IASbaba

[ENVIRONMENT-PART 2]

Integrated Learning Programme 2018 is a step towards 'Enabling a person located at the most remote destination a chance at cracking AIR 1 in UPSC/IAS'

CONTENTS

TERRESTRIAL ECOSYSTEMS

Natural Ecosystem

- A natural ecosystem is an assemblage of plants and animals which functions as a unit and is capable of maintaining its identity. There are two main categories of ecosystems – terrestrial ecosystem and Aquatic ecosystem.

Biomes or Terrestrial Ecosystems

- The **terrestrial** part of the biosphere is divisible into enormous regions called biomes, which are characterized, by distinct climate [precipitation and temperature mainly], vegetation, animal life and general soil type.
- No two biomes are alike. The climate determines the boundaries of a biome and abundance of plants and animals found in each one of them. The most important climatic factors are temperature and precipitation.

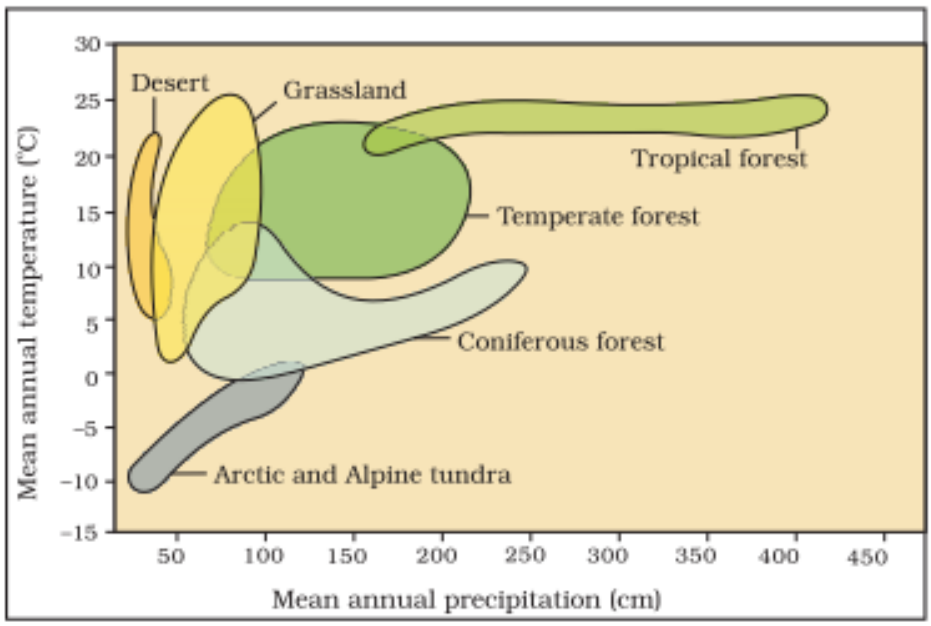
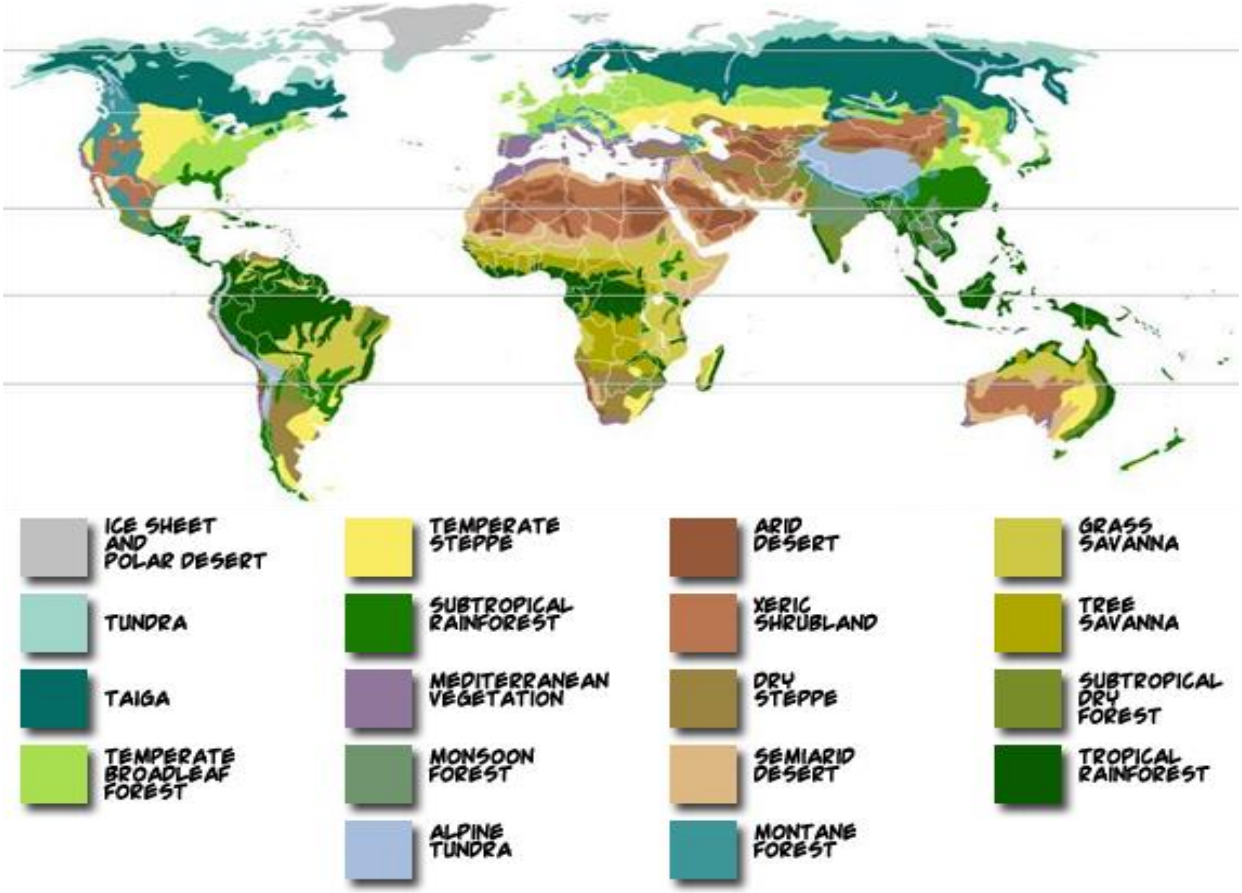


