms

In order to comply with BS-VI norms, the vehicle manufacturers need to move to the new technology to make vehicles compliant with the BS VI standards. The switch to BS-VI vehicles was to happen in 2022 but looking at the poor air condition, the move was advanced by four years. The standards covers two and four-wheelers and commercial vehicles. At present, BS IV and BS III fuels are available across India. Due to their use, hazardous pollutants in the air are increasing leading to health ailments like Asthma, Bronchitis, heart diseases and even cancer.

11.10.2 Advantages of BS-VI fuel Over BS-IV Fuel

In BS-VI fuel, the volume of PM 2.5 ranges from 20 to 40 micrograms per cubic metre whereas in BS-IV fuel it is up to 120 micrograms per cubic metre. BS-VI fuel will bring down sulphur content by 5 times from the current BS-IV levels. It has 10 ppm of sulphur as against 50 ppm in BS-IV. 2/4 Sulphur in the fuel contributes to fine particulate matter emissions. High sulphur content in the fuel also leads to corrosion and wear of the automobile engine. With BS-VI fuel, for every one kilometer, a car will emit 80% less particulate matter and nearly 70% less nitrogen oxide. Air pollutants in BS-VI fuel are much less as compared to BS-IV fuel. BS-VI norms also seek to reduce the level of certain harmful hydrocarbons in the emissions that are produced due to incomplete combustion of fuel.

11.11 Salient Features

- Air pollution is defined as the presence of pollutants in the atmosphere that are harmful to human and other living beings' health, as well as to the environment and materials.
- Primary Pollutants are directly emitted into the atmosphere from the processes such as fossil fuel consumption, volcanic eruption, etc. Example of primary pollutants: particulate matter, carbon monoxide, sulfur oxides, nitrogen oxides and volatile organic compounds.
- Secondary pollutants are not directly emitted into the atmosphere because they are formed by reacting with other pollutant. Example: tropospheric ozone and PAN.
- Smog is a condition of fog having soot or smoke in it. It is of two types: photochemical smog and classical smog.
- Acid rain, or acid deposition, is a broad term that includes any form of precipitation that contains acidic components, such as sulfuric acid or nitric acid. Wet deposition and dry deposition are the two types of acid deposition.
- Ocean acidification is the ongoing decrease in the pH of the Earth's oceans, caused by the uptake of **carbon dioxide (CO_2)** from the atmosphere.
- Indoor Air Pollution refers to the physical, chemical, and biological characteristics of air in the indoor environment within a home, building, or an institution or commercial facility.
- Electrostatic precipitators, wet scrubbers, gravity settling chambers, cyclonic separators, bag house and catalytic converter are the majorly used control device for controlling air pollution.
- The Bharat Stage (BS) is emission standards instituted by the Government of India to regulate the output of air pollutants from motor vehicles.

CHAPTER – 12

Water Pollution

12. Water Pollution

Water pollution occurs when undesired chemicals, such as organic, inorganic, biological, radiological and heat, are added to or present in water, degrade its quality and make it unsuitable for use. Natural sources of water pollution include soil erosion, mineral leaching from rocks (due to natural solubility and solubility caused by acid rain) and organic matter decomposition. All life forms that rely on water, whether directly or indirectly, suffer from pollution. Water contamination can have long-term effects.

12.1 Types of water pollutants

Water pollutants can be classified as follows:

12.1.1 Physical water pollutants

Physical factors such as temperature changes or even bigger particles can create a number of negative impacts. E.g. Excessive sediment load, resulting mostly from excessive land usage particles, plastic bags, and bottles.

12.1.2 Chemical water pollutants

These are atoms or molecules that have been released into natural water bodies, frequently as a result of human activity. E.g. Mercury emitted by mining, certain nitrogen compounds used in agriculture, chlorinated organic molecules released from sewage or water treatment plants and different acids emitted by various manufacturing processes.

