Unit 2: Ecosystem

Definition and concept of Ecosystem:

- The term Ecology was coined by Earnst Haeckel in 1869.
- It is derived from the Greek words Oikos- home + logos-study.
- Ecology deals with the study of organisms in their natural home interacting with their surroundings.
- The surroundings or environment consists of other living organisms (biotic) and physical (abiotic) components.
- Sir Arthur G. Tansley coined the term ecosystem in 1935.
- An ecosystem is a group of biotic communities of species interacting with one another and with their non-living environment exchanging energy and matter.
- Now ecology is often defined as the study of ecosystems.
- The living community of plants and animals in any area together with the non-living components of the environment such as soil, air, and water, constitute the ecosystem.
- An 'Ecosystem' is a region with a specific and recognizable landscape form such as forest, grassland, desert, wetland, or coastal area.
- The nature of the ecosystem is based on its geographical features such as hills, mountains, plains, rivers, lakes, coastal areas, or islands.
- It is also controlled by climatic conditions such as the amount of sunlight, the temperature, and the rainfall in the region.
- The geographical, climatic and soil characteristics form its non-living (abiotic) component.
- The living part of the ecosystem is referred to as its biotic component.
- Ecosystems are divided into terrestrial or land-based ecosystems, and aquatic ecosystems in water.

Structure of Ecosystem (biotic and abiotic):

Composition and organization of biological communities and abiotic components constitute the structure of an ecosystem.

Biotic Structure

The plants, animals and microorganisms present in an ecosystem form the biotic component. These organisms have different nutritional behaviour and status in the ecosystems and are accordingly known as Producers or Consumers, based on how they get their food.

(a) Producers:
- They are mainly the green plants, which can synthesize their food themselves by making use of carbon dioxide present in the air and water in the presence of sunlight by involving chlorophyll, the green pigment present in the leaves, through the process of photosynthesis.
- They are also known as photo autotrophs.
- There are some microorganisms also which can produce organic matter to some extent through oxidation of certain chemicals in the absence of sunlight. They are known as chemosynthetic organisms or chemoautotrophs.
- For example, in the ocean depths, where there is no sunlight, chemoautotrophic sulphur bacteria make use of the heat generated by the decay of radioactive elements present in the earth's core and released in oceans depths. They use this heat to convert dissolved hydrogen sulphide (H_2S) and carbon dioxide (CO_2) into organic compounds.

(b) Consumers:
All organisms which get their organic food by feeding upon other organisms are called consumers, which are of the following types:
- Herbivores (plant eaters): They feed directly on producers and hence also known as primary consumers. e.g., rabbit, insect, man.

- Carnivores (meat eaters):
    - They feed on other consumers.
    - If they feed on herbivores, they are called secondary consumers (e.g., frog) and if they feed on other carnivores (snake, big fish etc.) they are known as tertiary carnivores/consumers.
- Omnivores: They feed on both plants and animals. e.g., humans, rat, fox, many birds.
- Detritivores (Detritus feeders or Saprotrophs): They feed on the parts of dead organisms, wastes of living organisms and partially decomposed matter e.g., beetles, termites, ants, crabs, earthworms etc.

(c) Decomposers:
- They derive their nutrition by breaking down the complex organic molecules to simpler organic compounds and ultimately into inorganic nutrients.
- Various bacteria and fungi are decomposers.

Abiotic Structure:

➢ The physical and chemical components of an ecosystem constitute its abiotic structure.

➢ It includes climatic factors, edaphic (soil) factors, geographical factors, energy, and nutrients.

(a) Physical factors:
The sunlight and shade, intensity of solar flux, duration of sun hours, average temperature, maximum-minimum temperature, annual rainfall, wind, latitude and altitude, soil type, water availability, water currents etc are some of the important physical features which have a strong influence on the ecosystem.

(b) Chemical factors:
- Availability of major essential nutrients like carbon, nitrogen, phosphorus, potassium, hydrogen, oxygen and sulphur and various organic substances present in the soil or water largely influence the functioning of the ecosystem.
- All the biotic components of an ecosystem are influenced by the abiotic components and vice versa, and they are linked together through energy flow and matter cycling.

Function of Ecosystem:

Every ecosystem performs under natural conditions in a systematic way.

It receives energy from the sun and passes it on through various biotic components and in fact, all life depends upon this flow of energy.

- The major functional attributes of an ecosystems are as follows:
- Food chain, food webs, trophic structure, ecological succession (Biological)
- Energy flow (Physical)
- Cycling of nutrients (Biogeochemical)
- Primary and Secondary production
- Ecosystem development and regulation

Trophic structure:

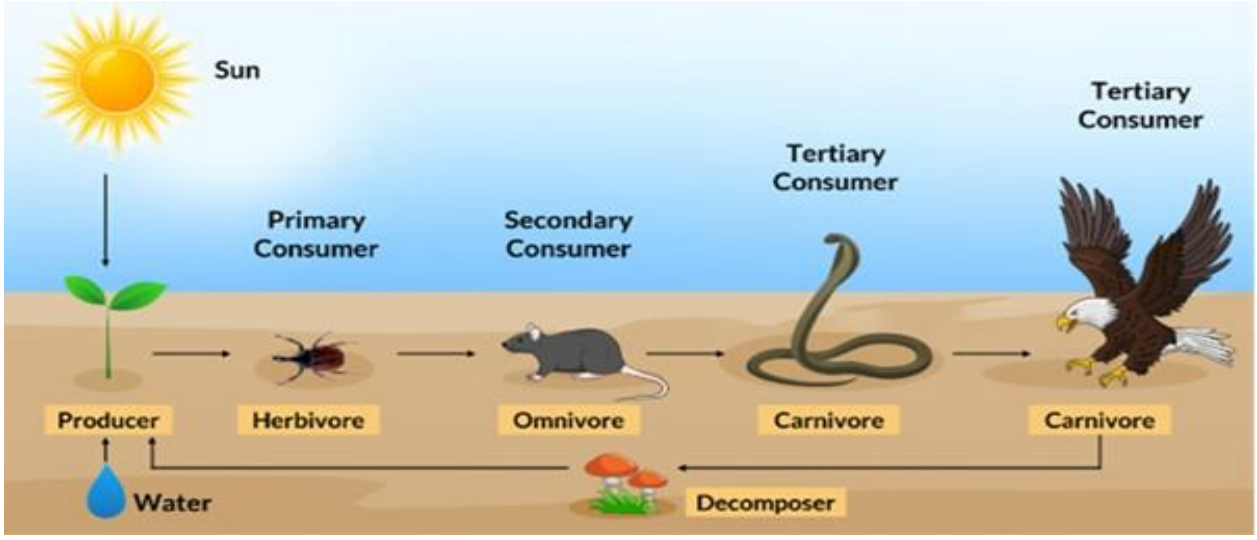
- The producers and consumers are arranged in the ecosystem in a definite manner and their interaction along with population size are expressed together as trophic structure. Each food level is known as trophic level.
- The amount of living matter at each trophic level at a given time is known as standing crop or standing biomass.

Food chain:

- The sequence of eating and being eaten in an ecosystem is known as food chain.
- A caterpillar eats a plant leaf, a sparrow eats the caterpillar, a cat or a hawk eats the sparrow and when they all die, they are all consumed by microorganisms like bacteria or fungi (decomposers) which break down the organic matter and convert it into simple inorganic substances that can again, be used by the plants the primary producers.
- Each organism in the ecosystem is assigned a feeding level or trophic level depending on its nutritional status. Thus, in the grassland food chain, grasshopper occupies the Ist trophic level, frog the IInd and snake and hawk occupy the IIIrd and the IVth trophic levels, respectively.
- The decomposers consume the dead matter of all these trophic levels.

Some common examples of simple food chains are:

- Grass → grasshopper → Frog → Snake → Hawk (Grassland ecosystem)
- Phytoplanktons → water fleas → small fish → Tuna (Pond ecosystem)
- Lichens → reindeer → Man (Arctic tundra)



In nature, we come across two major types of food chains:

- **Grazing food chain:**
  It starts with green plants (primary producers) and ends in carnivores.

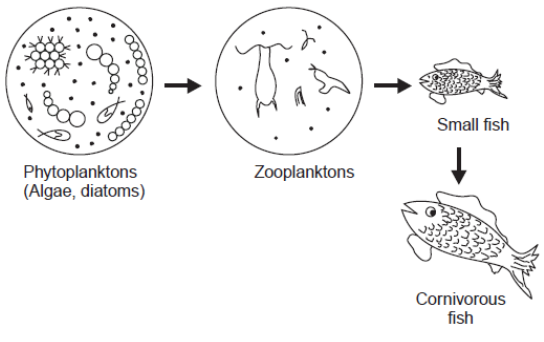


Fig. 3.2. A grazing food chain in a pond ecosystem.

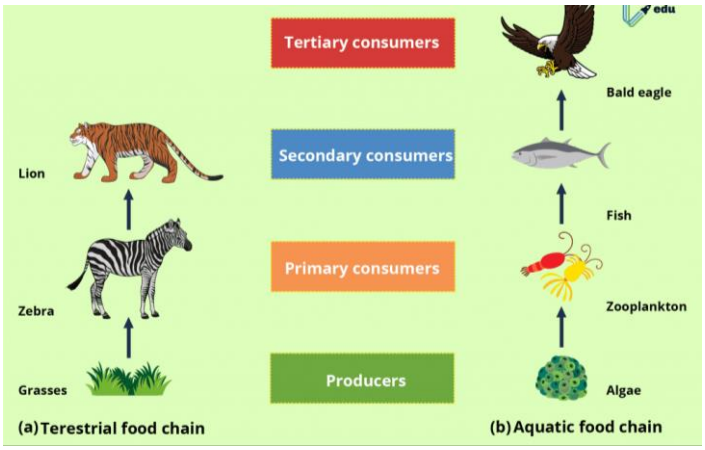


Fig. Grazing food chain

- Detritus food chain:

  ➢ It starts with dead organic matter which the detritivores and decomposers consume.

  ➢ Partially decomposed dead organic matter and even the decomposers are consumed by detritivores and their predators.

  ➢ An example of the detritus food chain is seen in a Mangrove (estuary).

  ➢ Thus the grazing food chain derives its energy basically from plant energy while in the detritus food chain it is obtained primarily from plant biomass, secondarily from microbial biomass and tertiarily from carnivores.

  ➢ Both the food chains occur together in natural ecosystems, but grazing food chain usually predominates.

Leaf litter → algae → crabs → small carnivorous fish → large carnivorous fish (Mangrove ecosystem)

Fig. Detritus food chain

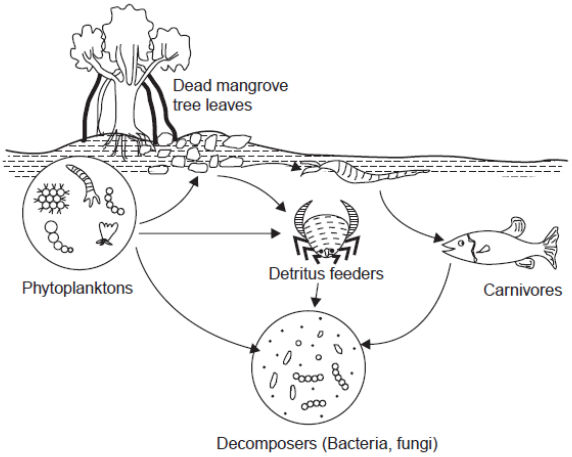


Fig. 3.3. A detritus food chain in an estuary based on dead leaves of mangrove trees.

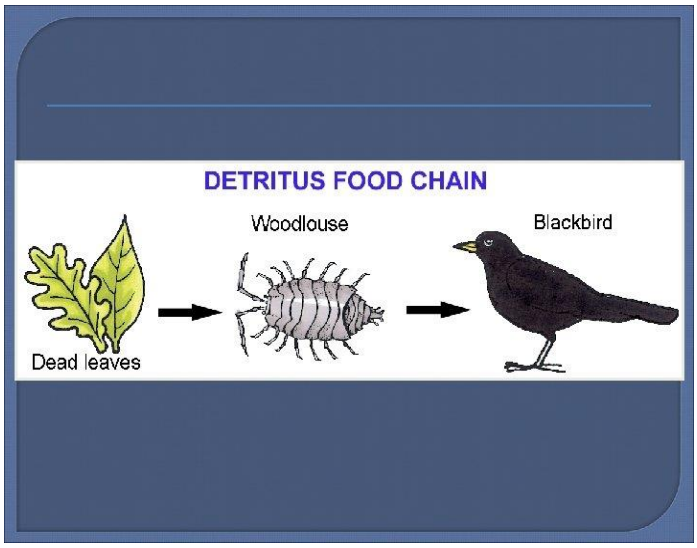


Fig. Detritus food chain

Food web

- Food web is a network of food chains where different types of organisms are connected at different trophic levels, so that there are a number of options of eating and being eaten at each trophic level.
- In a tropical region, the ecosystems are much more complex. They have a rich species diversity and therefore, the food webs are much more complex.
- Why has nature evolved food webs in ecosystems instead of simple linear food chains? This is because food webs give greater stability to the ecosystem.
- In a linear food chain, if one species becomes extinct or one species suffers then the species in the subsequent trophic levels are also affected.
- In a food web, on the other hand, there are several options available at each trophic level. So, if one species is affected, it does not affect other trophic levels so seriously.

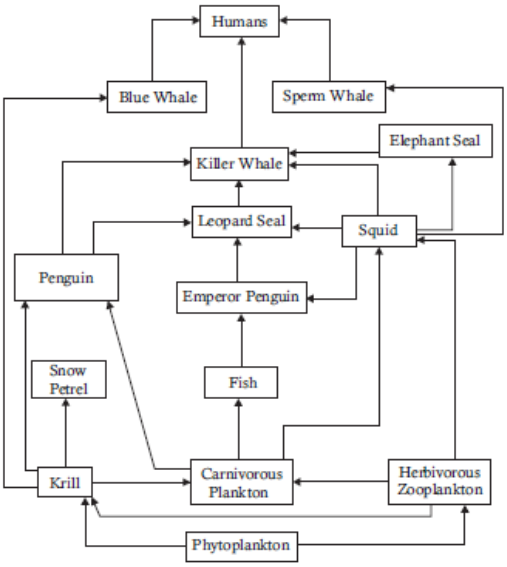
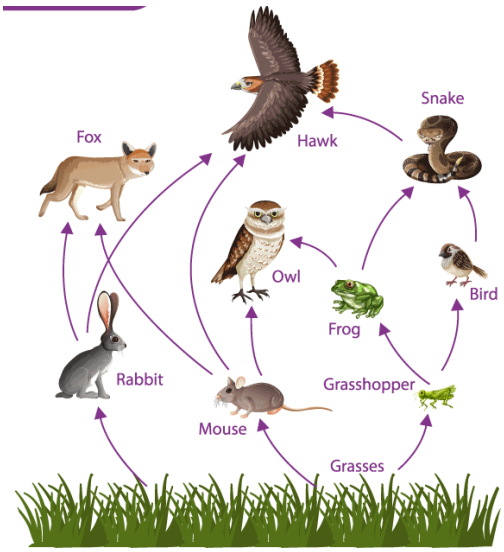


Fig. 3.4. A simplified food web in Antarctic ecosystem.



Significance of food chains and food webs:

- Food chains and food webs play a very significant role in the ecosystem because the two most important functions of energy flow and nutrient cycling take place through them.
- The food chains also help in maintaining and regulating the population size of different animals and thus, help maintain the ecological balance.
- Food chains show a unique property of biological magnification of some chemicals. There are several pesticides, heavy metals and other chemicals which are non-biodegradable in nature. Such chemicals are not decomposed by microorganism and they keep on passing from one trophic level to an-other. And, at each successive trophic level, they keep on increasing in concentration. This phenomenon is known as biological magnification.

Ecological pyramid

Graphic representation of trophic structure and function of an ecosystem, starting with producers at the base and successive trophic levels forming the apex is knows as an ecological pyramid.

Ecological pyramids are of three types:

Pyramid of numbers: It represents the number of individual organisms at each trophic level.

- It may have upright or inverted pyramid of numbers, depending upon the type of ecosystem and food chain.
- A grassland ecosystem and a pond ecosystem show an upright pyramid of numbers.
- The producers in the grasslands are grasses and that in a pond are phytoplankton (algae etc.), which are small and very large in number. So, the producers form a broad base. The herbivores in a grassland are insects while tertiary carnivores are hawks or other birds which are gradually less and less in number and hence the pyramid apex becomes gradually narrower forming an upright pyramid.
- Similar is the case with the herbivores, carnivores and top carnivores in pond which decrease in number at higher trophic levels.
- Parasitic food chain shows an inverted pyramid of number.
- The producers like a few big trees harbour fruit eating birds acting like herbivores which are larger in number. A much higher number of lice, bugs etc. grow as parasites on these birds while a still greater number of hyperparasites like bugs, fleas, and microbes feed upon them, thus making an inverted pyramid.