Figure 13.1 Biome distribution with respect to annual temperature and precipitation



Tundra Biome

- There are two types of tundra – arctic and alpine.

Distribution

- Arctic tundra extends as a continuous belt below the polar ice cap and above the tree line (taiga) in the northern hemisphere.
- It occupies the northern fringe of Canada, Alaska, European Russia, Siberia and island group of Arctic Ocean.
- On the South Pole, tundra is very small since most of it is covered by ocean.
- Alpine tundra occurs at high mountains above the tree line. E.g. High ranges of Himalayas, Andes, Alps etc.

Temperature

- The tundra climate is characterized by a very low mean annual temperature.
- In mid-winter temperatures are as low as 40 – 50 °C below freezing.

Precipitation

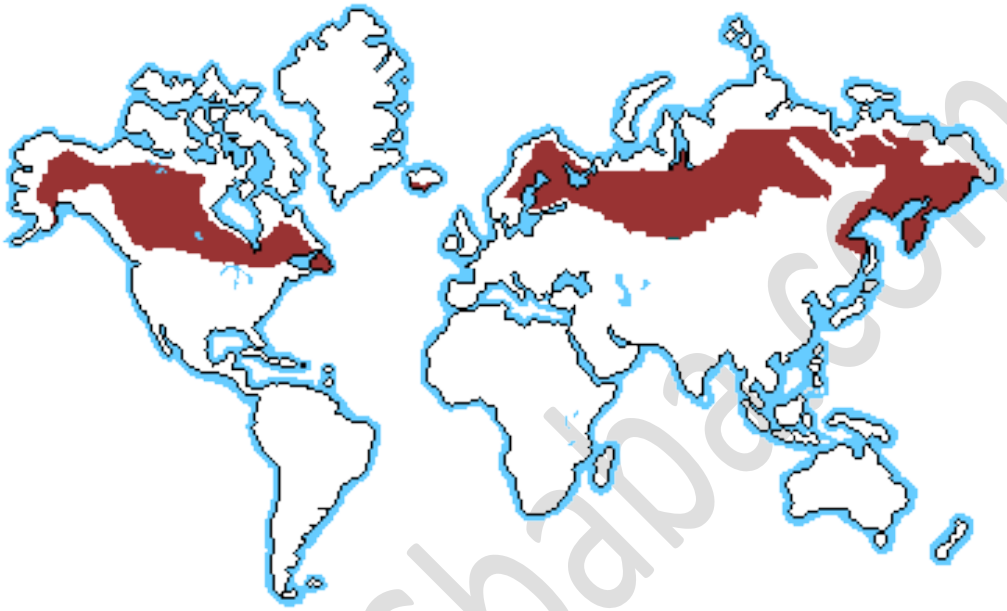
- Precipitation is mainly in the form of snow and sleet.

Natural Vegetation

- There are **no trees** in the tundra (Ground is frozen). Lowest form of vegetation like **mosses, lichens** etc. are found here and there.
- Coastal lowlands support hardy grasses and the reindeer moss which provide the only pasturage for **reindeers**.
- In the brief summer, berry-bearing bushes and Arctic flowers bloom.
- In the summer, birds migrate north to prey on the numerous insects which emerge when the snow thaws.
- Insects have short life cycles which are completed during favourable period of the year.
- Animals like the **reindeer, arctic fox, wolves, musk-ox, polar bear, lemming, arctic hare, arctic willow** etc. live in tundra region.
- Reptiles and amphibians are almost absent.
- Most of the animals have long life e.g. arctic willow has a life span of 150 to 300 years.
- They are protected from chillness by the presence of **thick cuticle and epidermal hair** or fur.

- Mammals of the tundra region have **large body size and small tail and ear to avoid the loss of heat from the surface** [less surface area = less heat loss = less food required to produce heat].

Taiga or Boreal Biome



Temperature

- Summers are brief and warm reaching
- 20-25 °C whereas winters are long and brutally cold – 30-40 °C below freezing.

Precipitation

- Typical annual precipitation ranges from 38 cm to 63 cm.
- It is quite **well distributed throughout the year**, with a **summer maxima**.
- In winter the precipitation is in the form of snow.

Soil

- Boreal forest soils are characterized by thin **podzols** and are rather poor.
- This is because the weathering of rocks proceeds slowly in cold environments and because the litter derived from conifer needle (leaf) is decomposed very slowly and is not rich in nutrients. Moreover, conifers don not shed their leaves frequently.
- Most podzols are poor soils for agriculture due to the **sandy** portion, resulting in a **low level of moisture and nutrients.**

- Some are sandy and excessively drained. Others have shallow rooting zones and poor drainage due to subsoil cementation.
- A **low pH (acidic)** further compounds issues, along with phosphate deficiencies and aluminium toxicity.
- The low pH (acidic) factor is due to **excessive leaching of alkaline oriented cations** which if present would neutralize the organic acids of the accumulating litter.