12.1.3 Radioactive substances

The majority of radioactivity comes from agricultural practices like tobacco production, where radioactive contamination of phosphate fertilizer is frequent.

12.1.4 Pathogens

Pathogens from untreated sewage or surface runoff from extensive livestock grazing are common pathogenic microorganisms. They are major sources of sickness and mortality in developing countries, where population density, water shortages and insufficient sewage treatment combine to generate widespread parasite and bacterial illnesses.

12.2 Indicators of water quality

Following are the key water quality indicators:

12.2.1 Dissolved oxygen (DO)

The amount of DO in water is reduced when organic and inorganic wastes are present. Water having a DO of less than 8.0 mg/L may be contaminated. Highly contaminated water has a DO content of less than 4.0 mg/L . The quantity of DO in water is crucial for the survival of aquatic organisms. A variety of variables influence the quantity of DO in water, including surface turbulence, photosynthesis activity, oxygen (O_2) consumption by organisms, and organic matter decomposition. The higher the amount of waste, the faster it decomposes and consumes oxygen, lowering the DO level of water.

12.2.2 Biological Oxygen Demand (BOD)

Water pollution by organic wastes is measured in terms of BOD. The quantity of dissolved oxygen required by bacteria to decompose organic wastes in water is BOD. It is expressed in milligrams of oxygen per liter of water. The greater the BOD, the lower the DO concentration of the water, because BOD is just for biodegradable materials. As a result, it is not a reliable way of determining the amount of pollution in water.

12.2.3 Chemical oxygen demand (COD)

This is a significantly better mode for measuring water pollution load. It is the oxygen equivalent of the oxidation demand of total organic matter in water (both biodegradable and non-biodegradable).

12.2.4 Total Oxygen Demand (TOD)

As the name implies, this metric defines the overall oxygen demand of the water sample. TOD works on the same principle as COD, which is that all organic compounds must be fully oxidized in order to determine the oxygen demand required. However, using thermal oxidation at 1,200 degrees C guarantees complete oxidation of all organic compounds and no chloride disturbances where the dichromate method is detectable.

12.2.5 Total Organic Carbon (TOC)

The measurement of organic (carbon-based) contaminants in a water system is referred to as total organic carbon. Organizations and labs use TOC as an analytical tool to assess whether a solution is acceptable for their procedures. Water will naturally include some organic compounds unless it is ultrapure; understanding how much is key.

12.3 Source of water pollution

Pollution enters the water through following two sources:

12.3.1 Point Source

Point source pollution occurs when pollutants are discharged from a single area, such as a drain pipe carrying industrial effluents dumped directly into a water body.

12.3.2 Non- point source

Non-point sources are pollutants discharged from diffused sources or across a greater region, such as runoff from agricultural fields, grazing lands, construction sites, abandoned mines and pits and roads and streets.

a. **Urban land use:** Rainfall runoff as storm water in our urban areas is frequently polluted with car oil, dust, animal faeces and soil. More toxicants and chemicals are commonly found in sediment run-off from construction sites and industrial areas.

b. **Agricultural land use:** Pesticides, fertilizers, animal dung and dirt washed into streams during rainfall run-off are examples of non-point sources of pollution. Fertilizers include nitrogen, phosphorous and potassium, which are essential plant nutrients. These may leach into water bodies.

c. **Forestry land use:** Removal of streamside vegetation, road building and usage, wood harvesting and mechanical preparation for tree planting are all sources of nonpoint source (NPS) pollution linked with forestry activities. On forested lands, road construction and road use are the primary drivers of NPS pollution, accounting for up to 90% of total sediment from forestry operations. An excessive amount of sediment in a water body can decrease aquatic organisms' capacity to effectively survive, forage and spawn, in addition to other water quality impacts. By reducing the stream bank shading that regulates water temperature and eliminating vegetation that stabilizes the stream banks, tree harvesting near a stream can impair water quality. These changes have the potential to impact aquatic life by limiting food, shade, and shelter, as well as decreasing areas suitable for species that are sensitive to higher temperatures.