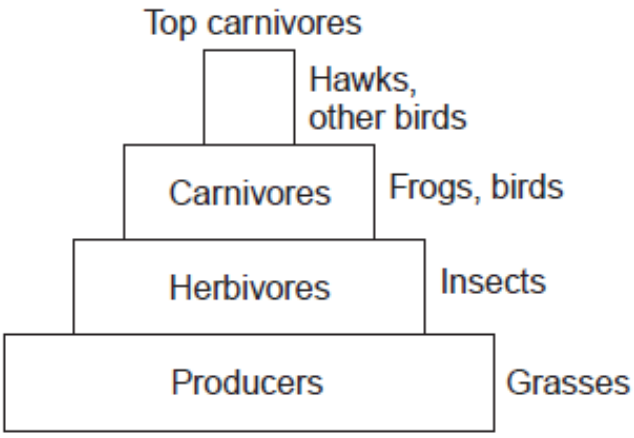


Fig. Pyramid of Number of Grassland Ecosystem

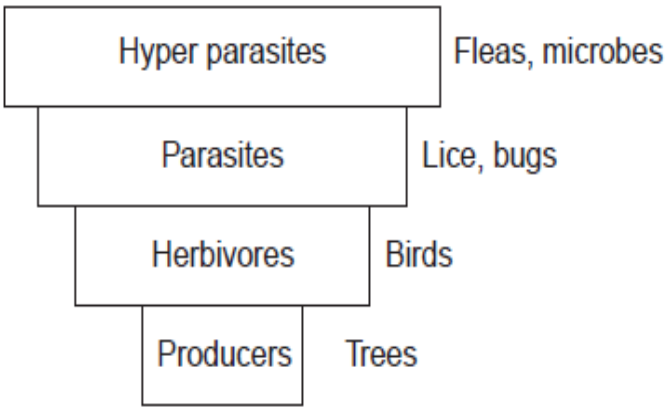


Fig. Pyramid of Number of Parasitic food chain

Pyramid of biomass

- It is based upon the total biomass (dry matter) at each trophic level in a food chain.
- The pyramid of biomass can also be upright or inverted.
- The pyramid of biomass in a forest is upright in contrast to its pyramid of numbers. This is because the producers (trees) accumulate a huge biomass while the consumers total biomass feeding on them declines at higher trophic levels, resulting. in broad base and narrowing top.
- The pond ecosystem shows an inverted pyramid of biomass. The total biomass of producers (phytoplankton) is much less as compared to herbivores (zooplanktons, insects), Carnivores (Small fish) and tertiary carnivores (big fish). Thus, the pyramid takes an inverted shape with narrow base and broad apex.

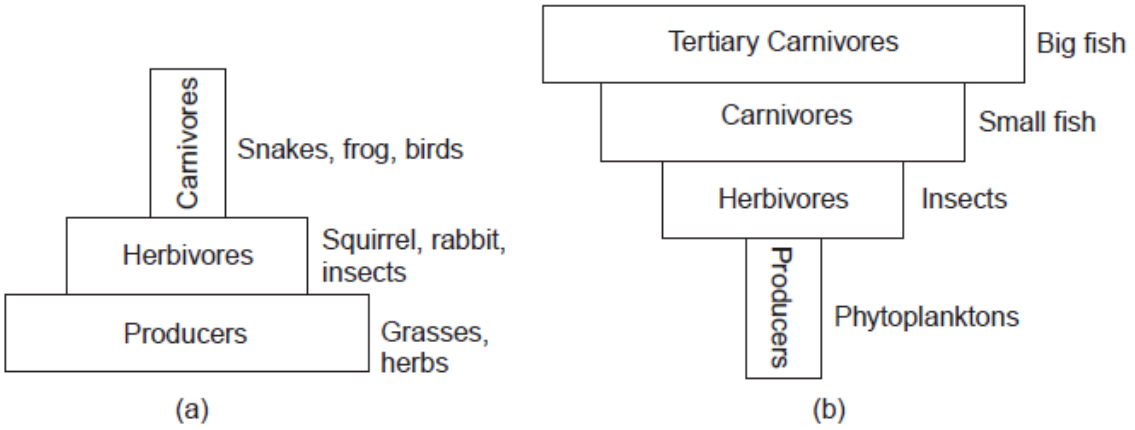


Fig. 3.6. Pyramid of biomass (*a*) Grassland (*b*) Pond.

Pyramid of Energy: The amount of energy present at each trophic level is considered for this type of pyramid.

- Pyramid of energy is always upright.
- At every successive trophic level, there is a huge loss of energy (about 90%) in the form of heat, respiration etc. Thus, at each next higher level only 10% of the energy passes on.

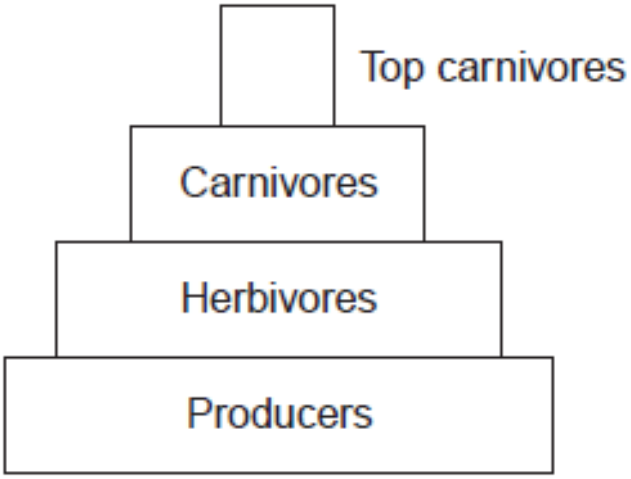


Fig. 3.7. Pyramid of energy.

Energy flow in the ecosystem

- Flow of energy in an ecosystem takes place through the food chain.
- Flow of energy in the ecosystem is unidirectional.
- Flow of energy follows two laws of thermodynamics.
- **Ist law of Thermodynamics:** It states that energy can neither be created nor be destroyed but it can be transformed from one form to another.
- The solar energy captured by the green plants (producers) gets converted into biochemical energy of plants and later into that of consumers.
- **IInd law of Thermodynamics:** It states that energy dissipates as it is used. As energy flows through the food chain, there occurs dissipation of energy at every trophic level.
- The loss of energy takes place through respiration, loss of energy in locomotion, running, hunting and other activities.
- At every level there is about 90% loss of energy and the energy transferred from one trophic level to the other is only about 10%.

Concept of productivity:

Primary production

- Primary productivity of an ecosystem is defined as the rate at which radiant energy is converted into organic substances by photosynthesis or chemosynthesis by the primary producers.
- When organic matter is produced by the primary producers (mainly green plants and some microorganisms), some of it is oxidized or burnt inside their body and converted into carbon-dioxide which is released during respiration and is accompanied by loss of energy.
- Respiratory loss of energy is a must because it is required for the maintenance of the organism. Now, the producers are left with a little less organic matter than what was produced by them. This is known as the net primary production (NPP) and the respiratory loss (R) added to it gives the gross primary production (GPP).

NPP = GPP - R.

Secondary production

- The food synthesized by green plants through photosynthesis is the primary production which is eaten by herbivores. The plant energy is used up for producing organic matter of the herbivores which, in turn, is used up by the carnivores. The amount of organic matter stored by the herbivores or carnivores (in excess of respiratory loss) is known as secondary production.
- The energy stored at consumer level for use by the next trophic level is thus defined as secondary production.

Ecological succession:

- An ecosystem is not static in nature. It is dynamic and changes its structure as well as function with time.
- It is observed that one type of a community is totally replaced by another type of community over a period of time and simultaneously several changes also occur. This process is known as ecological succession.
- The whole sequence of communities which are transitory are known as Seral stages or seres whereas the community establishing first of all in the area is called a pioneer community last stable community is known as climax community.
- Ecological successions starting on different types of areas or substrata are named differently as follows:

(i) Hydrarch or Hydrosere: Starting in watery area like pond, swamp.

(ii) Mesarch: starting in an area of adequate moisture.

(iii) Xerarch or Xerosere: Starting in a dry area with little moisture.

Process of Succession

- The process of succession takes place in a systematic order of sequential steps as follows:

(i) Nudation: It is the development of a bare area without any life form. The bare area may be caused due to landslides, volcanic eruption etc. (topographic factor), or due to drought, glaciers, frost etc. (Climatic factor), or due to overgrazing, disease outbreak, agricultural/industrial activities (biotic factors).

(ii) Invasion: It is the successful establishment of one or more species on a bare area through dispersal or migration, followed by establishment.

(iii) Competition: As the number of individuals grows there is competition, both inter-specific (between different species) and intra-specific (within the same species), for space, water, and nutrition.

(iv) Reaction: The living organisms grow, use water and nutrients from the substratum, and in turn, they have a strong influence on the environment which is modified to a large extent, and this is known as reaction.

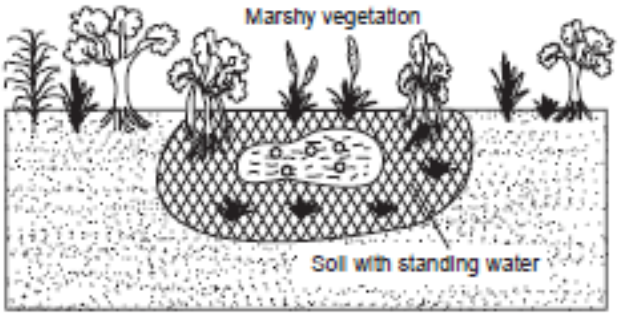
(v) Stabilization: The succession ultimately culminates in a stable community called climax which is in equilibrium with the environment. The climax community is characterized by maximum biomass.

Let us consider very briefly two types of succession.

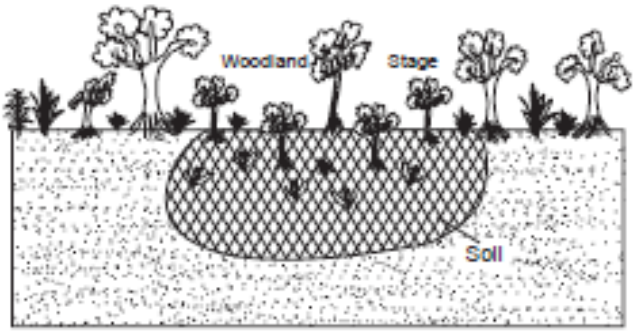
A. **Hydrosere (Hydrarch):** This type of succession starts in a water body like pond.

- Several intermediate stages come and ultimately it culminates in a climax community which is a forest.
- The pioneer community consists of phytoplankton, which are free floating algae, diatoms etc. Gradually these are replaced by rooted submerged plants followed by rooted-floating plants.

- Growth of these plants keep on adding organic matter to the substratum by death and decay and thus a layer of soil builds up and shallowing of water takes place.
- Then Reed swamp (marshy) stage follows in which the plants are partly in water and partly on land. This is followed by a sedge meadow stage of grasses then by a woodland consisting of shrubs and trees and finally by a forest acting as climax.

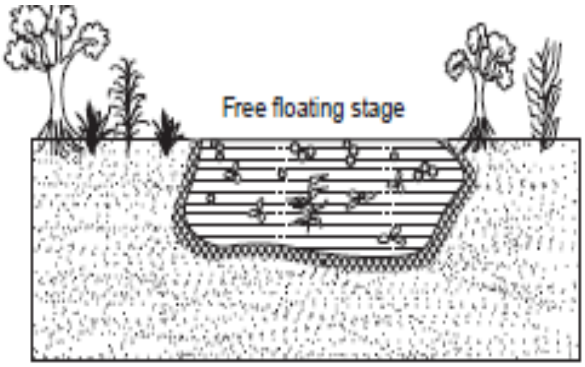


(*c*) A mat of vegetation covers the water which is mostly a marshy habitat now, with a small part as aquatic system.

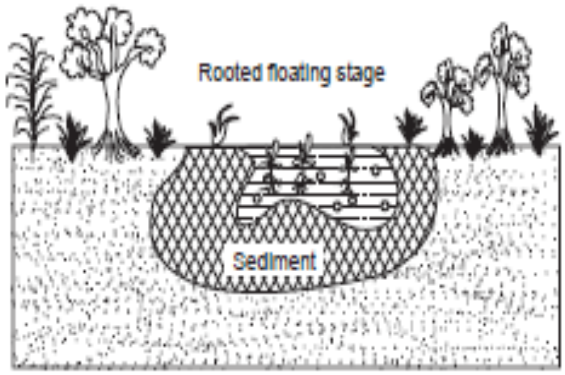


(*d*) Eventually the former lake is covered by climax woodland community, representating a terrestrial ecosystem.

Fig. 3.15. Ecological succession: A hydrach—from lake to woodland community.



(*a*) Open water body (lake), sediment brought in by river.



(*b*) Sediment accumulation continues, organic debris from plants too add to soil formation and shrinking of water body occurs.

B. Xerosere (Xerarch): This type of succession originates on a bare rock, which lacks water and organic matter. Interestingly, here also the climax community is a forest.

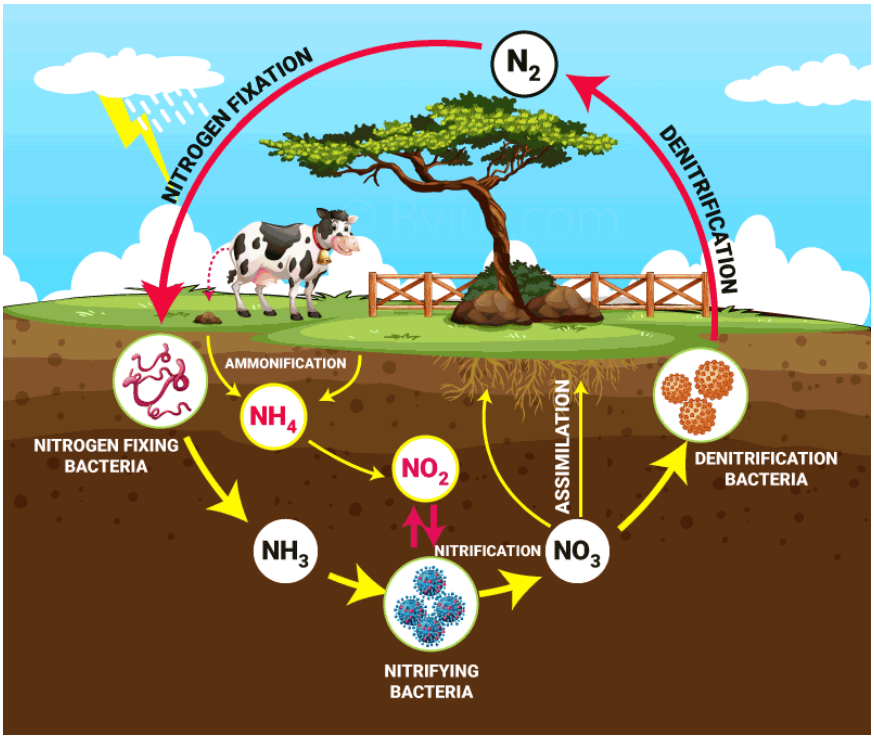
- The pioneer community here consists of crustose and foliose lichens. These lichens produce some weak acids and help in disintegrating the rock, a process known as weathering. Their growth helps in building up gradually some organic matter, humus and soil.
- Then comes the community of mosses, followed by herbs, shrubs and finally the forest trees.

Biogeochemical (nutrient cycling) processes:

- Nutrients like carbon, nitrogen, sulphur, oxygen, hydrogen, phosphorus etc. move in circular paths through biotic and abiotic components and are therefore known as biogeochemical cycles.
- The nutrients too move through the food chain and ultimately reach the detritus compartment (containing dead organic matter) where various micro-organisms carry out decomposition.

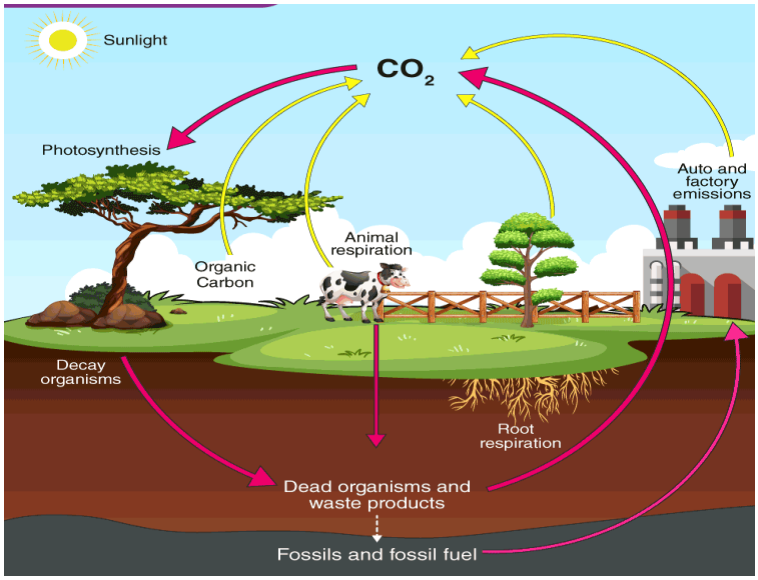
The Nitrogen cycle.