Natural Vegetation

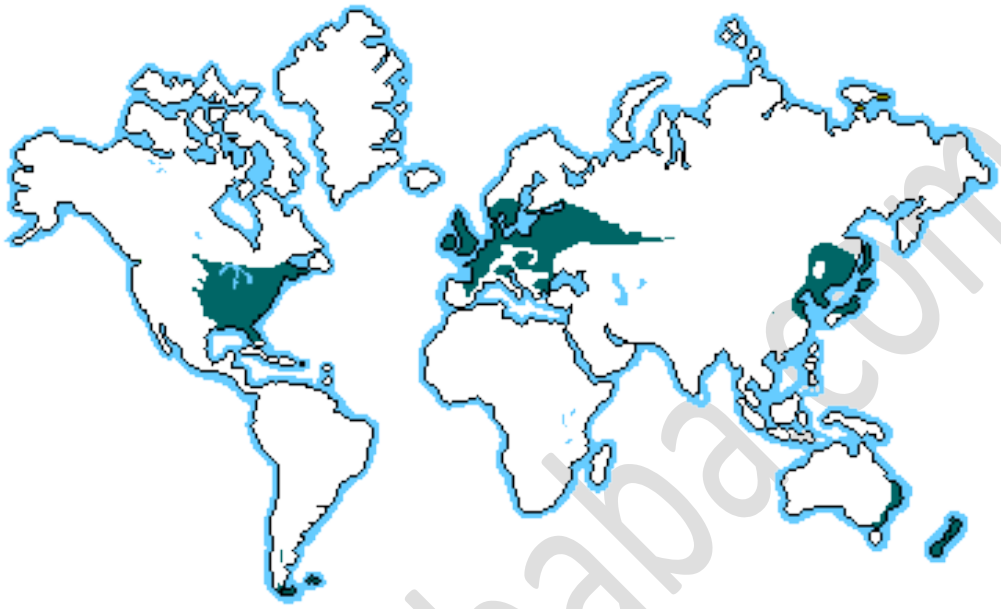
- The predominant vegetation is **evergreen coniferous forest**.
- Conifers are evergreen plant species such as Spruce, fir and pine trees, etc.
- The conifers require little moisture are best suited to this type of sub-Arctic climate.
- The productivity and community stability of a boreal forest are **lower** than those of any other forest ecosystem.
- Animals found in this region include Siberian tiger, wolverine, lynx, wolf, bear, red fox, squirrel, and amphibians like Hyla, Rana, etc.

Characteristics of Coniferous forests

- Unlike the equatorial rain forests, Coniferous forests are of **moderate density** and are more uniform. The trees in coniferous forests grow straight and tall.
- Almost all conifers are **evergreen**. There is no annual replacement of new leaves as in deciduous trees.
- The same leaf remains on the tree for as long as **five years**. Food is stored in the **trunks**, and the **bark is thick** to protect the trunk from excessive cold.
- Conifers are conical in shape. Their conical shape and sloping branches prevent snow accumulation. It also offers little grip to the winds.
- **Transpiration** can be quite rapid in the warm summer. So, leaves are small, thick, **leathery** and needle-shaped **to check excessive transpiration.**
- The soils of the coniferous forests are **poor.** They are excessively **leached** and very **acidic**.
- Humus content is also low as the evergreen leaves barely fall and the rate of decomposition is slow.
- Under-growth is negligible because of the poor soil conditions.
- Absence of direct sunlight and the short duration of summer are other contributory factors.
- Coniferous forests are also found in regions with high elevation [Example: The forests just below the snowline in Himalayas].

- But on very steep slopes where soils are immature or non-existent, even the conifer cannot survive [Example: Southern slopes of Greater Himalayas].

Temperate Deciduous Biome [North Western Europe]



- Moderately warm summers and fairly mild winters.

Temperature

- The mean annual temperatures are usually between 5° C and 15° C.
- Winters are **abnormally mild**. This is because of the warming effect brought by **warm North Atlantic Drift. [Eastern Australian warm current in case of New Zealand]**

Precipitation

- **Rainfall occurs throughout the year with winter maxima**.
- Adequate rainfall throughout the year.

Seasons

- As in other temperate regions there are **four distinct seasons**.
- Winter is the season of cloudy skies, foggy and misty mornings, and many rainy days from the passing depressions. (Trees shed their leaved in winter to prevent snow accumulation and protect themselves from severe cold)
- Spring is the driest and the **most refreshing** season when people emerge from the depressing winter to see everything becoming green again.
- This is followed by the long, sunny summer.