d. **Thermal pollution:** The temperature of the cooling water in power plants is raised by waste heat from boilers and other heating activities. The temperature of the receiving water may rise 10 to 15 degrees Celsius over the ambient temperature when hot water is discharged. This is thermal pollution. Increased water temperature reduces dissolved oxygen in the water, which has a negative impact on aquatic life.

e. **Groundwater pollution:** The ground water in many parts of India is endangered by seepage from industrial and municipal wastes and effluents, sewage channels, and agricultural runoff.

f. **Marine pollution:** Oceans are the ultimate sink of all natural and manmade pollutants. Pollution is discharged into the sea through rivers. Coastal cities' sewage and garbage are also discharged into the sea. Navigational discharges of oil, grease, detergents, sewage, garbage and radioactive wastes, off-shore oil mining and oil spills are some of the other forms of ocean pollution.

12.4 Effects of water pollution

Following are the major effects of water pollution:

12.4.1 Effects on aquatic ecosystem

- Polluted water lowers the amount of dissolved oxygen (DO) in the water, which eliminates sensitive organisms including plankton, mollusks, and fish etc.
- Biocides, polychlorinated biphenyls (PCBs) and heavy metals directly eliminates sensitive aquatic organisms.
- When hot water from industry is discharged into water bodies, it decreases the DO concentration.

12.4.2 Effects on human health

- Polluted water is a source of water-borne diseases such as jaundice, cholera, typhoid, and amoebiasis because it includes pathogens such as virus, bacteria, parasitic protozoa, and worms.

- Bacterial activity converts mercury compounds in waste water into extremely toxic methyl mercury, which can induce numbness in the limbs, lips and tongue, deafness, blurred eyesight and mental instability.
- Water polluted with cadmium can induce itai itai disease (a painful disease of the bones and joints) as well as liver and lung cancer.
- Lead compounds induce anemia, headaches, muscular weakness, and a blue line around the gums.

12.4.3 Effects of ground water pollution

- Excess nitrate in drinking water is harmful to human health and can even be lethal to newborns.
- Excess fluoride in drinking water causes neuromuscular disorders, gastrointestinal problems, teeth deformity, bone hardening and stiff and painful joints (skeletal fluorosis).
- Overuse of ground water can lead to arsenic leaching from soil and rock sources and contaminate groundwater. Black foot disease is caused by prolonged exposure to arsenic. Diarrhea, peripheral neuritis, hyperkeratosis and lung and skin cancer are among side effects.

Do you know?

- Excess nitrate in drinking water reacts with hemoglobin to form non-functional methemoglobin and impairs oxygen transport. This condition is called methemoglobinemia or blue baby syndrome.
- High concentration of fluoride ions is present in drinking water in 13 states of India. The maximum level of fluoride, which the human body can tolerate is 1.5 parts per million (mg/1 of water). Long term ingestion of fluoride ions causes fluorosis.
- Arsenic contamination is a serious problem (in tube well dug areas) in the Ganges Delta, West Bengal causing serious arsenic poisoning to large numbers of people. A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning of drinking water.

12.5 Control measures of water pollution

- Use of Riparian buffers (Interfaces between a flowing body of water and land created near the waterways, farms, roads, etc. in an attempt to filter pollution).

- Treatment of sewage water and the industrial effluents should be done before releasing it into water bodies.
- Hot water should be cooled before release from the power plants.
- Domestic cleaning in tanks, streams and rivers, which supply drinking water should be prohibited.
- Excessive use of fertilizers and pesticides should be avoided.
- Organic farming and efficient use of animal residues as fertilizers.
- Water hyacinth (an aquatic weed) can purify water by taking some toxic materials and a number of heavy metals from water.
- Oil spills in water can be cleaned with the help of bregoli – a by-product of paper industry resembling saw dust, oil zapper, micro-organisms.