- The major components of the atmosphere are nitrogen (78%).
- Nitrogen in the atmosphere cannot be directly used as a nutrient by the plant and animal.
- Plant use nitrogen in the form of nitrate (NO_3^-).
- Nitrogen fixation is the process of converting free nitrogen in the atmosphere into nitrogen molecules. So that plants can absorb and use it.
- Lightning can also fix nitrogen. The high temperature of a lightning can break the bonds of atmospheric nitrogen molecules. Free nitrogen atoms in the air bond with oxygen in the air to create nitrogen oxides, which dissolve in moisture to form nitrates that are carried to Earth's surface by precipitation and used by plant.
- Nitrogen cycle contains various steps such as ammonification, nitrification, nitrogen fixation and denitrification.
- Ammonification is the process where microscopic organisms like bacteria or other types of decomposing organisms, break down nitrogen-containing chemicals from dead organic matter, into simple substances like ammonia.
- Bacillus ramosus are ammonifying bacteria.
- Nitrification is the process that converts ammonia to nitrite and then to nitrate.
- Nitrification processes has been carried out by several bacteria such as Nitrosomonas, Nitrosococcus and Nitrobacter etc.
- Free-living bacteria such as Azotobacter, Clostridium, Nostoc, and Anabaena can fix nitrogen in the atmosphere.
- Root nodules of Leguminous plant such as beans, peas, lentils etc. contains various symbiotic bacteria such as Rhizobium leguminosarum etc. which fixes atmospheric nitrogen into leguminous plant.
- Finally the denitrification steps completes the nitrogen cycle as nitrogen leaves the soil and released into the atmosphere as nitrogen or nitrous oxide gas.
- Micrococcus denitrificans, Thiobacillus denitrificans etc. are examples of denitrifying bacteria.
- Nitrates are the part of plant metabolism, which help informing new plant proteins. This is used by animals that feed on plants.
- The nitrogen is then transferred to the carnivorous when they feed on herbivorous.



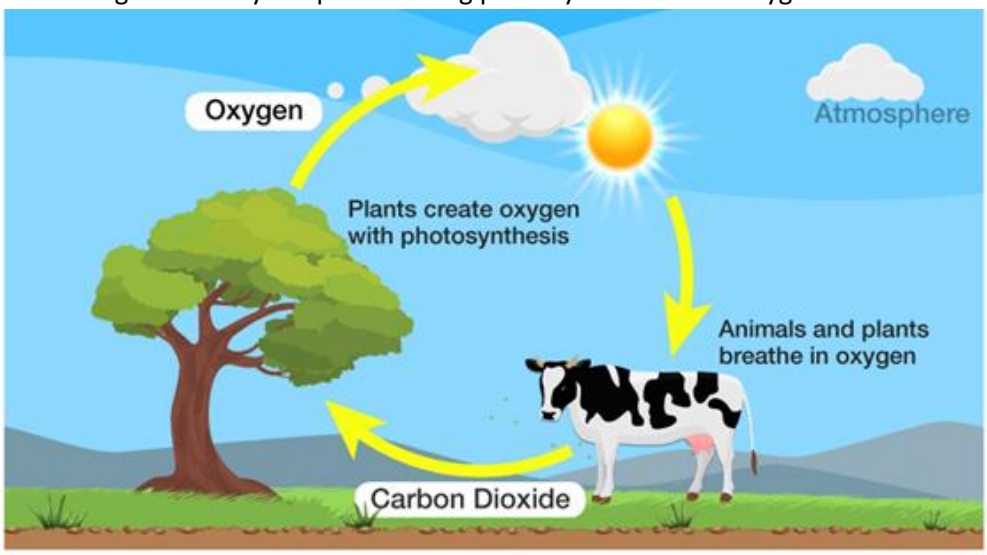
The Carbon cycles.

- The carbon, which occurs in organic compounds, is included in both the abiotic and biotic parts of the ecosystem.
- Carbon is a building block of both plant and animal tissues.
- In the presence of sunlight, plants take up carbon dioxide from the atmosphere through their leaves. The plants combine carbon dioxide with water, which is absorbed by their roots from the soil. In the presence of sunlight, they are able to form carbohydrates that contain carbon. This process is known as photosynthesis.
- Both plants and animals release carbon dioxide during respiration.
- They also return fixed carbon to the soil in the waste they excrete.
- When plants and animals die, they return their carbon to the soil. These processes complete the carbon cycle.



Oxygen cycle

- The air in the atmosphere is composed of different gases, namely nitrogen (78%), oxygen (21%), argon and other trace gases (1%).
- According to the earth's history, oxygen gas was first introduced by cyanobacteria through the process of photosynthesis. Earlier, around 4.6 billion years ago, there was no life on planet earth because the atmosphere was devoid of oxygen. Later, there was a gradual increase in the oxygen levels in the atmosphere.
- Today, oxygen is freely available in the air and dissolved in water. It is the second most abundant gas present in the atmosphere. All green plants during the process of photosynthesis, release oxygen back into the atmosphere as a by-product
- All aerobic organisms use oxygen for respiration. Animals exhale Carbon dioxide back into the atmosphere which is again used by the plants during photosynthesis. Now oxygen is balanced within the atmosphere



Types of Ecosystems:

Forest Ecosystem:

- According to Forest Survey report 2021, the total forest and tree cover in India is 80.9 million hectares, which is 24.62% of the geographical area of the country. It is less as compared to the recommended 33% by National Forest Policy (1988).
- Area-wise Madhya Pradesh has the largest forest cover in the country followed by Arunachal Pradesh, Chhattisgarh, Odisha, and Maharashtra.
- In terms of forest cover as percentage of total geographical area, the top five States are Mizoram (84.53%), Arunachal Pradesh (79.33%), Meghalaya (76.00%), Manipur (74.34%) and Nagaland (73.90%).
- 17 states/UT's have above 33 percent of the geographical area under forest cover. Out of these states and UT's, five states/UTs namely Lakshadweep, Mizoram, Andaman & Nicobar Islands, Arunachal Pradesh, and Meghalaya have more than 75 percent forest cover while 12 states/UTs namely Manipur, Nagaland, Tripura, Goa, Kerala, Sikkim, Uttarakhand, Chhattisgarh, Dadra & Nagar Haveli and Daman & Diu, Assam, Odisha, have forest cover between 33 percent to 75 percent.
- Depending upon the prevailing climatic conditions forests can be of various types:

(a) **Tropical Rain Forests:**

- They are evergreen broadleaf forests found near the equator. They are characterized by high temperature, high humidity and high rainfall, all of which favour the growth of trees.
- These forests have the richest biodiversity.

- The understorey trees usually receive very dim sunlight. They usually develop dark green leaves with high chlorophyll content so that they can use the diffused sunlight for photosynthesis.
- The shrub layer receives even less sunlight and the ground layer commonly known as forest floor receives almost no sunlight and is a dark layer.
- Warm temperature and high availability of moisture facilitate rapid breakdown (decomposition) of the dropped leaves, twigs etc. releasing the nutrients rapidly. These nutrients are immediately taken up by the mycorrhizal roots of the trees.
- The Silent Valley in Kerala is the tropical rain forest lying in India which is the natural habitat for a wide variety of species.

(b) Tropical deciduous forests: They are found a little away from the equator and are characterized by a warm climate the year round.

- Rain occurs only during monsoon. A large part of the year remains dry and therefore different types of deciduous trees are found here, which lose their leaves during dry season.

(c) Tropical scrub forests: They are found in areas where the dry season is even longer. Here there are small deciduous trees and shrubs.

(d) Temperate rain forests: They are found in temperate areas with adequate rainfall. These are dominated by coniferous trees like pines, firs, redwoods etc.

(e) Temperate deciduous forests:

- They are found in areas with moderate temperatures.
- There is a marked seasonality with long summers, cold but not too severe winter and abundant rainfall throughout the year.

- The major trees include broad leaf deciduous trees like oak, hickory, poplar etc.

(f) Evergreen coniferous forests (Boreal Forests): They are found just south of arctic tundra.

- Here winters are long, cold, and dry. Sunlight is available for a few hours only. In summer, the temperature is mild.
- The major trees include pines, spruce, fir, cedar etc. which have tiny, needle-shaped leaves having a waxy coating so that they can withstand severe cold and drought.
- Species diversity is rather low in these forests.

Grassland Ecosystem

- Grasslands are dominated by grass species but sometimes also allow the growth of a few trees and shrubs. Rainfall is average.
- Three types of grasslands are found to occur in different climatic regions:

(a) **Tropical grasslands:**

- They occur near the borders of tropical rain forests in regions of high average temperature and low to moderate rainfall. In Africa, these are typically known as Savannas, which have tall grasses with scattered shrubs and stunted trees.
- Tropical savannas have a highly efficient system of photosynthesis. Most of the carbon assimilated by them in the form of carbohydrates.

(b) Temperate grasslands:

- They are usually found on flat, gentle sloped hills, winters are very cold, but summers are hot and dry.
- In United States and Canada these grasslands are known as prairies, in South America as Pampas, in Africa as Velds and in central Europe and Asia they are known as Steppes.

(c) Polar grasslands (Arctic Tundra):

- They are found in arctic polar region where severe cold and strong, frigid winds along with ice and snow create too harsh a climate for trees to grow.
- The animals include arctic wolf, arctic fox, reindeer etc.
- A thick layer of ice remains frozen under the soil surface throughout the year and is known as permafrost.

Desert Ecosystem

- These ecosystems occur in regions where evaporation exceeds precipitation (rainfall, snow etc.).

- The precipitation is less than 25 cm per year.
- About 1/3rd of our worlds land area is covered by deserts.
- Deserts have little species diversity and consist of drought resistant or drought avoiding plants.

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

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

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

(c) Cold deserts like the Gobi Desert in China has cold winters and warm summers. Desert plants and animals are having most typical adaptations for conservation of water. Many desert plants are found to have reduced, scaly leaves so as to cut down loss of water due to transpiration or have succulent leaves to store water.

Aquatic Ecosystem

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

(a) **Lake ecosystems:**

- Lakes are usually big freshwater bodies with standing water.
- They have a shallow water zone called Littoral zone, an open-water zone where effective penetration of solar light takes place, called Limnetic zone and a deep bottom area where light penetration is negligible, known as profundal zone.
- The Dal Lake in Srinagar (J & K), Naini Lake in Nainital (Uttaranchal), Chandratal Lake (Himachal Pradesh) and Loktak lake in Manipur are some of the famous lakes of our country.
    - **Organisms:** The lakes have several types of organisms:
        - Planktons that float on the surface of waters e.g. phytoplankton like algae and zooplanktons.
        - Nektons that swim e.g. fishes.
        - Neustons that rest or swim on the surface.
        - Benthos that are attached to bottom sediments e.g. snails.
        - Periphytons that are attached to other plants or any other surface e.g. crustaceans.
    - **Stratification :**
        - The lakes show stratification or zonation based on temperature differences.
        - During summer, the top waters become warmer than the bottom waters. Therefore, only the warm top layer circulates without mixing with the colder layer, thus forming a distinct zonation:
        - **Epilimnion:** Warm, lighter, circulating surface layer.
        - **Hypolimnion:** Cold, viscous, non-circulating bottom layer.
        - In between the two layers is thermocline, the region of sharp drop in temperature.

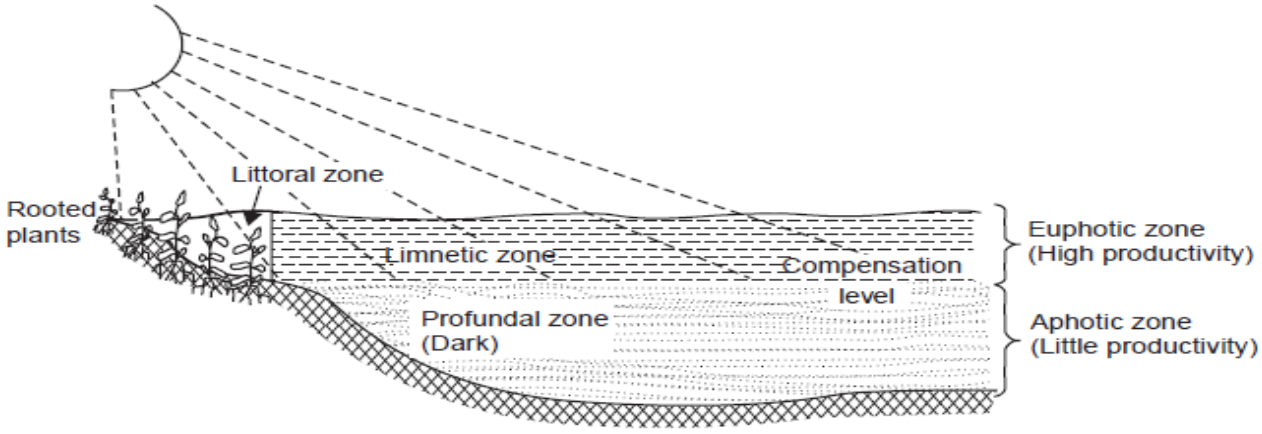


Fig. 3.16. Zonation in a lake ecosystem.

- **Types of Lakes:**
  - **Oligotrophic lakes:** Which have low nutrient concentrations.
  - **Eutrophic lakes:** Which are over-nourished by nutrients like nitrogen and phosphorus, usually as a result of agricultural run-off or municipal sewage discharge.
  - They are covered with. algal blooms. e.g., Dal Lake.
  - **Dystrophic lakes**: That have low pH, high humic acid content and brown waters e.g., bog lakes.
  - **Desert salt lakes:** That occur in arid regions and have developed high salt concentrations as a result of high evaporation. e.g., Sambhar lake in Rajasthan.
  - **Artificial lakes:** That are created due to construction of dams e.g. Govindsagar lake at Bhakra-Nangal.

Tundra:

- The Tundra is the coldest of the biomes (contains extremely low temperatures).
- Tundra ecosystems are treeless regions found in the Arctic and on the tops of mountains, where the climate is cold and windy, and rainfall is scant. Tundra lands are covered with snow for much of the year.
- It also receives low amounts of precipitation, making the tundra like a desert.
- Three types of tundra exist: Antarctic, Alpine, and Arctic. The main difference between these types of tundra is their location on the earth.
- Some notable regions with a large amount of Alpine tundra are: The Himalayas, The Tibetan Plateau in Asia, The Alps etc.
- The tundra has few nutrients to support plant and animal life.
- For most of the year, the tundra biome is a cold, frozen landscape. This biome has a short growing season, followed by harsh conditions that the plants and animals in the region need special adaptations to survive.
- Animals found in the tundra include the polar bear, the Arctic fox, Reindeer etc.
- Tundra regions have extreme cold conditions and hence, vegetation such as lichens and mosses have adapted to grow by performing photosynthesis with the little sunlight that they receive.

Oceans:

- These are huge reservoirs of water covering more than 70% of our earth's surface and play a key role in the survival of about 2,50,000 marine species.
- Ocean contains around 97% of total water present on the earth.
- Oceans are the major sinks of carbon dioxide and play an important role in regulating many biogeochemical cycles and hydrological cycle, thereby regulating the earths climate.
- The oceans have two major life zones.
- **Coastal zone:** It is relatively warm, nutrient rich shallow water.
- Due to high nutrients and high sunlight this is the zone of high primary productivity.

Open sea:

- It is the deeper part of the ocean, away from the continental shelf (The submerged part of the continent).
- It is vertically divided into three regions:

(i) Euphotic zone: Which receives abundant light and shows high photosynthetic activity.

(ii) Bathyal zone: It receives dim light and is usually geologically active.

(iii) Abyssal zone: It is the dark zone, 2000 to 5000 metres deep.

- The abyssal zone has no primary source of energy i.e. solar energy.

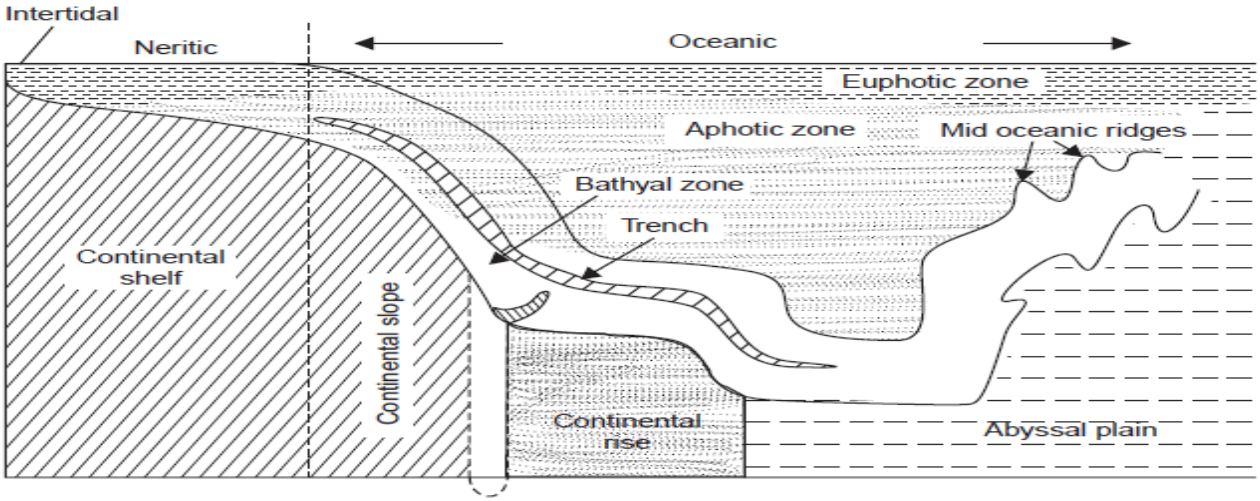


Fig. 3.17. Vertical and horizontal zonation of a marine ecosystem.