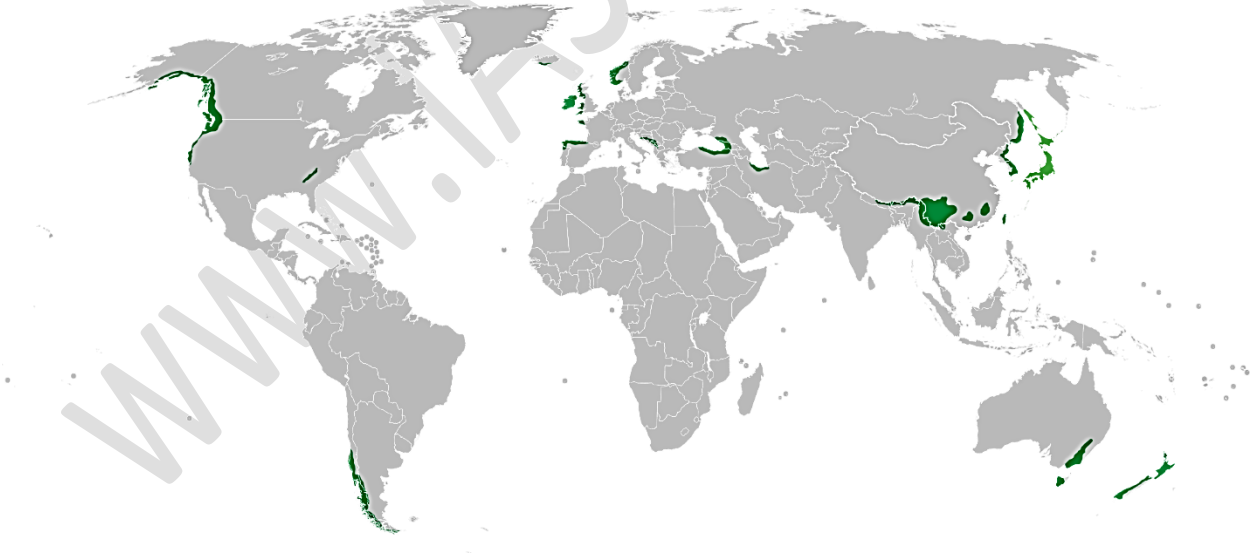
- Next is the autumn with the roar of gusty winds; and the cycle repeats itself.
- This type of climate with its four distinct seasons is something that is **conspicuously absent in the tropics.** [Rainforest = Only Rainy season, Tropical Monsoon = Summer, Winter and Rainy, Tropical Savanna = Summer (rains) and Winter]

Natural Vegetation

- Soils of temperate forests are podozolic and fairly deep.
- The natural vegetation of this climatic type is **deciduous forest.**
- The trees shed their leaves in the **cold season.**
- This is an adaptation for protecting themselves against the winter snow and frost.
- Shedding begins in **autumn, the 'fall' season**. Growth begins in spring.
- Some of the common species include **oak, elm, ash, birch, beech, and poplar**.
- In the wetter areas grow willows (Light weight cricket bats are made from willows. In India willows are found in Kashmir).
- Most animals are the familiar vertebrates and invertebrates.

Temperate Rainforest Biome

- Temperate rain forests receive an annual precipitation of 200 cm, mostly due to on shore westerlies.
- Precipitation occurs in the form of fog, rain as ac as snow. Fog is quite common and is an important source of water.