12.6 Oil Spills

- Oil spills is one of the most dangerous of all water pollutants. Oil spills from tankers at sea or leaks from underground storage tanks on land are very difficult to control as oil tends to spread very fast, affecting a large area in a very short time.
- On land, crude is transported through pipelines or tankers which can get damaged and spew out crude oil over the land, thereby contaminating it. Since crude oil is lighter than water, it floats of the surface and poses the threat of swift-spreading fire.
- Oil spills at sea decrease the oxygen level in the water and cause harm to the organisms. They are also a source of air and ground pollution.

12.7 Salient Features

- Water pollution is the addition/presence of undesirable substances to/in water which degrades the quality of water and makes it unfit for use.
- There are four types of water pollutants: physical pollutants (physical factors such as temperature change or much larger particles), chemical pollutants (atoms and molecules), radioactive substances (uranium, thorium) and pathogens (pathogenic microbes from untreated sewage or surface runoff from intensive livestock grazing).
- Indicators of water quality include: dissolved oxygen (amount of oxygen present in water), biological oxygen demand (quantity of dissolved oxygen required by bacteria to decompose

organic wastes in water), chemical oxygen demand (amount of oxygen required to chemically oxidize the organic material and inorganic nutrients), total oxygen demand (overall oxygen demand of the water sample) and total organic carbon (measurement of organic contaminants in a water system).

- Source of water pollution includes: point source (when pollutants are discharged from a single area) and non-point source (discharged from diffused sources or across a greater region).
- Groundwater pollution occurs when man-made products and chemicals get into the groundwater and make it unsafe for use.
- Marine pollution is a combination of chemicals and waste, most of which comes from land sources and is washed or blown into the ocean.
- Water pollution has various effects on aquatic ecosystem, human health and ground water which leads to various diseases in animals, fish, humans, etc.
- In order to control water pollution, various methods like use of riparian buffers, treatment of sewage water, etc. should be considered.
- Oil spill is the leakage of petroleum onto the surface of a large body of water.

CHAPTER – 13

Noise Pollution

13.Noise Pollution

Noise pollution is defined as the presence of unwanted or excessive noise that adversely affects the quality of people, wildlife, and the environment. Normal humans can hear sounds in the range of 0 dB to 140 dB. WHO believes that 45 dB is the ideal sound threshold for a city. Anything above the 120 dB threshold is excessive and painful. Hertz (Hz) measures the frequency of sound waves, and the human ear can hear sounds from 20 Hz to 20,000 Hz.

13.1 Properties of Sound

13.1.1 Loudness

- It is the intensity or strength of sound perceived by the individual. It is measured in decibels (dB).
- The sound you hear is about 10 dB.
- The maximum sound that a person can hear without discomfort is approximately 80 dB.
- If it exceeds 80 dB, the sound becomes unpleasant noise.
- WHO has set a safe noise level of 45 dB for the city.
- Bombay, New Delhi, Kolkata and Chennai usually record over 90dB.

13.1.2 Frequency

- It is defined as the number of vibrations per second and is expressed in hertz (Hz).
- The human audible range is 20-20,000Hz.
- Below 20Hz is called infrasound, and above 20,000Hz is called ultrasound.

Do You Know?

UNEP recently released a report titled '**Annual Frontiers Report 2022**' mentioning the name of **Moradabad (city of Uttar Pradesh) being the 2nd noisiest city in India (with range between 29 – 114dB) among the five listed cities of India.**
The first was Dhaka, Bangladesh at a maximum value of 119dB.

13.2 Sources of Noise Pollution

Noise pollution is becoming an increasingly big problem. All human activity contributes to noise pollution at different extent. There are many causes of noise pollution i.e. indoors and outdoors.