The Pond ecosystem

- The pond is the simplest aquatic ecosystem to observe.
- Most ponds become dry after the rains are over and are covered by terrestrial plants for the rest of the year.
- When a pond begins to fill during the rains, its life forms such as the algae and microscopic animals, aquatic insects, snails, and worms come out of the floor of the pond where they have remained dormant in the dry phase.

- Gradually more complex animals such as crabs frogs and fish return to the pond. The vegetation in the water consists of floating weeds and rooted vegetation on the periphery which grow on the muddy floor under water and emerge out of the surface of the water.

Streams

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

River Ecosystem:

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

(1) **The mountain highland part**

- This region is cold, clear waters rushing down as water falls with large amounts of dissolved oxygen The plants are attached to rocks (periphytons) and fishes lives in cold-water, high oxygen requiring fish like trouts.

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

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

Estuaries:

- An estuary is a partially enclosed, coastal water body where freshwater from rivers and streams mixes with salt water from the ocean.
- Estuaries, and their surrounding lands, are places of transition from land to sea.
- In estuaries, the salty ocean mixes with a freshwater river, resulting in brackish water. Brackish water is somewhat salty, but not as salty as the ocean.
- The Hooghly-Matlah estuarine system located in West Bengal is the largest among the estuaries on the Indian coast covering the Gangetic delta called Sundarbans which is the world's largest delta endowed with largest mangrove vegetation in India.
- The dominant plant groups in estuaries are seagrass, mangroves, saltmarsh, macroalgae and microalgae etc.
- Plants that live in estuaries tolerate remarkable environmental stresses, such as changes in water levels or tides, rainfall, currents, and salinity etc.
- Shellfish, salmon fish, oysters, shrimp, crabs, snails, turtle, and marine worms are very common in estuaries.

Ecosystem services

- An ecosystem service is any positive benefit that wildlife or ecosystems provide to people.
- Life and biodiversity on earth depend on these services.

Ecosystem services are classified into four types:

(1) Provisioning Services

- This includes the products/raw materials or energy outputs like food, water, medicines, and other resources from ecosystems. Ecosystems are a source of food, water, medicines, wood, biofuels, etc.

(2) Regulating Services

- This includes the services which regulate the ecological balance. For example, terrestrial environs like forest purify and regulates air quality, prevent soil erosion, and control greenhouse gases. Biotic components such as birds, rats, frogs, act as natural controllers and thus help in pest and disease control. Hence, ecosystems act as regulators.

(3) Supporting services

- Supporting services form the basis for other services. They provide habitat for different life forms, retain biodiversity, nutrient cycling, and other services for supporting life on the earth.

(4) Cultural services

- It includes tourism; provides recreational, cultural, and spiritual services, etc.
- Most natural elements such as landscapes, mountains, caves, are used as a place for cultural purposes.
- Moreover, ecosystems provide enormous economic benefits in the name of tourism.

Ecosystem preservation and conservation strategies

- We have examined human activities that can have adverse effects on the environment. However, this does not mean that human activities always have a negative impact on the environment.
- In managing development, measures of conservation, preservation and restoration of ecosystems need to be taken to ensure sustainable development.

Preservation of ecosystems:

- Ecosystem preservation is an effort to protect the components in an ecosystem in order to maintain its natural state.
- One of the conservation measures is to gazette the forest reserve to maintain the natural beauty of its flora and fauna.
- The forest reserve is protected from any development activities.

Conservation of ecosystems:

- Ecosystem conservation means the effort to restore environmental resources such as water, forests, energy, air, minerals and others that have been used without letting those resources become extinct.
- Conservation strategies are carried out to ensure that the endangered ecosystem components can be saved.
- There are two types of conservation strategies, namely in situ conservation and ex situ conservation.
- In situ conservation maintains wildlife species in their original habitats (natural habitat) such as national parks and wildlife sanctuary, biosphere reserve etc.
- Ex-situ conservation preserves wildlife species outside of their original/natural habitats such as zoos and botanical gardens.

Restoration of ecosystems:

- Ecosystem restoration means efforts to renew and restore natural ecosystems that have been degraded, damaged, or destroyed by human activities.
- Reforestation and the planting of land cover crops are among the remedial measures that can be taken to ensure the continuity of natural resources for future generations.

Unit 3: Natural Resources

Land resources:

Land is a finite and valuable resource upon which we depend for our food, fibre and fuel wood, the basic amenities of life.

Soil:

- Soil is an important component of natural cycles.
- Soil is breakdown product of rock.
- Soil, especially the top soil, is classified as a renewable resource because it is continuously regenerated by natural process though at a very slow rate.
- About 200-1000 years are needed for the formation of one inch or 2.5 cm soil, depending upon the climate and the soil type.
- In general, soil has a loose structure consisting of solid mineral and organic matter and air spaces.
- The top layer, upto several inches thick, is known as the topsoil which is an index of the soil quality.
- The Soil is essentially silicate minerals, 74.3% of which consists of silicon and oxygen.
- The common elements of soil are oxygen 46.6%, silicon 27.7%, aluminium 8.1%, iron 5%, calcium 3.6% etc.

Minerals:

- More than 90% on the crust is composed of silicate minerals.
- The crust of the earth is made up of more than 2000 minerals, but out of these, only six are the most abundant and contribute the maximum. These six most abundant minerals are feldspar, quartz, pyroxenes, amphiboles, mica, and olivine.

Mineral resources

- A mineral is a naturally occurring substance of definite chemical composition and identifiable physical properties.
- An ore is a mineral or combination of minerals from which a useful substance, such as a metal, can be extracted and used to manufacture a useful product.
- Minerals are formed over a period of millions of years in the earth's crust. Iron, aluminium, zinc, manganese, and copper are important raw materials for industrial use.
- Important non-metal resources include coal, salt, clay, cement, and silica.
- Stone used for building material, such as granite, marble, limestone, constitute another category of minerals.
- Minerals in the form of oil, gas and coal were formed when ancient plants and animals were converted into underground fossil fuels.
- Minerals and their ores need to be extracted from the earth's interior so that they can be used. This process is known as mining. Mining operations generally progress through four stages:
    a. Prospecting: Searching for minerals.

b. Exploration: Assessing the size, shape, location, and economic value of the deposit.
c. Development: Work of preparing access to the deposit so that the minerals can be extracted from it.
d. Exploitation: Extracting the minerals from the mines.

- Mines are of two types – surface (open cut or strip mines) or deep or shaft mines.

Some Major Minerals of India

(a) Energy generating minerals

- ✓ Coal and lignite: West Bengal, Jharkhand, Orissa, M.P., A.P.
- ✓ Uranium (Pitchblende or Uranite ore): Jharkhand, Andhra Pradesh (Nellore, Nalgonda), Meghalaya, Rajasthan (Ajmer).

(b) Other commercially used minerals

- ✓ Aluminium (Bauxite ore): Jharkhand, West Bengal, Maharashtra, M.P., Tamil Nādu.
- ✓ Iron (haematite and magnetite ore): Jharkhand, Orissa, M.P., A.P., Tamil Nādu, Karnataka, Maharashtra, and Goa.
- ✓ Copper (Copper Pyrites): Rajasthan (Khetri), Bihar, Jharkhand, Karnataka, M.P., West Bengal and Andhra Pradesh.

Medicinal plants

- A medicinal plant is any plant which, in one or more of its parts, contains substances/alkaloids that can be used for medicinal purposes for the synthesis of useful drugs.
- Numerous medicinal and aromatic crops are being exploited for economic uses. Approximately 12.5% of the more than 422,000 plant species have been universally documented for medicinal properties.
- Some of the herbal plants with medicinal properties are.

a. **Tulsi- Ocimum sanctum:**

- Tulsi is aromatic perennial plant.
- It is native to the Indian subcontinent and widespread as a cultivated plant throughout the Southeast Asia.
- In Ayurveda, Tulsi is known as The Queen of Herbs.
- Some of the phytochemical constituents of *tulsi* are oleanolic acid, ursolic acid, rosmarinic acied etc which have various medical properties.
- Tulasi leaves are rich in antioxidants and exhibit anti-fungal properties.
- Tulsi's have broad-spectrum antimicrobial activity. It uses in as a hand sanitizer, mouthwash and water purifier, immunity booster, wound healing etc.

b. **Turmeric: *Curcuma longa***

- Turmeric contains various alkaloids/phytochemical such as curcumin, which have medicinal property.

- Turmeric has various medicinal properties such as

1. Turmeric Gradually Increases Antioxidants in our body.
2. Turmeric Can Help Control Diabetes
3. Turmeric Might Prevent Cancer
4. (4) Turmeric Helps Lower Cholesterol
5. (5) Turmeric Can Treat Skin Conditions
6. (6) Turmeric Can Benefit People with Depression
7. (7) Turmeric Can Treat Gastrointestinal Conditions
8. (8) Turmeric Can Help Relieve Arthritis

c. **Spearmint: *Mentha spicata***

- The leaves of these plants are rich in Vitamins, Antioxidants, and Manganese.
- Mint leaves use in cramps, Arthritis, Diarrhea, Fatigue etc. Mint essential oils are also used in relieving muscle pains.

d. **Carom:**

- Carom seeds also known as Ajwain.
- Carom seeds are rich in Antioxidants, Vitamins, minerals, fiber and exhibit antibacterial and antifungal properties.
- Carom seeds also use in Ulcers, Acidity, Arthritis, Bad Cholesterol, Blood pressure and even common cold or cough.

e. **Giloy:**

- Giloy herbs are particularly famous for its ability to increase platelet count and it's really helpful for people suffering from low blood platelets. Apart from that, these herbs help solve Diabetes, Arthritis, Dengue, Chikungunya, Indigestion, respiratory problems and also maintain healthy heart conditions.

f. **Neem: *Azadirachta indica***

- Neem fruit, seeds, leaves, stems, and bark contain diverse phytochemical/alkaloids such as azadirachtin etc. which have various medicinal property.
- Neem contains chemicals that might help reduce blood sugar levels, heal ulcers in the digestive tract, kill bacteria, Nourishes Skin, Treats Fungal Infections, Increases Immunity, Insect & Mosquito Repellent etc.

g. **Ashwagandha: *Withania somnifera***

- Ashwagandha contaions various alkaloids/phytochemicals such as withanolides, which have several medicinal properties.

- Ashwagandha extracts are mainly used to relieve stress and depression, arthritis, Bipolar Disorder, Hyperactivity Disorder and also help maintain Blood sugar levels, Cholesterol levels etc.

h. **Sarpagandha: *Rauvolfia serpentina***

- Sarpagandha plant contains various alkaloids/ phytochemical such as reserpine, serpentine, which have medicinal values.
- Sarpagandha may be used in the production of sleep-inducing and blood pressure-lowering drugs.

Forest-based industries and livelihoods

- The industries that use forest raw material are known as forest-based industries. The major forest-based industries are the paper and pulp industry, match wood industry, Timber and Sandalwood industry, Plywood industries, oil, and biodiesel industry, etc.
- Forests provide us with shelter, livelihoods, water, food, and fuel security. All these activities directly or indirectly involve forests.
- Rural people are dependent on forest resources for their livelihoods. For many of them, not only do the resources provide economic sustenance, but the forest is also a way of life socially and culturally. It meets basic needs like fuelwood, fodder and small timber that are important for them and their livestock.
- Madhya Pradesh is the largest producer of beedi because the tendu leaves are found mostly in the forests of this state. Several chemical industries related to sandalwood in Karnataka and eucalyptus in Tamil Nadu has developed because these products are found abundant quantity in this state.

Land cover:

- Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other.
- Identifying, delineating, and mapping land cover is important for global monitoring studies, resource management, and planning activities.
- Land use and land cover areas are classified into various major categories: urban or built-up land, agricultural, forest, water areas, wetland, barren land, tundra, and perennial snow or ice.
- Changes in land cover continue to impact local- to global-scale weather and climate by altering the flow of energy, water, and greenhouse gases between the land and the atmosphere.

Land use change:

- Land use change simply refers to the conversion of a piece of land's use by humans, from one purpose to another. For example, land may be converted from cropland to grassland, or from wild land (e.g., tropical forests) to human-specific land uses (e.g., palm oil plantations).
- Land-use changes from forest cover to cultivated land may reduce input or organic residues that lead to a decline in soil fertility, increased rates of soil erosion, loss of soil organic matter, and nutrients etc.
- The major factors for land use change are deforestation, urbanization, industrialization and agricultural expansion.

Land degradation

- With increasing population growth, the demands for arable land for producing food, fibre and fuel wood is also increasing. Hence there is more and more pressure on the limited land resources which are getting degraded due to over-exploitation.
- Soil erosion, water-logging, salinization and contamination of the soil with industrial wastes like fly-ash and heavy metals all cause degradation of land.

Soil erosion

- The literal meaning of soil erosion. is wearing away of soil. Soil erosion is defined as the movement of soil components, especially surface litter and topsoil from one place to another.
- Soil erosion results in the loss of fertility because it is the top soil layer which is fertile.
- Soil erosion is basically of two types based upon the cause of erosion

  (i) Normal erosion or geologic erosion: caused by the gradual removal of topsoil by natural processes.

  (ii) Accelerated erosion: This is mainly caused by anthropogenic (man-made) activities and the rate of erosion is much faster than the rate of formation of soil.
- Overgrazing, deforestation and mining are some important activities causing accelerated erosion.There are two types of agents which cause soil erosion:

(i) Climatic agents: water and wind are the climatic agents of soil erosion.

a. **Water induced soil erosion** is of the following types:
   i. **Sheet erosion:** when there is uniform removal of a thin layer of soil from a large surface area, it is called sheet erosion. This is usually due to run-off water.
   ii. **Rill erosion:** When there is rainfall and rapidly running water produces finger-shaped grooves or rills over the area, it is called rill erosion.
   iii. **Gully erosion:** It is a more prominent type of soil erosion. When the rainfall is very heavy, deeper cavities or gullies are formed, which may be U, or V shaped.
   iv. **Slip erosion:** This occurs due to heavy rainfall on slopes of hills and mountains.
   v. **Stream bank erosion:** During the rainy season, when fast running streams take a turn in some other direction, they cut the soil and make caves in the banks.

b. **Wind erosion** is responsible for the following three types of soil movements:
   i. **Saltation:** This occurs under the influence of direct pressure of stormy wind and the soil particles of 1-1.5 mm diameter move up in vertical direction.
   ii. **Suspension:** Here fine soil particles (less than 1 mm dia) which are suspended in the air are kicked up and taken away to distant places.
   iii. **Surface creep:** Here larger particles (5-10 mm diameter) creep over the soil surface along with wind.

(ii) Biotic agents:

- Excessive grazing, mining and deforestation are the major biotic agents responsible for soil erosion.
- Overgrazing accounts for 35% of the worlds soil erosion while deforestation is responsible for 30% of the earths seriously eroded lands. Unsustainable methods of farming cause 28% of soil erosion.

Soil Conservation Practices

In order to prevent soil erosion and conserve the soil the following conservation practices are employed:

(i) Contour farming:

- On gentle slopes, crops are grown in rows across, rather than up and down, a practice known as contour farming.
- Each row planted horizontally along the slope of the land acts as a small dam to help hold soil and slow down loss of soil through run-off water.

(ii) Terracing:

- It is used on still steeper slopes are converted into a series of broad terraces which run across the contour.
- Terracing retains water for crops at all levels and cuts down soil erosion by controlling run off.

(iii) Strip cropping:

- Here strips of crops are alternated with strips of soil saving cover crops like grasses or grass-legume mixture.
- Whatever run-off comes from the cropped soil is retained by the strip of cover crop and this reduces soil erosion.
- Nitrogen fixing legumes also help in restoring soil fertility.

(iv) Alley cropping:

- It is a form of inter-cropping in which crops are planted between rows of trees or shrubs. This is also called Agro forestry.

(v) Wind breaks or shelterbelts: They help in reducing erosion caused by strong winds.

- The trees are planted in long rows along the cultivated land boundary so that wind is blocked.
- The wind speed is substantially reduced which helps in preventing wind erosion of soil.

Desertification

- Desertification is a process whereby the productive potential of arid or semiarid lands falls by ten percent or more.
- Moderate desertification is10-25% drop in productivity, severe desertification causes 25-50% drop while very severe desertification results in more than 50% drop in productivity.
- Desertification leads to the conversion of irrigated croplands to desert like conditions in which agricultural productivity falls.
- Desertification is characterized by de-vegetation and loss of vegetal over, depletion of groundwater, salinization, and severe soil erosion.