Distribution

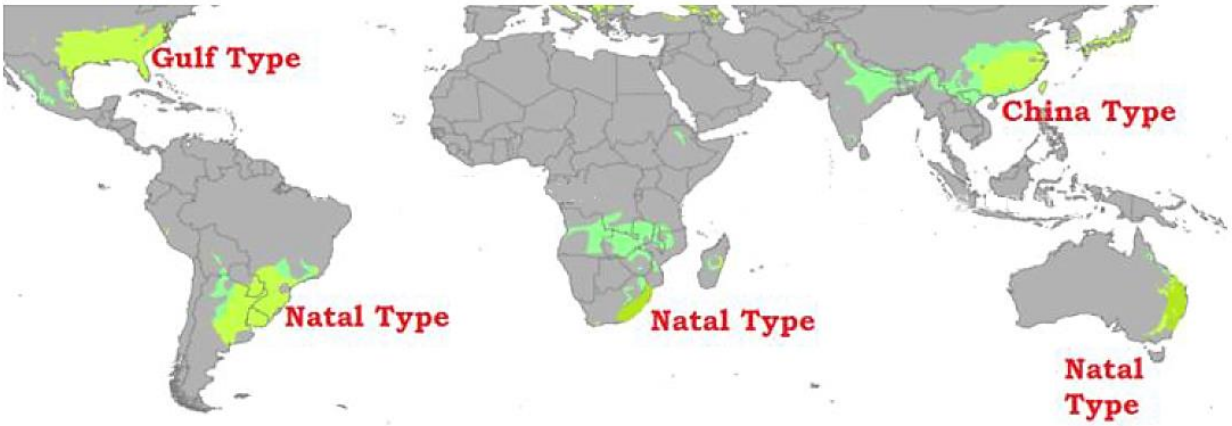
- This biome covers small area.
- Northwestern coast of North America from northern California though southern Alaska.
- There are also small areas in southern Chile, New Zealand, Australia and a few other

places around the world.

Natural Vegetation

- Big coniferous trees dominate this habitat, including **Douglas fir, Western red cedar, Mountain hemlock, Western hemlock, Sitka spruce and Lodgepole pine**.
- In addition to the trees, mosses and lichens are very common, often growing as epiphytes.
- Grizzly Bears are the common mammals found in Alaska.

Sub-Tropical Deciduous Biome in Eastern China, South Eastern USA



Climate

- Characterized by a **warm moist summer** and a **cool, dry winter** (one exception: winters are also moist in Natal Type).

Temperature

- The mean monthly temperature varies between 4° C and 25° C and is strongly modified by **maritime influence.**

Precipitation

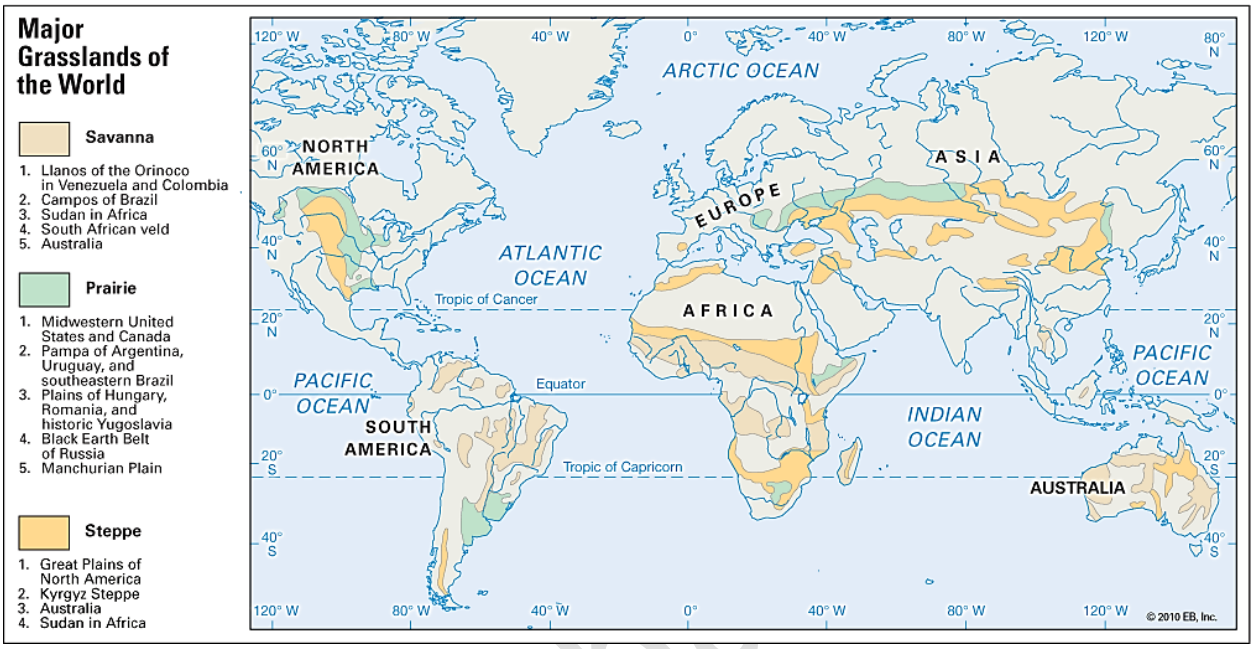
- Rainfall is more than moderate, anything from **60 cm to 150 cm**.
- There is the **fairly uniform distribution of rainfall throughout the year**.