13.2.1 Indoor Pollution

This includes noise from radios, televisions, generators, air coolers, electric fans, air conditioners, various appliances and family conflicts. Noise pollution is more in the city due to the high concentration of population and industry and by the means of transportation. Like other pollutants, noise is a by-product of industrialization and urbanization.

13.2.2 Outdoor Pollution

This includes indiscriminate use of activities such as speakers, industrial activities, automobiles, railroads, planes, and markets, religious, social and cultural events, sports and political rallies. In rural areas, agricultural machinery and pump units are the main causes of noise pollution. The use of fireworks contributes to noise pollution at parties, weddings and many other occasions.

Table 13.1 Permissible Noise Level Standards in India

Zone	Permissible noise level standards in the daytime (dB)	Permissible noise level standards in the nighttime (dB)
Industrial Zone	75	70
Commercial Zone	65	55
Residential Zone	55	45
Silent Zone	50	40

13.3 Effects of Noise Pollution

13.3.1 Effect on Humans

- High blood pressure
- Loss of hearing
- May affect the sleep cycles
- Impair cognitive functions
- Irritability
- High stress

13.3.2 Effects on Animals

- It can increase the risk of death by altering prey-predator behavior (avoidance or detection).
- It may interfere with navigation.
- It affects the reproductive behavior of animals.
- Risk of hearing loss
- Unusual animal behavior – some studies indicate that certain species of whales beached themselves after exposure to sonar.

13.4 Prevention and Control of Noise Pollution

- Road traffic noise can be reduced by improving vehicle design and performing proper maintenance.
- Noise reduction measures include creating noise hills, noise barriers, well-maintained roads, and smooth road surfaces.
- Locomotive modifications, continuously welded tracks, the use of electric locomotives, or the use of quieter vehicles reduce the noise emitted by trains.
- Aircraft noise can be reduced by proper isolation and the introduction of noise regulations for aircraft takeoff and landing.
- Industrial noise can be reduced by soundproofing equipment.
- Do not allow power tools, very loud music or industrial trucks, public events with speakers, etc. at night. Use of horns, alarm systems, cooling units, etc. should be restricted. The use of fireworks, which are noisy and cause air pollution, should be restricted.
- A green belt of trees is an efficient noise absorber.

13.5 Salient Features

- Noise pollution is defined as the presence of unwanted or excessive noise that adversely affects the quality of people, wildlife, and the environment.
- Loudness is the intensity or strength of sound perceived by the individual. It is measured in decibels (dB).
- It is defined as the number of vibrations per second and is expressed in hertz (Hz).
- There are two sources of noise pollution i.e. indoor and outdoor noise pollution.

CHAPTER – 14

Soil Pollution

14.Soil Pollution

Soil is a thin layer of organic and inorganic materials that cover the Earth's rocky surface. Soil pollution is described as the "addition of substances to the soil, which adversely affect physical, chemical and biological properties of soil and reduces its productivity". It is the accumulation of persistent toxic compounds, chemicals, salts, radioactive materials or disease-causing agents in the soil that have negative impacts on plant growth, human and animal health. Any factor that degrades the quality, texture, or mineral content of the soil, or disturbs the biological balance of the soil's organisms, is referred to as a soil pollutant.

14.1 Cause of soil pollution

Following are the various causes of soil pollution:

a) **Farming:** Pesticides, fertilizers and other chemicals alter the soil's composition, making it more susceptible to erosion by water and air.

b) **Mining and quarrying:** The majority of mining waste is left on site in the form of spoil heaps. These spoil heaps may include a wide variety of harmful or dangerous substances, which then leach into the soil as a result of rainfall and negatively impact vegetation.

c) **Disposal of household waste:** Much of our household waste is either burnt (perhaps causing air pollution) or buried in landfills (maybe causing future problems due to waste leaching).

d) **Factory waste:** Heavy industry frequently creates large amounts of unwanted chemicals, which, if allowed to come into contact with the soil, can result in significant pollution.

e) **Road Traffic:** Vehicles are a major source of pollution in the soil near roadways, especially when they operate on old leaded petrol.

f) **Accidental oil spills:** Oil leaks can occur during chemical storage and transportation. Chemicals in petrol degrade soil quality and make it unfit for agriculture.

g) **Acid Rain:** Acid rain occurs when pollutants in the air combine with rain and fall back to the earth. Polluted water has the potential to dissolve important nutrients in soil and alter the structure of the soil.

h) **Radioactive wastes:** Mining and nuclear power plants release radioactive elements into the water, which eventually enter the land.