Causes of Desertification:

Formation of deserts may take place due to natural phenomena like climate change or may be due to abusive use of land. The major anthropogenic activities responsible for desertification are as follows:

(a) Deforestation: The process of denuding and degrading a forested land initiates a desert producing cycle that feeds on itself.

(b) Overgrazing: The region's most seriously affected by desertification are the cattle producing areas of the world. This is because the increasing cattle population heavily graze in grasslands or forests and as a result denude the land area.

(c) Mining

- These activities are also responsible for loss of vegetal cover and denudation of extensive land areas leading to desertification.
- During the last 50 years about 900 million hectares of land have undergone desertification over the world.
- It is estimated that in the last 50 years, human activities have been responsible for desertification of land area equal to the size of Brazil.

Impacts of mining on the environment:

- **Devegetation and defacing of landscape:** The topsoil as well as the vegetation are removed from the mining area to get access to the deposit. large scale deforestation or devegetation leads to several ecological losses.
- **Subsidence of land:** This is mainly associated with underground mining. Subsidence of mining areas often results in tilting of buildings, cracks in houses, buckling of roads etc.
- **Groundwater contamination:** Mining disturbs the natural hydrological processes and also pollutes the groundwater. Sulphur, usually present as an impurity in many ores is known to get converted into sulphuric acid through microbial action, thereby making the water acidic.
- **Surface water pollution:**
    - The acid mine drainage often contaminates the nearby streams and lakes.
    - Sometimes radioactive substances like uranium also contaminate the water bodies through mine wastes and kill aquatic animals.
    - Heavy metal pollution of water bodies near the mining areas is a common feature creating health hazards.
- **Air pollution:** In order to separate and purify the metal from other impurities in the ore, smelting is done which emits enormous quantities of air pollutants damaging the vegetation nearby and has serious environmental health impacts.
- **Occupational Health Hazards:** Most of the miners suffer from various respiratory and skin diseases due to constant exposure to the suspended particulate matter and toxic substances.

Water resources:

- Water covers 70% of the earth's surface but only 3% of this is fresh water. Of this, 2% is in polar ice caps and only 1% is usable water in rivers, lakes and subsoil aquifers. Only a fraction of the friction of water can used.
- Generally, 70% of water is used for agriculture about 25% for industry and only 5% for domestic use.
- India uses 90% for agriculture, 7% for industry and 3% for domestic use.
- One of the greatest challenges facing the world in this century is the need to rethink the overall management of water resources.
- Studies indicate that a person needs a minimum of 20 to 40 liters of water per day for drinking and sanitation. More than one billion people worldwide have no access to clean water.
- Local conflicts are already spreading to states. Eg. Karnataka and Andhra Pradesh are fighting over the waters of the Krishna River, Karnataka and Tamil Nadu are fighting over the water of the Cauvery River.
- India is expected to face critical levels of water stress by 2025.
- At the global level 31 countries are already short of water and by 2025 there will be 48 countries facing serious water shortages.
- The UN has estimated that by the year 2050, 4 billion people will be seriously affected by water shortages. This will lead to multiple conflicts between countries over the sharing of water.

- There are 100 countries that share the waters of 13 large rivers and lakes. The upstream countries could starve the downstream nation's leading to political unstable areas across the world. Examples are Ethopia, which is upstream on the Nile and Egypt, which is downstream and highly dependent on the Nile.
- International accords that will look at a fair distribution of water in such areas will become critical to world peace.
- India and Bangladesh already have a negotiated agreement on the water use of the Ganges.

Over exploitation of surface and groundwater resources:

- With the growth of human population there is an increasing need for larger amounts of water to fulfil a variety of basic needs. Today in many areas this requirement cannot be met.
- Agriculture also pollutes surface water and underground water stores by the excessive use of chemical fertilizers and pesticides.
- Methods such as the use of biomass as fertilizer and nontoxic pesticides such as neem products reduces the agricultural pollution of surface and ground water.
- There are many ways in which farmers can use less water without reducing yield, such as by using the drip irrigation system.

Floods:

- Floods have been a serious environmental hazard for centuries.
- Wetlands in flood plains are nature's flood control systems into which overfilled rivers could spill and act like a temporary sponge holding the water and preventing fast flowing water from damaging surrounding land.
- Deforestation in the Himalayas causes floods, kill people, damage crops and destroy homes in the Ganges and its tributaries and the Brahmaputra.
- Rivers change their course during floods and tons of valuable soil is lost to the sea.
- As the forests are degraded, rainwater no longer percolates slowly into the subsoil but runs off down the mountainside bearing large amounts of topsoil.

Drought:

- In most arid regions of the world the rains are unpredictable.
- Drought has been a major problem in our country especially in arid regions.
- It is an unpredictable climatic condition and occurs due to the failure of one or more monsoons. It varies in frequency in different parts of our country.
- Several measures can be taken to minimise the serious impacts of a drought. However, this must be done as a preventive measure so that if the monsoons fail its impact on local people's lives is minimised.
- In years when the monsoon is adequate, we use up the good supply of water without trying to conserve it and use the water judiciously. Thus, during a year when the rains are poor, there is no water even for drinking in the drought area.
- One of the factors that worsens the effect of drought is deforestation.
- Once hill slopes are denuded of forest cover the rainwater rushes down the rivers and is lost.

- Forest cover permits water to be held in the area permitting it to seep into the ground. These charges the underground stores of water in natural aquifers. This can be used in drought years if the stores have been filled during a good monsoon.
- If water from the underground stores is overused, the water table drops, and vegetation suffers.

International & interstate conflict over water

Water conflict in the Middle East:

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

The Indus Water Treaty:

- In 1960, the Indus water treaty was established vide which Indus, the Jhelum and the Chenab were allocated to Pakistan and the Satluj, the Ravi and the Beas were allocated to India.
- Being the riparian state, India has pre-emptive right to construct barrages across all these rivers in Indian territory. However, the treaty requires that the two rivers allocated to Pakistan may be used for non-consumptive purposes by India i.e., without changing its flow and quality.

The Cauvery water dispute:

- The Cauvery River water is a bone of contention between Tamilnadu and Karnataka and the fighting is almost hundred years old.
- Tamilnadu, occupying the downstream region of the river wants water-use regulated in the upstream. Whereas the upstream state Karnataka refuses to do so and claims its primacy over the river as upstream user.

Energy resources: Renewable and non-renewable resources

Renewable Resources:

- Renewable Resources which can be generated continuously in nature and are inexhaustible e.g., wood, solar energy, wind energy, tidal energy, hydropower, biomass energy, biofuels, geo-thermal energy and hydrogen.
- They are also known as non-conventional sources of energy, and they can be used again and again in an endless manner.

Non-renewable Resources

- Non-renewable Resources which have accumulated in nature over a long span of time and cannot be quickly replenished when exhausted e.g., coal, petroleum, natural gas and nuclear fuels like uranium and thorium.
- Non-renewable resources are such type of natural resources that take millions of years to regenerate.
- Wood is a renewable resource as we can get new wood by growing a sapling into a tree within 15-20 years, but it has taken millions of years for the formation of coal from trees and cannot be regenerated in our life time, hence coal is not renewable.

Renewable Energy Resources

(1) Solar energy:

- Sun is the ultimate source of energy, directly or indirectly for all other forms of energy. The nuclear fusion reactions occurring inside the sun release enormous quantities of energy in the form of heat and light.
- The solar energy received by the near-earth space is approximately 1.4 kilojoules/second/m^2 known as solar constant.
- Some important solar energy harvesting devices are.
  a. **Solar cells:** They are also known as photovoltaic cells or PV cells. Solar cells are made of thin wafers of semiconductor materials like silicon and gallium. When solar radiations fall on them, a potential difference is produced which causes flow of electrons and produces electricity.
  b. **Solar cooker:** Solar cookers make use of solar heat by reflecting the solar radiations using a mirror directly on to a glass sheet. which covers the black insulated box within which the raw food is kept.
  c. **Solar power plant:** Solar energy is harnessed on a large scale by using concave reflectors which cause boiling of water to produce steam. The steam turbine drives a generator to produce electricity.

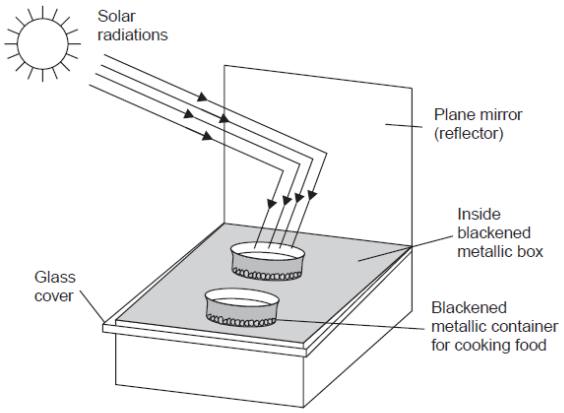


Fig. 2.5.3. Simple box-type solar cooker.

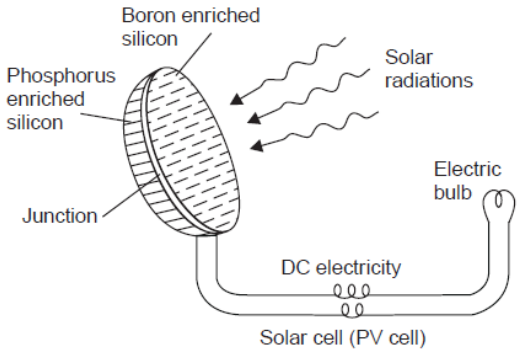


Fig. 2.5.2. (*a*) Solar cell.

(2) Wind energy

- The high-speed winds have a lot of energy in them as kinetic energy due to their motion.
- The wind energy is harnessed by making use of windmills. The blades of the windmill keep on rotating continuously due to the force of the striking wind. The rotational motion of the blades drives several machines like water pumps, flour mills and electric generators.
- The minimum wind speed required for satisfactory working of a wind generator is 15 km/hr.
- The wind power potential of our country is estimated to be about 20,000 MW, while at present we are generating about 1020 MW. The largest wind farm of our country is near Kanyakumari in Tamil Nadu generating 380 MW electricity.
- Wind energy is very useful as it does not cause any air pollution.
- It is believed that by the middle of the century wind power would supply more than 10% of worlds electricity.

(3) Hydropower

- The water flowing in a river is collected by constructing a big dam where the water is stored and allowed to fall from a height. The blades of the turbine located at the bottom of the dam move with the fast-moving water which in turn rotate the generator and produces electricity.
- The hydropower potential of India is estimated to be about 4×10^{11} KW-hours.
- Hydropower does not cause any pollution, it is renewable and normally the hydro power projects are multi-purpose projects helping in controlling floods, used for irrigation, navigation etc.

(4) Tidal Energy

- Ocean tides produced by gravitational forces of sun and moon contain enormous amounts of energy.
- The high tide and low tide refer to the rise and fall of water in the oceans. A difference of several meters is required between the height of high and low tide to spin the turbines.
- The tidal energy can be harnessed by constructing a tidal barrage. During high tide, the seawater flows into the reservoir of the barrage and turns the turbine, which in turn produces electricity by rotating the generators. During low tide, when the sea-level is low, the sea water stored in the barrage reservoir flows out into the sea and again turns the turbines.

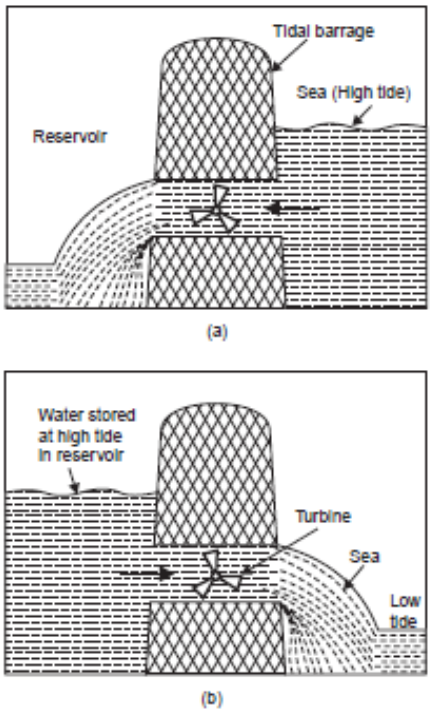


Fig. 2.5.4. Water flows into the reservoir to turn the turbine at high tide (*a*), and flows out from the reservoir to the sea, again turning the turbine at low tide (*b*).

(5) Geothermal energy

- The energy harnessed from the hot rocks present inside the earth is called geothermal energy.
- High temperature, high pressure steam fields exist below the earth's surface in many places. This heat comes from the fission of radioactive material naturally present in the rocks.
- In some places, the steam or the hot water comes out of the ground naturally through cracks in Manikaran, Kullu and Sohana, Haryana.
- Sometimes the steam or boiling water underneath the earth do not find any place to come out. We can artificially drill a hole up to the hot rocks and by putting a pipe in it make the steam or hot water gush out through the pipe at high pressure which turns the turbine of a generator to produce electricity.

(6) Biomass Energy

- Biomass is the organic matter produced by the plants or animals which include wood, crop residues, cattle dung, manure, sewage, agricultural wastes etc. Biomass energy is of the following types:

(a) **Energy Plantations:** Solar energy is trapped by green plants through photosynthesis and converted into biomass energy.

- Fast growing trees like cottonwood and poplar, non-woody herbaceous grasses, crop plants like sugarcane, sweet sorghum and sugar beet, aquatic weeds like water hyacinth and sea-weeds and carbohydrate rich potato, cereal etc. are some of the important energy plantations.
- They may produce energy either by burning directly or by getting converted into burnable gas or may be converted into fuels by fermentation.

(b) **Petro-crops:** Certain latex-containing plants like Euphorbias and oil palms are rich in hydrocarbons and can yield an oil like substance under high temperature and pressure. This oily material may be burned in diesel engines.

(c) **Agricultural and Urban Waste biomass:** Crop residues, bagasse (sugarcane residues), coconut shells, peanut hulls, cotton stalks etc. are some of the common agricultural wastes which produce energy by burning.

(7) Biogas

- Biogas is a mixture of methane, carbon dioxide, hydrogen and hydrogen sulphide, the major constituent being methane.
- Biogas is produced by anaerobic degradation of animal wastes (sometimes plant wastes) in the presence of water.
- Biogas is a non-polluting, clean and low-cost fuel which is very useful for rural areas where a lot of animal waste and agricultural waste are available.
- India has the largest cattle population in the world (240 million) and has tremendous potential for biogas production.
- Biogas has the following main advantages: It is clean, nonpolluting and cheap.
- There is direct supply of gas from the plant and there is no storage problem.
- The sludge left over is a rich fertilizer containing bacterial biomass with most of the nutrients preserved as such.

(8) Biofuels

- Biomass can be fermented to alcohols like ethanol and methanol which can be used as fuels. Ethanol can be easily produced from carbohydrate rich substances like sugarcane.
- It burns clean and is non-polluting. However, as compared to petrol its calorific value is less and therefore, produces much less heat than petrol.
- **Gasohol:** It is a common fuel used in Brazil and Zimbabwe for running cars and buses.
- In India too gasohol is planned to be used on trial basis in some parts of the country, to start with in Kanpur. Gasohol is a mixture of ethanol and gasoline.
- **Methanol:** It is very useful since it burns at a lower temperature than gasoline or diesel. Methanol too is a clean, non-polluting fuel.

(9) Hydrogen as a fuel

- As hydrogen burns in air, it combines with oxygen to form water and a large amount of energy (150 kilojoules per gram) is released.
- Due to its high, rather the highest calorific value, hydrogen can serve as an excellent fuel.
- Moreover, it is non-polluting and can be easily produced.
- Hydrogen is highly inflammable and explosive in nature. Hence, safe handling is required for using H_2 as a fuel. Also, it is difficult to store and transport.
- Presently, H_2 is used in the form of liquid hydrogen as a fuel in spaceships.

Non-Renewable Energy Sources

(1) Coal

- Coal was formed 255-350 million years ago in the hot, damp regions of the earth during the carboniferous age.
- The ancient plants along the banks of rivers and swamps were buried after death into the soil and due to the heat and pressure gradually got converted into peat and coal over millions of years of time.
- There are mainly three types of coal, namely anthracite (hard coal), bituminous (Soft coal) and lignite (brown coal).
- Anthracite coal has maximum carbon (90%) and calorific value (8700 kcal/kg.)
- At the present rate of usage, the coal reserves are likely to last for about 200 years and if its use increases by 2% per year, then it will last for another 65 years.
- India has about 5% of worlds coal and Indian coal is not very good in terms of heat capacity.
- Major coal fields in India are Raniganj, Jharia, Bokaro, Singrauli, and Godavari valley.
- The coal states of India are Jharkhand, Orissa, West Bengal, Madhya Pradesh, Andhra Pradesh, and Maharashtra.
- When coal is burnt it produces carbon dioxide, which is a greenhouse gas responsible for causing enhanced global warming.