Natural Vegetation

- Supports a luxuriant vegetation.
- The lowlands carry both evergreen broad-leaved forests and deciduous trees [**hardwood**].
- On the highlands, are various species of conifers such as pines and cypresses which are important **softwoods.**

- Perennial plant growth is not checked by either a dry season or a cold season.

Steppe or Temperate Grassland Biome



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Name of the Temperate Grassland	Region
Pustaz	Hungary and surrounding regions
Prairies	North America (Between the foothills of the rockies and the great lakes)
Pampas	Argentina and Uruguay [Rain-shadow effect]
Bush-veld (more tropical)	Northern South Africa
High Veld (more temperate)	Southern South Africa
Downs	Australia: Murray – Darling basin of southern Australia
Canterbury	New zealand

Temperature

- Climate is continental with **extremes of temperature**.
- Temperatures vary greatly between summer and winter.

Precipitation

- The average rainfall may be taken as about 45 cm, but this varies according to location from 25 cm to 75 cm.

Natural Vegetation of Steppe Climate

Grasses

- Greatest difference from the tropical savanna is that steppes are practically **treeless** and the **grasses are much shorter**.
- Grasses are fresh and **nutritious**. This is typical of the grass of the wheatlands in North America, the **rich black earth or chernozem areas of Russian Ukraine** and the better watered areas of the Asiatic Steppes.