14.2 Effects of soil pollution

Effects of soil pollution can be studied under the following heads:

a) On human health

- Health risks are associated with the consumption of crops and plants cultivated on polluted soil.
- Long-term exposure to contaminated soil alters the body's genetic make-up, perhaps resulting in congenital illness and chronic disease.
- Chronic exposure to heavy metals, petroleum, solvent and agricultural chemicals can be carcinogenic.

b) On plant growth

- Contamination of the soil has an impact on the ecological system's equilibrium.
- Plants are generally unable to adjust to changes in soil chemistry.
- The number of soil microorganisms are decreasing.
- Soil pollution reduces soil fertility, making it unsuitable for agriculture and local plants to thrive.

c) On soil fertility

- Pollution-related chemicals in the soil are harmful and can reduce soil fertility, lowering soil output.
- Agriculture on polluted soil creates nutrient-deficient fruits and vegetables. These can be hazardous and cause major health concerns if consumed.

d) On soil structure

- Soil pollution can cause the death of numerous soil organisms, such as earthworms, causing changes in the soil structure.

14.3 Control measures of soil pollution

- Following are the examples of forestry and agriculture methods that can help to reduce soil erosion:
    - Planting trees on barren slopes, contour cultivation and strip cropping instead of shifting cultivation.
    - Terracing and diversion channel construction may be conducted.

    - In the long run, reducing deforestation and replacing animal waste for artificial manures helps to prevent soil erosion.
- Proper dumping of unwanted materials: Excess waste from humans and animals creates a disposal issue. The most often used approach is open dumping. Solid waste disposal is now done by controlled tipping.
- Production of natural fertilizers: Toxic chemical pesticides should be replaced by bio-pesticides. Synthetic chemical fertilizers should be replaced with organic fertilizers.
- Proper hygienic condition: People should be educated on hygienic practices.
- Public awareness: Informal and formal public awareness programs should be imparted to educate people on health hazards by environmental education.
- Recycling and reuse of wastes: Wastes such as paper, plastics, metals, glassware, organics, petroleum products, and industrial effluents, among others, should be recycled and utilised to reduce soil pollution. Integrated waste treatment technologies, for example, should be used.
- Ban on toxic chemicals: Chemicals and pesticides such as DDT (Dichlorodiphenyltrichloroethane), BHC (Benzene Hexachloride), and others should be banned.

14.4 Biofertilizer

Biofertilizers are compounds that fertilise the soil by using microorganisms. These fertilisers, unlike chemical fertilisers, are not hazardous to crops or other plants. They are extracted from animal wastes and mixed with microbial mixes. In India's Fertilizer Control Order (FCO), 1985, five biofertilizers were included: Rhizobium, Azotobacter, Azospirillum, Phosphate solubilizing bacteria, and mycorrhiza. Traditional biofertilizers include Rhizobium, Azotobacter, Azospirillum, and blue green algae (BGA). Leguminous crops, such as pulses, benefit from Rhizobium inoculants. Wheat, maize, mustard, cotton, potato, and other vegetable crops can all benefit from Azotobacter. Blue green algae like Nostoc, Anabaena, Tolypothrix, and Aulosira absorb nitrogen from the air and are utilised as paddy crop inoculants. Phosphate-solubilizing bacteria like *Pantoea agglomerans* strain P5 and *Pseudomonas putida* strain P13 may solubilize phosphate from inorganic sources and make it usable.