(2) Petroleum

- It is the lifeline of global economy.
- There are 13 countries in the world having 67% of the petroleum reserves which together form the OPEC (Organization of Petroleum exporting countries).
- About $1/4^{th}$ of the oil reserves is in Saudi Arabia.
- Crude petroleum is a complex mixture of alkane hydrocarbons. Hence it must be purified and refined by the process of fractional distillation, during which process different constituents separate out at different temperatures. We get a large variety of products from this, namely, petroleum gas, kerosene, petrol, diesel, fuel oil etc.
- Petroleum is a cleaner fuel as compared to coal as it burns completely and leaves no residue. It is also easier to transport and use.

(3) Liquefied petroleum gas (LPG)

- The main component of petroleum gas is butane, the other being propane and ethane.
- The petroleum gas is easily converted to liquid form under pressure as LPG.
- It is odourless, but the LPG in our domestic gas cylinders gives a foul smell. This is, in fact, due to ethyl mercaptan, a foul-smelling gas, added to LPG so that any leakage of LPG from the cylinder can be detected instantaneously.
- Oil fields in India are located at Digboi (Assam), Gujarat Plains and Bombay High, offshore areas in deltaic coasts of Gadavari, Krishna, Kaveri, and Mahanadi.

(4) Natural gas

- It is mainly composed of methane (95%) with small amounts of propane and ethane.
- Natural gas deposits mostly accompany oil deposits because it has been formed by decomposing remains of dead animals and plants buried under the earth.
- Natural gas is the cleanest fossil fuel. It can be easily transported through pipelines.
- It has a high calorific value of about 50KJ/G and burns without any smoke.
- Russia has maximum reserves (40%), followed by Iran (14%) and USA (7%).
- Natural gas is used as a domestic and industrial fuel. It is used as a fuel in thermal power plants for generating electricity.

(5) Compressed natural gas (CNG):

- It is being used as an alternative to petrol and diesel for transport of vehicles.
- Delhi has totally switched over to CNG where buses and auto rickshaws run on this new fuel.
- CNG use has greatly reduced vehicular pollution in the city.

- **Synthetic natural gas (SNG):** It is a mixture of carbon monoxide and hydrogen. It is a connecting link between a fossil fuel and substituted natural gas.

(6) Nuclear Energy

- Nuclear energy is known for its high destructive power as evidenced from nuclear weapons.
- Nuclear energy can be generated by two types of reactions:

i) Nuclear Fission:

- It is the nuclear change in which nucleus of certain isotopes with large mass numbers are split into lighter nuclei on bombardment by neutrons and a large amount of energy is released through a chain reaction.
- Uranium-235 nuclei are most used in nuclear reactors.
- Little Boy nuclear bomb was dropped on Hirosima city of Japan on 6 August 1945 by USA during world war-II.
- In this bomb U^{235} radioactive material was used.
- Fat man nuclear bomb was dropped on Nagasaki city of Japan on 9 August 1945.
- In this bomb, Pu^{239} radioactive materials was used.

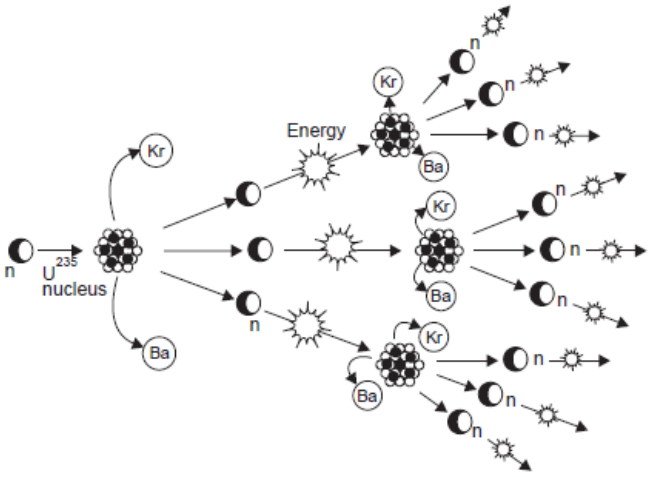


Fig. 2.5.7. (*a*) Nuclear fission—a chain reaction initiated by one neutron that bombards a Uranium (U^{235}) nucleus, releasing a huge quantity of energy, two smaller nuclei (Ba, Kr) and 3 neutrons.

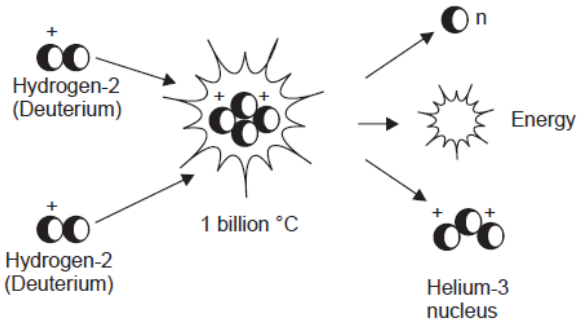


Fig. 2.5.7. (*b*) Nuclear fusion reaction between two hydrogen-2 nuclei, which take place at a very high temperature of 1 billion °C; one neutron and one fusion nucleus of helium-3 is formed along with a huge amount of energy.

$$ {}_1H^2 + {}_1H^2 \longrightarrow {}_3He^2 + {}_0n^1 + \text{Energy} $$

$$ {}_{92}U^{235} + {}_0n^1 \longrightarrow {}_{36}Kr^{92} + {}_{56}Ba^{141} + 3\ {}_0n^1 + \text{Energy} $$

ii) Nuclear fusion:

- Here two isotopes of a light element are forced together at extremely high temperatures (1 billion °C) until they fuse to form a heavier nucleus releasing enormous energy in the process.
- It is difficult to initiate the process, but it releases more energy than nuclear fission.

- Nuclear power in India is still not very well developed.
- There are four nuclear power stations with an installed capacity of 2005 MW. These are located at Tarapur (Maharashtra), Rana Pratap Sagar near Kota (Rajasthan), Kalpakkam (Tamil Nadu) and Narora (U.P.).

Case studies

National Solar Mission:

- ✓ The National Solar Mission is an initiative of the Government of India and State Governments to promote solar power.
- ✓ The program was inaugurated as the Jawaharlal Nehru National Solar Mission by former Prime Minister Dr. Manmohan Singh on 11 January 2010 with a target of 20 GW by 2022. This was later increased to 100 GW by Prime Minister Narendra Modi in the 2015 Union budget of India.
- ✓ National Institute of Solar Energy has assessed the Country's solar potential of about 748 GW.
- ✓ Solar energy has taken a central place in India's National Action Plan on Climate Change with National Solar Mission as one of the key Missions.
- ✓ The objective of the National Solar Mission is to establish India as a global leader in solar energy.
- ✓ Under the original plan, the Government aimed to achieve a total installed solar capacity of 20 GW by 2022. This was proposed to be achieved in three phases.
- ✓ The first phase comprised the period from 2010 to 2013, the first year of the 12th five-year plan. The second phase extended up to 2017, while the third phase would have been the 13th five-year plan (2017–22). Targets were set as 1.4 GW in the first phase, 11–15 GW by the end of the second phase and 20 GW by the end of the third phase in 2022.
- ✓ The Government revised the target from 20 GW to 100 GW on 1 July 2015.
- ✓ The National Solar Mission is aimed at reducing the cost of solar power generation in the country through

    (ii) long term policy.
    (iii) (ii) large scale deployment goals.
    (iv) (iii) aggressive R&D; and
    (v) (iv) domestic production of critical raw materials.

- ✓ Recently, the Ministry for New and Renewable Energy has reported that the government has so far sanctioned the development of solar project with a capacity of nearly 39,000 MW.
- ✓ These solar projects were sanctioned under the 'Scheme for Development of Solar Parks and Ultra Mega Solar Power Projects.'
- ✓ Rajasthan has the highest solar power generation potential of any state in the country. As of December 2022, Rajasthan's operational solar power projects produced roughly 16,060 MW of solar energy.
- ✓ Bhadla Solar Park is the largest solar park in the world as of 2022 and is spread over a total area of 5,700 hectares (14,000 acres) in Bhadla, Phalodi tehsil, Jodhpur district, Rajasthan, India. The park has a total capacity of 2245 MW.

Sardar Sarovar Dam:

- ✓ The Sardar Sarovar Dam is built on the Narmada River in Navagam near the town of Kevadiya, Narmada District, in the state of Gujarat, India.
- ✓ The dam was constructed to provide water and electricity to four Indian states: Gujarat, M.P, Maharashtra, and Rajasthan.
- ✓ The construction for dam begun in 1987, but the project was stalled by the Supreme Court of India in 1995 in the backdrop of Narmada Bachao Andolan over concerns of displacement of people.

- ✓ In 2000–01 the project was revived but with a lower height of 111 meters under directions from Supreme Court of India, which was later increased in 2006 to 123 meters and 139 meters in 2017.
- ✓ The Sardar Sarovar Dam is 1210 meters long.
- ✓ The dam was inaugurated in 2017 by Prime Minister Narendra Modi.
- ✓ The Sardar Sarovar Project includes two powerhouses, the Riverbed Power House – RBPH with an installed capacity of 1,200 Mega Watt and the Canal Head Power House with 250 Mega Watt).
- ✓ This dam irrigates 17,920 km^2 (6,920 sq mi) of land spread over 12 districts, 62 talukas, and 3,393 villages (75% of which is drought-prone areas) in Gujarat and 730 km^2 (280 sq mi) in the arid areas of Barmer and Jalore districts of Rajastan.
- ✓ The dam provides drinking water to 9490 villages and 173 urban centers in Gujarat; and 1336 villages & 3 towns in Rajasthan.
- ✓ The Government of Gujarat constructed a statue of Sardar Vallabhbhai Patel (Statue of Unity) in front of Sardar Sarovar Dam and is considered as one of the major tourist attraction.
- ✓ Medha Patkar and Babd Amte is related with Narmada Bachao Andolan against the constriction of Sardar Sarovar Dam on the Narmada River.

Tarun Bharat Sangh:

- ✓ Tarun Bharat Sangh (TBS) is a non-profitable environmental NGO with its headquarters in Alwar Rajasthan.
- ✓ Dr Rajendra Singh (water man of India) is the founder of Tarun Bharat Sangh NGO.
- ✓ The organization is best known for doing ecological research and land development to provide clean water to people.
- ✓ Tarun Bharat Sangh has built rainwater harvesting structures to recharge ground water and restore ecology of 1,200 semi-arid villages in Rajasthan.
- ✓ Dr. Rajendra Singh was awarded by Ramon Magsaysay Award for community leadership in 2001 for his pioneering work in community-based efforts in water harvesting and water management .
- ✓ In 2015, he won the Stockholm Water Prize an award known as "the Nobel Prize for water".
- ✓ Tarun Bharat Sangh is focused on self-governance and political empowerment for villagers living around exploited rivers.
- ✓ On 1 August 2007, Tarun Bharat Sangh initiated a protest against the construction for Commonwealth Games on the Yamuna riverbed. Later, the chief minister Mrs Sheila Dixit and Governor Mr. Tejendra Khanna were issued instructions to prohibit construction on the riverbed.
- ✓ Tarun Bharat Sangh has also focused on preserving the natural forest ecosystems through its SAVE THE TIGER CAMPAIGN.

Unit 4: Environmental Pollution

Environmental Pollution

➢ Environmental pollution can be defined as any undesirable change in the physical, chemical or biological characteristics of any component of the environment (air, water, soil), which can cause harmful effects on various forms of life or property.

➢ Environmental pollution could be of various types:

- **Air Pollution**
  - It is an atmospheric condition in which certain substances are present in concentrations which can cause undesirable effects on man and his environment. These substances include gases, particulate matter, radioactive substances etc.
  - Gaseous pollutants include oxides of sulphur (mostly SO2, SO3) oxides of nitrogen (mostly NO and NO2 or NOx), carbon monoxide (CO), volatile organic compounds (mostly hydrocarbons) etc. Particulate pollutants include smoke, dust, soot, fumes, aerosols, liquid droplets, pollen grains etc.
- **Sources of Air Pollution**
  - The sources of air pollution are natural and man-made(anthropogenic).
  - Natural Sources: The natural sources of air pollution are volcanic eruptions, forest fires, sea salt sprays, biological decay, marshes, extra-terrestrial bodies, pollen grains of flowers, spores etc.
  - Radioactive minerals present in the earth crust are the sources of radioactivity in the atmosphere.
  - Man-made: Man made sources include thermal power plants, industrial units, vehicular emissions, fossil fuel burning, agricultural activities etc.
  - Thermal power plants have become the major sources for generating electricity in India. Fertilizer plants, textile mills, tanneries, refineries, chemical industries, paper and pulp mills are other sources of air pollution.
  - Automobile exhaust is another major source of air pollution. Automobiles release gases such as carbon monoxide (about 77%), oxides of nitrogen (about 8%) and hydrocarbons (about 14%).
  - Heavy duty diesel vehicles generate more NOx and suspend particulate matter (SPM) than petrol vehicles which produce more carbon monoxide and hydrocarbons.
- **Indoor Air Pollution**
  - The most important indoor air pollutant is radon gas.
  - Radon gas and its radioactive daughters are responsible for many lung cancer deaths each year.
  - Radon can be emitted from building materials like bricks, concrete, tiles etc. which are derived from soil containing radium.
  - Radon is also present in groundwater and natural gas and is emitted indoors while using them.
  - Many houses in the under-developed and developing countries including India use fuels like coal, dung-cakes, wood and kerosene in their kitchens. Complete combustion of fuel produces carbon dioxide which may not be toxic. However, incomplete combustion produces the toxic gas carbon monoxide which is toxic.
  - Coal contains varying amounts of sulphur which on burning produces sulphur dioxide.
  - Fossil fuel burning produces black soot. These pollutants i.e. CO, SO2, soot and many others like formaldehyde, benzo- (a) pyrene (BAP) are toxic and harmful for health.
  - Benzo-(a)pyrene is also found in cigarette smoke and is considered to cause cancer.
  - Person using wood as fuel for cooking inhales benzo- (a) pyrene equivalent to 20 packets of cigarette a day.
- **Effects of air pollution**: Air pollution has adverse effects on living organisms.
- **Effects on Human Health:** Human respiratory system has several mechanisms for protection from air pollution.

- Bigger particles (> 10 µm) can be trapped by the hairs and sticky mucus in the lining of the nose. Smaller particles can reach tracheobronchial system and there get trapped in mucus. They are sent back to throat by beating of hair like cilia from where they can be removed by spitting or swallowing.
- Years of exposure to air pollutants (including cigarette smoke) adversely affect these natural defences and can result in lung cancer, asthma, chronic bronchitis etc.
- Suspended particulates can cause damage to lung tissues and diseases like asthma, bronchitis, and cancer especially when they bring with them cancer causing or toxic pollutants attached on their surface.
- In the presence of suspended particulates, SO2 can form acid sulphate particles, which can go deep into the lungs and affect them severely.
- Oxides of nitrogen especially NO2 can irritate the lungs and cause conditions like chronic bronchitis.
- Carbon monoxide (CO) reaches lungs and combines with haemoglobin of blood to form carboxyhaemoglobin. CO has affinity for haemoglobin 210 times more than oxygen. Haemoglobin is, therefore, unable to transport oxygen to various parts of the body. This causes suffocation.
- Long exposure to CO may cause dizziness, unconsciousness and even death.

- **Effects on Plants:** Air pollutants affect plants by entering through stomata (leaf pores through which gases diffuse), destroy chlorophyll and affect photosynthesis.
  - Pollutants also erode waxy coating of the leaves called cuticle. Cuticle prevents excessive water loss and damage from diseases, pests, drought, and frost.
  - Damage to leaf structure causes necrosis (dead areas of leaf), chlorosis (loss or reduction of chlorophyll causing yellowing of leaf) and abscission (dropping of leaves).
  - Particulates deposited on leaves causes plugging of the stomata. The damage can result in death of the plant.
  - Effects on aquatic life: Air pollutants mixing up with rain can cause high acidity (lower pH) in freshwater lakes. This affects aquatic life especially fish. Some of the freshwater lakes have experienced total fish death.
- **Effects on materials:** Because of their corrosiveness, particulates can cause damage to exposed surfaces.
  - Presence of SO2 and moisture can accelerate corrosion of metallic surfaces. SO2 can affect fabric, leather, paint, paper, marble and limestone.
  - Ozone in the atmosphere can cause cracking of rubber. Oxides of nitrogen can also cause fading of cotton and rayon fibres.

Control of Air Pollution

Air pollution can be minimized by the following methods:

- Sitting of industries after proper Environmental Impact Assessment studies.
- Using low sulphur coal in industries.
- Removing sulphur from coal (by washing or with the help of bacteria).
- Removing NOx during the combustion process.
- Removing particulate matter by using electrostatic precipitators, cyclone separators etc.
- Vehicular pollution can be checked by regular tune-up of engines, replacement of more polluting old vehicles,
- emissions and slow and cooler burning of fuels to reduce NOx emission (Honda Technology).
- Using mass transport system, bicycles etc.
- Shifting to less polluting fuels (hydrogen gas).
- Using non-conventional sources of energy.

- Planting more trees.

Air quality index (AQI)

- An air quality index (AQI) is used by government agencies to communicate to the public how the air is polluted currently.
- The National Air Quality Index (AQI) was launched in New Delhi on September 17, 2014, under the Swachh Bharat Abhiyan.
- The Central Pollution Control Board along with State Pollution Control Boards has been operating National Air Monitoring Program (NAMP) covering 240 cities of the country having more than 342 monitoring stations.
- There are six AQI categories, namely Good, Satisfactory, Moderate, Poor, Severe, and Hazardous.
- The proposed AQI will consider eight pollutants (PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb) for which shortterm (up to 24-hourly averaging period)

AQI	Associated Health Impacts
Good (0–50)	**Minimal impact**
Satisfactory (51–100)	**May cause minor breathing discomfort to sensitive people.**
Moderate (101–200)	**May cause breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children and older adults.**
Poor (201–300)	**May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease.**
Severe (301–400)	**May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases.**
Hazardous (401+)	**May cause respiratory impact even on healthy people, and serious health impacts on people with lung/heart disease. The health impacts may be experienced even during light physical activity.**

Primary pollutants:

- Pollutants that are formed and emitted directly from sources.
- Examples are particulates, carbon monoxide, nitrogen oxide, and sulphur oxide etc.

Secondary pollutants:

- Secondary pollutants are those pollutants that are not directly emitted from a specific source but are formed in the atmosphere when primary pollutants interact in the atmosphere.
- Peroxyacetyl nitrate (PAN) which is considered as a secondary pollutant as it is formed by the reaction of hydrocarbons, nitrogen oxides in the presence of sun light.
- Ozone (Ground-level ozone) is secondary pollutant.

Noise pollution

- Sound is mechanical energy from a vibrating source.
- A type of sound may be pleasant to someone and at the same time unpleasant to others. The unpleasant and unwanted sound is called noise.
- Sound can propagate through a medium like air, liquid or solid.
- The noise measurements are expressed as Sound Pressure Level (SPL) which is logarithmic ratio of the sound pressure to a reference pressure. It is expressed as a dimensionless unit, decibel (dB).
- Decibel scale is a measure of loudness.
- Noise can affect human ear because of its loudness and frequency (pitch).
- The Central Pollution Control Board (CPCB) committee has recommended permissible noise levels for different locations.

Table 5.1 Noise standards recommended by CPCB committee

Area code	Category of Area	Noise level in dB (A) Leq	
		Day	Night
(A)	Industrial	75	70
(B)	Commercial	65	55
(C)	Residential	55	45
(D)	Silence Zone	50	40

Sources of Noise Pollution:

- The main sources of noise are various modes of transportation (like air, road, rail-transportation), industrial operations, construction activities and celebrations (social/religious functions, elections etc) electric home appliances.
- High levels of noise have been recorded in some of the cities of the world. In Nanjing (China) noise level of 105 dB has been recorded, while in some other cities of the world these levels are: Rome 90 dB, New York 88 dB, Calcutta 85 dB, Mumbai 82 dB, Delhi 80 dB, Kathmandu 75 dB.

Effects of Noise:

- **Interferes with man's communication**: In a noisy area communication is severely affected.
- **Hearing damage:** Noise can cause temporary or permanent hearing loss. It depends on intensity and duration of sound level.
- **Physiological and Psychological changes:** Continuous exposure to noise affects the functioning of various systems of the body. It may result in hypertension, insomnia (sleeplessness), gastro-intestinal and digestive disorders, peptic ulcers, blood pressure changes, behavioural changes, emotional changes etc.

Honourable Supreme Court in a Writ Petition (civil) of 1998 concerning noise pollution had passed the following directions as an interim measure and order regarding firecrackers.

- The manufacture, sale or use of firecrackers generating noise level exceeding 125 dB at 4 meters distance from the point of bursting shall be prohibited.
- The use of fireworks or firecrackers shall not be permitted except between 6.00 p.m. and 10.00 p.m. No fireworks or fire crackers shall be used between 10.00 p.m. and 6.00 a.m.
- Fire crackers shall not be used at any time in silence zones, as defined by the Ministry of Environment and Forests. Silence Zone has been defined as:
  - ✓ Silence Zone in an area comprising not less than 100 meters around hospitals, educational institutions, courts, religious places, or any other area which is declared as such by the competent authority.

Control of Noise Pollution

- ✓ **Reduction in sources of noise:** Sources of noise pollution like heavy vehicles and old vehicles may not be allowed to ply in the populated areas.
- ✓ Noise making machines should be kept in containers with sound absorbing media. The noise path will be in interrupted and will not reach the workers.
- ✓ Proper oiling will reduce the noise from the machinery.
- ✓ Use of sound absorbing silencers: Silencers can reduce noise by absorbing sound. For this purpose, various types of fibrous material could be used.
- ✓ Planting more trees having broad leaves.

Water Pollution

Water pollution can be defined as alteration in physical, chemical, or biological characteristics of water making it unsuitable for designated use in its natural state.

Sources of water pollution

- ✓ Water has the property to dissolve many substances in it, therefore, it can easily get polluted.
- ✓ Pollution of water can be caused by point sources or non-point sources.
- ✓ Point sources are specific sites near water which directly discharge effluents into them. Major point sources of water pollution are industries, power plants, underground coal mines, offshore oil wells etc.
- ✓ The discharge from non-point sources is not at any site, rather, these sources are scattered, which individually or collectively pollute water.
- ✓ Surface run-off from agricultural fields, atmospheric deposition etc. are the non-point sources of water pollution.

Ground water pollution:

- ➢ Ground water forms about 6.2% of the total water available on planet earth and is about 30 times more than surface water (streams, lakes, and estuaries).
- ➢ Ground water seems to be less prone to pollution as the soil mantle through which water passes helps to retain various contaminants due to its cation exchange capacity There are several potential sources of ground water pollution. Septic tanks, industry (textile, chemical, tanneries), mining etc. are mainly responsible for ground water pollution.
- ➢ Ground water pollution with arsenic, fluoride and nitrate are posing serious health hazards.
- ➢ As per the BIS Standard for drinking water (BIS 1991 and subsequent modifications), the maximum permissible limit of Arsenic concentration in ground water is 10 ppb.
- ➢ Long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions. It has also been associated with cardiovascular disease.
- ➢ According to WHO 1984 and Indian standard drinking water specification 1991 the maximum permissible limit of fluoride in drinking water is 1.5 ppm.
- ➢ Fluoride concentrations above 1.5 ppm in drinking water cause dental fluorosis and much higher concentration skeletal fluorosis.

Surface water pollution:

The major sources of surface water pollution are:

1. Sewage: Drains of sewers in freshwater bodies causes water pollution. The problem is severe in cities.

2. Industrial effluents: Industrial wastes containing toxic chemicals, acids, alkalis, metallic salts, phenols, cyanides, ammonia, radioactive substances, etc. are sources of water pollution.

3. Synthetic detergents: Synthetic detergents used in washing and cleaning produce foam and pollute water.

4. Agrochemicals: Agrochemicals like fertilizers (containing nitrates and phosphates) and pesticides (insecticides, fungicides, herbicides etc.) washed by rainwater and surface run-off pollute water.

5. Oil: Oil spillage into seawater during drilling and shipment pollute it.

Yamuna River Frothing:

- It is one of the signatures of water pollution in the Yamuna River.
- Surfactants and phosphates found in detergent in households and industrial laundry gets dumped into Yamuna river through untreated sewage causes frothing inside river.
- Short-term exposure can lead to skin irritation and allergies. Some neurological issues may occur.
- The Delhi Pollution Control Committee (DPCC) banned the sale, storage and transportation of soaps and detergents not conforming to the quality standards set by the Bureau of Indian Standards (BIS).

Effect of water pollution

Following are some important effects of various types of water pollutants.

(1) Oxygen demanding wastes: Organic matter which reaches water bodies is decomposed by micro-organisms present in water. For this degradation oxygen dissolved in water is consumed.

- Dissolved oxygen (DO) is the amount of oxygen dissolved in each quantity of water at a particular temperature and atmospheric pressure.
- Lower DO may be harmful to animals especially fish population.
- Oxygen depletion (deoxygenation) helps in release of phosphates from bottom sediments and causes eutrophication.

(2) Nitrogen and Phosphorus Compounds (Nutrients):

- Addition of compounds containing nitrogen and phosphorus helps in the growth of algae and other plants which when die and decay consume oxygen of water.
- Excess growth or decomposition of plant material will change the concentration of CO_2 which will further change pH of water. Changes in pH, oxygen and temperature will change many. physico-chemical characteristics of water.

(3) Pathogens:

- Many wastewaters especially sewage contain many pathogenic (disease causing) and non-pathogenic micro-organisms and many viruses.
- Water borne diseases like cholera, dysentery, typhoid, etc. are spread by water contaminated with sewage.

(4) Toxic Compounds:

Pollutants such as heavy metals, pesticides, cyanides and many other organic and inorganic compounds are harmful to aquatic organisms.

- The demand of DO increases with addition of biodegradable organic matter which is expressed as biological oxygen demand (BOD).
- BOD is defined as the amount of DO require to aerobically decompose biodegradable organic matter of a given volume of water over a period of 5 days at 20°C.
- More BOD values of any water sample are associated with poor water quality.
- Substances like DDT are not water soluble and have affinity for body lipids. These substances tend to accumulate in the organism's body. This process is called bioaccumulation. The concentration of

these toxic substances builds up at successive levels of food chain. This process is called biomagnification.

- Mercury dumped into water is transformed into water soluble methyl mercury by bacterial action. Methyl mercury accumulates in fish.
- 1953, people in Japan suffered from vision and hearing problems and abnormal mental behaviour. This disease called Minamata disease occurred due to consumption of methyl mercury contaminated fish caught from Minamata bay in Japan.
- Pollution by another heavy metal cadmium had caused the disease called Itai-itai in the people of Japan. The disease was caused by cadmium contaminated rice.
- Arsenic pollution of ground water in Bangladesh and West Bengal is causing various types of abnormalities.
- Nitrate when present in excess in drinking water causes blue baby syndrome or methemoglobinemia.
- Excess of fluoride in drinking water causes defects in teeth and bones called fluorosis.

Control of Water Pollution

- It is easy to reduce water pollution from point sources by legislation.
- However, due to absence of defined strategies it becomes difficult to prevent water pollution from non-point sources. The following points may help in reducing water pollution from non-point sources.
    - Judicious use of agrochemicals like pesticides and fertilizers which will reduce their surface run-off and leaching.
    - Use of nitrogen fixing plants to supplement the use of fertilizers.
    - Prevent run-off of manure.
    - Planting trees would reduce pollution by sediments and will also prevent soil erosion.
- For controlling water pollution from point sources, treatment of wastewaters is essential before being discharged.
- Wastewaters should be properly treated by primary and secondary treatments to reduce the BOD, COD levels up to the permissible levels for discharge.
- Advanced treatment for removal of nitrates and phosphates will prevent eutrophication.
- Before the discharge of wastewater, it should be disinfected to kill the disease-causing organisms like bacteria.

Water quality standard:

- The quality standards for drinking water in India is prescribed by Bureau of Indian Standards laid down IS 10500 : 2012.
- This standard has two limits i.e., acceptable limits and permissible limits in the absence of an alternate source. If any parameter exceeds the limit, the water is considered unfit for human consumption.
- There are various water quality parameters: such as pH, biological oxygen demand (BOD), suspended solids (SS), dissolved oxygen (DO), and total coliform bacteria.

Test parameters	Requirement (Acceptable limit)	Permissible limit (In the Absence of alternate source)
pH	**6.5-8.5**	**No-relaxation**
Turbidity (NTU), max	**1**	**5**
Total Dissolved Solid, mg/L, max	**500**	**2000**
Fluoride, mg/L, max	**1.0**	**1.5**
Nitrate, mg/L, max	**45**	**No-relaxation**
Total hardness as ($CaCO_3$)	**200**	**600**
Fecal Coliform (presence/absence)	**Shall not be detectable in any 100 ml sample**	**Shall not be detectable in any 100 ml sample**
E.Coli (presence/absence)	**Shall not be detectable in any 100 ml sample**	**Shall not be detectable in any 100 ml sample**

Thermal Pollution

Thermal pollution can be defined as presence of waste heat in the water which can cause undesirable changes in the natural environment.

Causes of thermal pollution:

- Heat producing industries i.e. thermal power plants, nuclear power plants, refineries, steel mills etc. are the major sources of thermal pollution.
- Power plants utilize only 1/3 of the energy provided by fossil fuels for their operations. Remaining 2/3 is generally lost in the form of heat to the water used for cooling.
- Cold water, generally, is drawn from some nearby waterbody, passed through the plant and returned to the same water body, with temperature 10-16°C higher than the initial temperature. Excess of heat reaching such water bodies causes thermal pollution of water.

Effects of Thermal Pollution

- The dissolved oxygen content of water is decreased as the solubility of oxygen in water is decreased at high temperature.
- High temperature becomes a barrier for oxygen penetration into deep cold waters.
- Toxicity of pesticides, detergents and chemicals in the effluents increases with increase in temperature.
- The composition of flora and fauna changes because the species sensitive to increased temperature due to thermal shock will be replaced by temperature tolerant species.
- Metabolic activities of aquatic organisms increase at high temperature and require more oxygen, whereas oxygen level falls under thermal pollution.
- Discharge of heated water near the shores can kill young fishes.
- Fish migration is affected due to formation of various thermal zones.

Control of Thermal Pollution

The following methods can be employed for control of thermal pollution:

- Cooling ponds
- Spray Ponds
- Cooling towers

(i) **Cooling Ponds:** Water from condensers is stored in ponds where natural evaporation cools the water which can then be recirculated or discharged in nearby water body.

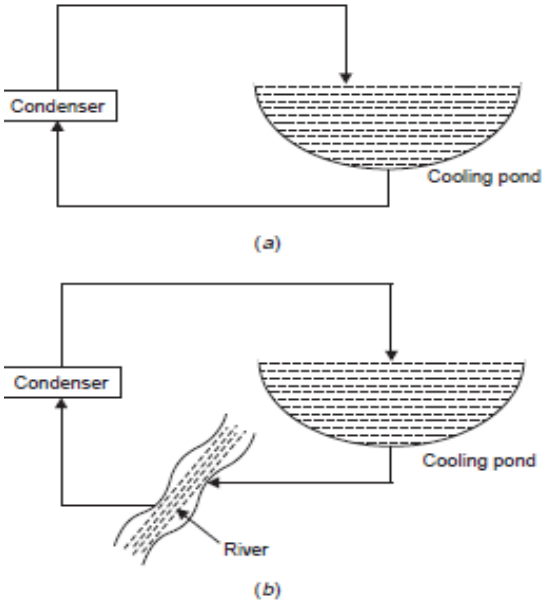


Fig. 5.2. Dissipation of heat by cooling ponds.

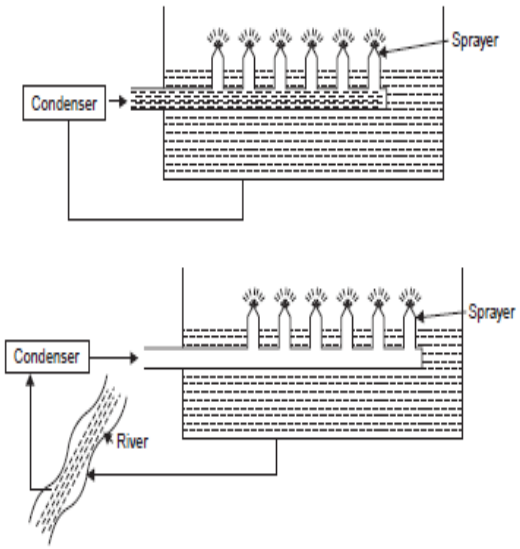


Fig. 5.3. Dissipation of heat by spray ponds.

(ii) **Spray Ponds:** The water from condensers is received in spray ponds. Here the water is sprayed through nozzles where fine droplets are formed. Heat from these fine droplets is dissipated to the atmosphere.

(iii) **Cooling Towers:** A cooling tower is an efficient way to reduce thermal pollution because it transfers the heat from the water into the atmosphere. Cooling towers are wet or dry.

Soil Pollution

- Soil is the upper layer of the earth crust which is formed by weathering of rocks. Organic matter in the soil makes it suitable for living organisms.
- Dumping of various types of materials especially domestic and industrial wastes causes soil pollution.
- Domestic wastes include garbage, rubbish material like glass, plastics, metallic cans, paper, fibres, cloth, containers, paints, varnishes etc.
- Leachates from dumping sites and sewage tanks are harmful and toxic, which pollute the soil.
- Industrial wastes are the effluents discharged from chemical industries, paper and pulp mills, tanneries, textile mills, steel industries, refineries, pesticides and fertilizer industries, pharmaceutical industries, cement industries, thermal and nuclear power plants, mining industries etc.
- Thermal power plants generate a large quantity of Fly ash. Huge quantities of these wastes are dumped on soils, thus contaminating them.

Effects of Soil Pollution

- Sewage and industrial effluents which pollute the soil ultimately affect human health.
- Various types of chemicals like acids, alkalis, pesticides, insecticides, weedicides, fungicides, heavy metals etc. in the industrial discharges affect soil fertility by causing changes in physical, chemical, and biological properties.
- The sewage sludge contains many pathogenic organisms, bacteria, viruses, and intestinal worms which cause pollution in the soil.
- Some of the persistent toxic chemicals inhibit the soil flora and fauna and reduce soil productivity. These chemicals accumulate in food chain and ultimately affect human health.