14.5 Biopesticides

Biopesticides are animals or plants that are purposefully used to kill pests. Bioherbicides and bioinsecticides are the two types. Bioherbicides are pesticides that kill plants. Animals (including insects) that kill other insects are known as bioinsecticides.

14.6 Salient Features

- Soil pollution is defined as the addition of substances to the soil, which adversely affect physical, chemical and biological properties of soil and reduces its productivity.
- Farming, mining and quarrying, manufacturing wastes, and radioactive wastes are all sources of soil pollution.
- Soil pollution has a variety of consequences, including health risks, damage to the ecological system, and a reduction in soil fertility.
- With proper disposal of waste, public awareness, ban on toxic chemicals, etc. soil pollution can be controlled.
- Biofertilizers are the substances which make use of microorganisms to fertile the soil. Rhizobium, Azotobacter, Azospirillum and blue green algae (BGA) have been traditionally used as biofertilizers.
- Animals or plants used wilfully to destroy pests are called Biopesticides. These are of two types: bioherbicides (pesticides destroying herbs) and bioinsecticide (animals that kill other insects).

CHAPTER – 15

Thermal Pollution

15. Thermal Pollution

The rise or reduction in temperature of a natural aquatic environment induced by human intervention is known as thermal pollution. Due to the increasing call of globalization everywhere, this has become an increasing and current pollution. Thermal pollution is generated by dumping hot water from factories and power plants, or by removing trees and vegetation that shade streams, allowing sunlight to raise the temperature of these waters, and then releasing cold water to cool them down. Thermal pollution, like other types of water pollution, is widespread, impacting numerous lakes and a large number of streams and rivers across the world.

15.1 Source of thermal pollution

Following are the source of thermal pollution:

15.1.1 Water as a cooling agent in industrial facilities

The largest sources of thermal pollution are production and manufacturing plants. These plants collect water from a nearby source to keep machines cool, then release it at higher temperatures back to the source. The water temperature rises dramatically when heated water returns to the river or ocean.

When oxygen levels in the water are adjusted, it can affect the quality and longevity of life in underwater organisms. This process can also wipe out streamside vegetation, which relies on constant oxygen and temperature levels to survive.

By altering natural environments, industries are essentially assisting in the reduction of the quality of life for these marine-based living forms, which might lead to habitat destruction if their operations are not monitored and careful.

15.1.2 Deforestation

Trees and plants block direct sunlight from reaching lakes, ponds, and rivers. When forests are cut down, these water bodies are exposed to direct sunlight, absorbing more heat and boosting their temperature. Deforestation is also the primary cause of increased greenhouse gas concentrations in the atmosphere, resulting in global warming.

15.1.3 Soil erosion

Another major cause of thermal pollution is soil erosion. Water bodies rise as a result of constant soil erosion, exposing them to more sunlight. The high temperature may cause anaerobic conditions in aquatic biomes, which could be lethal.

15.1.4 Runoff from Paved Surfaces

Runoff from paved surfaces such as roads and parking lots can warm surface waters. During the summer, the pavement becomes quite hot, resulting in heated runoffs into sewer systems and water bodies.

15.1.5 Natural Causes

Warm lava can be triggered by natural processes such as volcanoes, geothermal vents, and hot springs beneath the oceans and seas, raising the temperature of water bodies. Lightning can also cause large amounts of heat to be released into the oceans. This indicates that the water source's overall temperature will rise, having major environmental consequences.

15.1.6 Retention Ponds

Retention ponds can be another source of thermal shock because the water bodies that are relatively small and shallow can absorb quite a bit of heat energy from the sun.

When the water is pumped directly into a river, lake, or bay, the temperature rises dramatically. It's similar to pouring hot water into a bathtub full of water, which causes the temperature to rise a few degrees.