- Nitrogen and phosphorus from the fertilizers in soil reach nearby water bodies with agricultural run-off and cause eutrophication.
- Chemicals or their degradation products from soil may percolate and contaminate ground-water resources.

Control of Soil Pollution

- Effluents should be properly treated before discharging them on the soil.
- Solid wastes should be properly collected and disposed off by appropriate method.
- Biodegradable organic waste should be used for generation of biogas.
- Cattle dung should be used for methane generation.
- Microbial degradation of biodegradable substances is also one of the scientific approaches for reducing soil pollution.

Nuclear Hazards

- Radioactive substances are present in nature.
- They undergo natural radioactive decay in which unstable isotopes spontaneously give out fast moving particles, high energy radiations or both, at a fixed rate until a new stable isotope is formed.
- The isotopes release energy either in the form of gamma rays (high energy electromagnetic radiation) or ionization particles i.e. alpha particles and beta particles.
- The alpha particles are fast moving positively charged particles whereas beta particles are high speed negatively charged electrons. These ionization radiations have variable penetration power.
- Alpha particles can be interrupted by a sheet of paper while beta particles can be blocked by a piece of wood or a few millimetres of aluminium sheet. The gamma rays can pass through paper and wood but can be stopped by concrete wall.

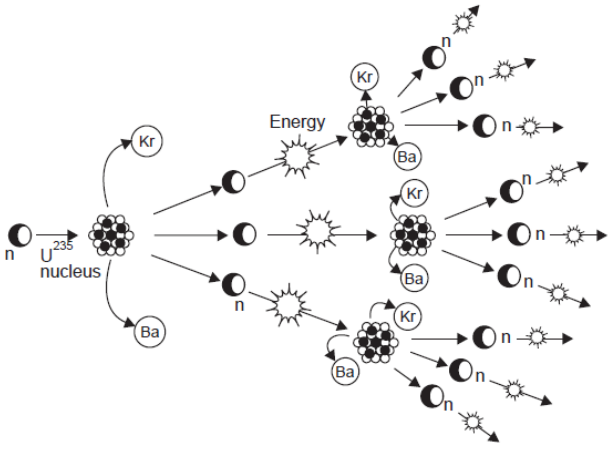


Fig. 2.5.7. (*a*) Nuclear fission—a chain reaction initiated by one neutron that bombards a Uranium (U^{235}) nucleus, releasing a huge quantity of energy, two smaller nuclei (Ba, Kr) and 3 neutrons.

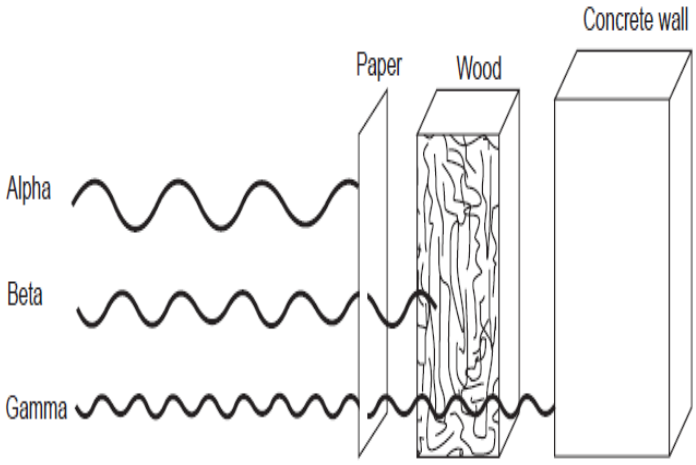


Fig. 5.5 Variable penetration power of ionisation radiations emitted by radioisotopes.

Sources of Radioactivity

(i) **Natural sources**: Sources of natural radioactivity include cosmic rays from outer space, radioactive radon-222, soil, rocks which contain one or more radioactive substances.

(ii) **Anthropogenic sources:** These sources are nuclear power plants, nuclear accidents, X-rays, diagnostic kits, test laboratories etc. where radioactive substances are used.

Effects of Radiations

- Ionisation radiations can affect living organisms by causing harmful changes in the body cells and changes at genetic level.
  - Genetic damage is caused by radiations, which induce mutations in the DNA, thereby affecting genes and chromosomes. The damage is often seen in the offspring's and may be transmitted up to several generations.
  - Somatic damage includes eye cataract and cancer of bone, thyroid, lungs and skin.
- Radioisotopes enter the environment during mining of uranium. The radioactivity in the earth's crust enters the crops grown there and ultimately in human beings.
- Radioactive iodine (I^{131}) accumulates in thyroid gland and causes cancer. Similarly, strontium-90 accumulates in the bones and causes leukaemia or cancer of bone marrow.

Control of Nuclear Pollution

(i) Sitting of nuclear power plants should be carefully done after studying long term and short term effects.
(ii) Proper disposal of wastes from laboratory involving the use of radioisotopes should be done.

- Pokhran-II nuclear bomb test consisted of five detonations, the tests were initiated on 11 May 1998, under the assigned code name Operation Shakti
- Operation Smiling Buddha (Pokhran-I) was the assigned code name of India's first successful nuclear bomb test on 18 May 1974.

Solid Waste Management

Solid waste (waste other than liquid or gaseous) can be classified as municipal, industrial, agricultural, medical, mining waste and sewage sludge.

Sources of Urban and Industrial Wastes

- **Urban waste:** It consists of medical waste from hospitals; municipal solid wastes from homes, offices, markets (commercial waste), and horticulture waste from parks, gardens etc.
- **Waste from homes (Domestic waste):** It contains a variety of discarded materials like polyethylene bags, empty metal and aluminium cans, scrap metals, glass bottles, wastepaper, cloth, food waste etc.
- **Waste from shops:** It mainly consists of wastepaper, packaging material, cans, bottles, polyethylene bags, eggshells, tea leaves etc.
- **Biomedical waste:** It includes pathological wastes, infectious wastes etc.
- **Construction/demolition waste:** It includes debris and rubbles, wood, concrete etc.
- **Horticulture waste and waste from slaughterhouses:** It include vegetable parts, residues, and remains of slaughtered animals, respectively.
- **Biodegradable wastes:** The urban solid waste materials that can be degraded by microorganisms are called biodegradable wastes. Examples of this type of waste are vegetable wastes, food, tea leaves, eggshells, peanut shells, dry leaves etc.

- **Non-biodegradable wastes**: Wastes that cannot be degraded by microorganisms are called non-biodegradable wastes. For example, polyethylene bags, scrap metal, glass bottles etc.

Industrial waste:

- Industrial waste consists of a large number of materials including factory rubbish, packaging material, organic wastes, acids, alkalis etc.
- The main sources of industrial wastes are chemical industries, metal, and mineral processing industries.
- Radioactive wastes are generated by nuclear power plants.
- Thermal power plants produce fly ash in large quantities.
- Solid wastes from other types of industries include scrap metal, rubber, plastic, paper, glass, wood, oils, paints, asphalt, dyes, scrap leather, ceramics, heavy metals, asbestos, batteries etc.

Effects of Solid Wastes

- Municipal solid wastes heap up on the roads due to improper disposal system.
- People clean their own houses and litter their immediate surroundings which affects the community including themselves. This type of dumping allows biodegradable materials to decompose under uncontrolled and unhygienic conditions. This produces foul smell and breeds various types of insects and infectious organisms.
- Industrial solid wastes are sources of toxic metals and hazardous wastes, which may spread on land and can cause changes in physico-chemical and biological characteristics of soil and thereby affecting productivity of soils.
- Toxic substances may leach or percolate to contaminate the ground water.

Management of Solid Waste:

- For waste management we stress on three R.s.-Reduce, reuse, and recycle before destruction and safe storage of wastes.
- **Reduction in use of raw materials:** Reduction in the use of raw materials will decrease the production of waste.
- **Reuse of waste materials:** The refillable containers which are discarded after use can be reused. Making rubber rings from the discarded cycle tubes which are used by the newspaper vendors, instead of rubber bands, reduces the waste generation during manufacturing of rubber bands.
- **Recycling of materials:** Recycling is the reprocessing of discarded materials into new useful products. Formation of some old type products e.g., old aluminium cans and glass bottles are melted and recast into new cans and bottles.

Disposal methods for solid waste management:

(1) **Landfill**

- A landfill site, also known as rubbish dump, garbage dump, or dumping ground, is a site for the disposal of waste materials.
- Landfill is the oldest and most common form of waste disposal.
- landfill sites are used for waste management purposes.
- They are carefully designed structures built into the ground so that waste is kept separate from the surrounding environment.
- In the modern landfills the bottom is covered with an impermeable liner, usually several layers of clay, thick plastic, and sand. The liner protects the ground water from being contaminated due to percolation of leachate.
- Three main landfills site in Delhi — Okhla, Bhalswa and Ghazipur.
- The Deonar dumping ground is a waste dumping ground or landfill in the city of Mumbai, located in Shivaji Nagar, it is India's oldest and largest dumping ground, set up in 1927.

- Landfill sites are often responsible for the contamination of soil and groundwater, as the contaminating materials (such as heavy materials like lead and mercury) that the stored waste may contain can spread to the soil and water near the plant.
- Methane produced by anaerobic decomposition is collected and burnt to produce electricity or heat.

(2) **Composting:**

- Due to shortage of space for landfill in bigger cities, the biodegradable yard waste (kept separate from the municipal waste) is allowed to degrade or decompose in an oxygen rich medium.
- A good quality nutrient rich and environmentally friendly manure is formed which improves the soil conditions and fertility.

(3) **Incineration:**

- It is the process of burning hazardous materials at high temperatures to destroy contaminants.
- Incineration will emit more toxins gases that harm local air quality.

Pollution case study:

(1) The Bhopal Gas Tragedy:

- The world's worst industrial accident occurred in Bhopal, M.P., India on the night of 2nd and morning of 3rd December, 1984.
- It happened at Union Carbide Company which used to manufacture Carbaryl (Carbamate) pesticide using Methyl isocyanate (MIC).
- Due to accidental entry of water in the tank, the reaction mixture got overheated and exploded because its cooling system had failed.
- Forty tons of MIC leaked into the atmosphere which might have contained 40 kg of phosgene as an impurity.
- MIC gas at lower concentrations affects lungs and eyes and causes irritation in the skin. Higher amounts remove oxygen from the lungs and can cause death.
- MIC gas spread over 40 Km^2 area. About 5100 persons were killed.
- About 2,50,000 persons got exposed to MIC.
- An estimated 65,000 people suffered from severe eye, respiratory, neuromuscular, gastrointestinal, and gynaecological disorders.
- About 1000 persons became blind.

(2) Ganga Action Plan

- The Ganga Action Plan (GAP) was launched by Sri Rajiv Gandhi Ji former Prime Minister of India in June 1986 for cleaning Ganga.
- Approximately Rs 862.59 crore were spent.
- GAP – Ganga Action Plan is a 100% centrally sponsored scheme. Under this plan, the National River Ganga basin authority was established and declared Ganga as a national river of India.
- Ganga Action Plan was directed by Rajiv Gandhi. The authority is headed by the prime minister and chief ministers of all the states in which river Ganga flows.
- GAP was divided into two phases. Phase-I started in 1985 and covered the then three states, Uttar Pradesh (UP), Bihar and West Bengal (WB).
- Phase-II of GAP was launched in 1993, which covers seven states that include Uttarakhand, UP, Bihar, Jharkhand, West Bengal, Delhi, and Haryana.
- The Main objective of Ganga Action plan was to improve the water quality of Ganga River by the interception, diversion, and treatment of domestic sewage and to prevent toxic and industrial chemical wastes from identified polluting units from entering the river.
- Central Ganga Authority (CGA) came into existence under the Environment Protection Act 1986, headed by the Prime Minister of India.

- In 2014 the present government started Namami Gange Mission to ensure clean Ganga.

(3) **Delhi air pollution and public health issues:**

- The air quality of Delhi, the capital territory of India, according to a WHO survey of 1,650 world cities, and a survey of 7,000 world cities by the US-based Health Effects Institute in August 2022, is the worst of any major city in the world.
- Air pollution in India is estimated to kill about 2 million people every year; it is the fifth largest killer in India.
- India has the world's highest death rate from chronic respiratory diseases and asthma, according to the WHO . In Delhi, poor quality air damages the lungs of 2.2 million.
- On 25 November 2019, the Supreme Court of India made statements on the pollution in Delhi saying "Delhi has become worse than narak (hell) ".
- Ministry of Earth Sciences published a research paper in October 2018 attributing almost 41% to vehicular emissions, 21.5% to dust and 18% to industries causing air pollution.
- Air Quality Index of Delhi is generally in the Good (0–50), Satisfactory (51–100), and Moderate (101–200) levels between March to September, and then it drastically deteriorates to Poor (201–300), Severe (301–400), or Hazardous (401–500+) levels during October to February due to various factors including bursting of firecrackers stubble burning, road dust, vehicle pollution and cold weather etc.
- According to data released by environment ministry in 2022, the Air Quality Index of Delhi National Capital Region is over 200 for at least half the year.
- In 2010, the year of the WHO survey, the average PM_{10} level in Delhi was 286 $\mu g/m^3$. In 2013, the $PM_{2.5}$ level was 153 $\mu g/m^3$. These levels are considered very unhealthy.
- Motor vehicle emission are one of the causes of poor air quality in Delhi. Other causes include wood-burning fires on agricultural land, exhaust from diesel generators, dust from construction sites, burning garbage and illegal industrial activities in Delhi.
- The Badarpur Thermal Power Station, a coal-fired power plant built in 1973, was another major source of air pollution in Delhi.
- Fire in Bhalswa landfill is a major reason for airborne particles in Delhi.
- Agricultural stubble burning in Haryana and Punjab, coupled with north-westerly winds also affects Delhi's air quality since the 1980s when crops are being harvested. This is the one of the major causes of air pollution in Delhi and as can be seen from air pollution index data, the air quality drastically deteriorated in October, the season of crop burning in Punjab and Haryana.
- During the crop-burning season, the practice can account for up to 45% of Delhi's pollution, according to government meteorologists.
- A study in 2016 measured the sources and average levels of various types of air pollution in Delhi. Of PM2.5 pollution, 38% came from road dust, 20% to vehicles, 12% to domestic fuel burning, and 11% to industrial point sources. Of PM10 pollution, 56% came from road dust, 10% from concrete batching, 10% from industrial point sources, and 9% from vehicles.
- 2.2 million children in Delhi have irreversible lung damage due to the poor quality of the air.
- In addition, research shows that pollution can lower children's immune system and increase the risks of cancer, diabetes etc.
- Poor air quality is a cause of reduced lung capacity, headaches, sore throats, coughs, fatigue, lung cancer etc.
- On 25 November 2017, the Supreme Court of India banned the sale of firecrackers in Delhi to alleviate pollution.

Plastic Waste Management Rules

Plastic Waste Management Rules, 2016

- Increase minimum thickness of plastic carry bags from 40 to 50 microns and stipulate minimum thickness of 50 micron for plastic sheets also to facilitate collection and recycle of plastic waste.
- To introduce collection of plastic waste management fee through pre-registration of the producers, importers of plastic carry bags etc.
- To promote use of plastic waste for road construction as per Indian Road Congress guidelines.
- Plastic products are left littered after the public events (marriage functions, religious gatherings, public meetings etc) held in open spaces. First time, persons organising such events have been made responsible for management of waste generated from these events.
- Producers to keep a record of their vendors to whom they have supplied raw materials for manufacturing carry bags, plastic sheets etc.

Plastic Waste Management Amendment Rules, 2021

- The Ministry of Environment, Forest and Climate Change, Government of India, has notified the Plastic Waste Management Amendment Rules, 2021 on August 12, 2021.
- The rules prohibits identified single use plastic items which have low utility and high littering potential by 2022.
- The manufacture, import, stocking, distribution, sale and use of following single-use plastic, including polystyrene and expanded polystyrene shall be prohibited with effect from the 1st July, 2022.
- In order to stop littering due to light weight plastic carry bags, with effect from 30th September, 2021, the thickness of plastic carry bags has been increased from fifty microns to seventy five microns and to one hundred and twenty microns with effect from the 31st December, 2022. This will also allow reuse of plastic carry due to increase in thickness.
- The waste management infrastructure in the States/UTs is being strengthened through the Swachh Bharat Mission. The following steps have also been taken to strengthen implementation of Plastic Waste Management Rules, 2016 and also to reduce the use of identified single use plastic items:
    i. The States/UTs have been requested to constitute a Special Task Force for elimination of single use plastics and effective implementation of Plastic Waste Management Rules, 2016.
    ii. A National Level Taskforce has also been constituted by the Ministry for taking coordinated efforts to eliminate identified single use plastic items and effective implementation of Plastic Waste Management Rules, 2016.
    iii. The Government has also been taking measures for awareness generation towards elimination of single use plastics and effective implementation of Plastic Waste Management Rules, 2016.
    iv. To encourage innovation in development of alternatives to identified single use plastic items and digital solutions to plastic waste management.