15.1.7 Domestic Sewage

Domestic sewage is frequently dumped untreated into rivers, lakes, canals, and streams. The temperature of municipal sewage is usually higher than the temperature of receiving water.

The dissolved oxygen (DO) in the receiving water drops as the temperature rises, while the demand for oxygen rises, resulting in anaerobic conditions.

15.2 Effects of thermal pollution

Following are the effects of thermal pollution:

15.2.1 Decrease in DO (Dissolved Oxygen) Levels

The warm temperature lowers the amount of dissolved oxygen (DO) in the water. Warm water has a lower oxygen content than cold water. Reduced DO can cause suffocation in plants and animals like fish, amphibians, and copepods, resulting in anaerobic conditions.

Warmer water allows algae to develop on the water's surface, and increasing algae can reduce oxygen levels in the water over time.

15.2.2 Increase in Toxins

With the constant flow of high-temperature discharge from industries, the amount of pollutants being regurgitated into natural bodies of water has increased dramatically. These toxins could comprise chemicals or radiation that have a negative impact on the surrounding ecology and make people susceptible to diseases.

15.2.3 Loss of Biodiversity

A reduction in biological activity in the water could result in considerable biodiversity loss. Changes in the environment may drive certain species of organisms to relocate, whereas warmer seas may cause a considerable number of species to migrate in.

Organisms that can easily adapt to the warmer temperatures may have an edge over organisms that aren't adapted to them.

15.2.4 Ecological Impact

Fish, insects, plants, and amphibians can all perish as a result of a severe heat shock. Hotter water may be beneficial to some species, but it could be fatal to others. The amount of activity increases as the water temperature drops, while the level of activity reduces as the temperature rises.

Small temperature fluctuations, such as one degree Celsius, can induce considerable changes in organism metabolism and other negative cellular biology effects in many aquatic organisms.

15.2.5 Affects Reproductive Systems

Increased temperatures can cause a significant halt in the reproduction of marine wildlife (although this is not true, reproduction can still occur amongst fish – but the likelihood of abnormalities in newborns is significantly higher). Excessive heat might cause immature eggs to be released or prevent particular eggs from developing normally.

15.2.6 Increases Metabolic Rate

Thermal pollution increases the metabolic rate of organisms by boosting enzyme activity, causing them to eat more food than they would if their environment had not altered. It affects the food chain's stability and changes the species composition's balance.

15.2.7 Migration

Warm water can also induce certain types of organisms to relocate to a more favorable environment that meets their survival needs. As a result, those species that rely on them for their daily food may suffer as their food chain is disrupted.

15.3 Measures to control thermal pollution

- Instead of discharging heated water into lakes and streams, power plants and factories can transport it through cooling towers or cooling ponds, where it is cooled by evaporation before being discharged.
- Power plants, on the other hand, can be designed or retrofitted to be more efficient and generate less waste heat in the first place.
- Cogeneration is a technique in which excess thermal energy from electricity generation is utilized in another manufacturing process that requires it. Where homes or other buildings are located near industrial plants, waste hot water can be used for heating – which is a common arrangement in Scandinavian towns and cities and is being proposed for usage in China.
- The solution to preventing thermal pollution caused by devegetation is simple: Do not devegetate and leave strips of trees and plants along streams and shorelines.
- All efforts to control erosion also have the effect of keeping water clearer and thus, cooler.

15.4 Salient Features

- Thermal pollution in the rise or reduction in temperature of a natural aquatic environment induced by human intervention.
- Water as a cooling agent in industrial facilities, deforestation, soil erosion, runoff from paved surfaces etc. are some of the sources of thermal pollution.
- Decrease in DO levels, increase in toxins, loss of biodiversity, migration, etc. are some of the effects of thermal pollution.
- Some measures to control thermal pollution includes cogeneration, transportation of heated water through cooling towers before discharging it in lakes, redesigning or retrofitting of power plants to be more efficient, etc.