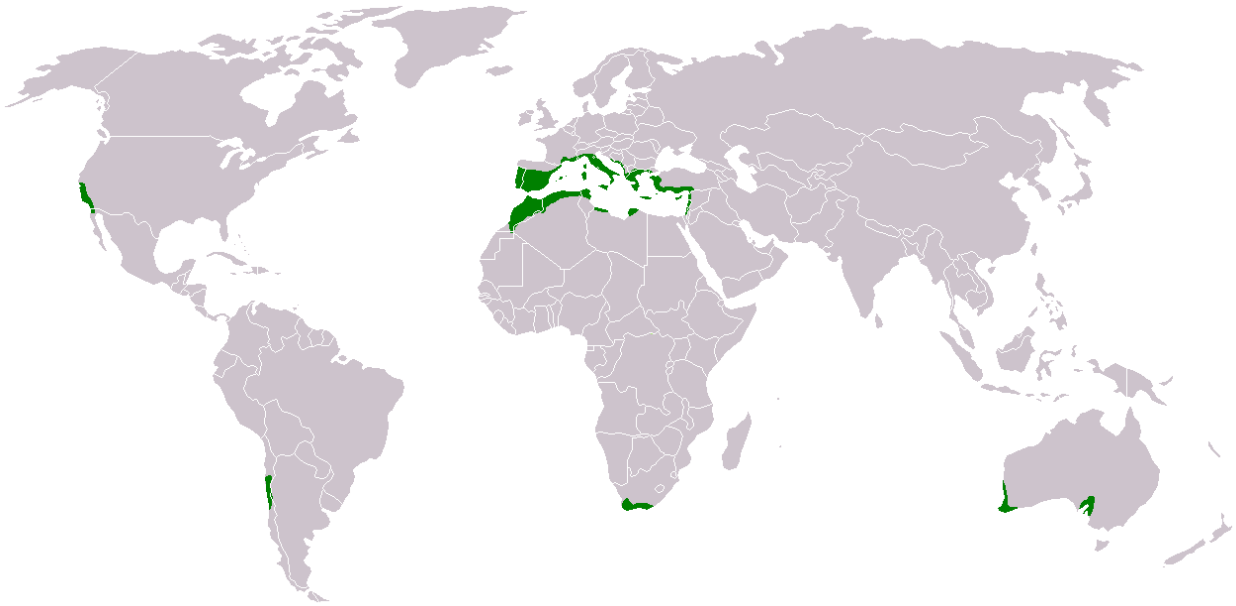
Trees

- Polewards, an increase in precipitation gives rise to a transitional zone of wooded steppes where some **conifers** gradually appear.

Animals

- Does not have much animal diversity.
- **Horses** are common in Asian Steppes.

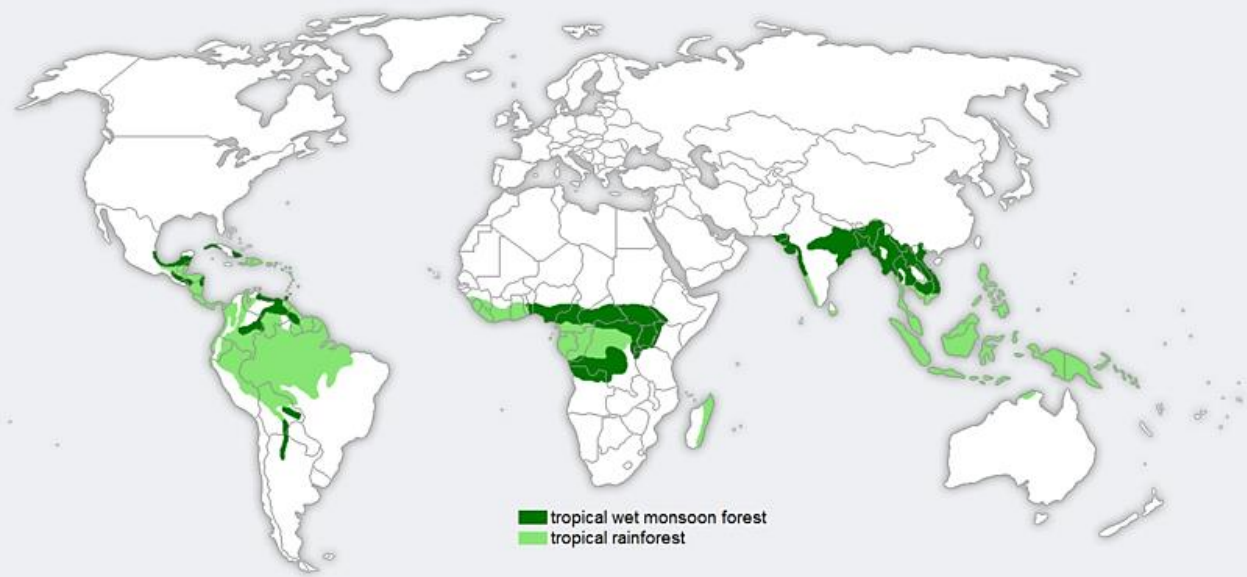
Temperate Deciduous Biome [Mediterranean Region]



- Parts of the world that have Mediterranean type of climate are characterized **by warm, dry summers and cool, moist winters**.
- Trees with **small broad leaves** are widely spaced and **never very tall**.
- Regions with adequate rainfall are inhabited by low broad leafed evergreen trees [mostly evergreen oaks].
- Fire is an important hazardous factor in this ecosystem and the adaptation of the plants enable them to **regenerate quickly** after being burnt.
- Plants are in a continuous struggle against heat, dry air, excessive evaporation and prolonged droughts.
- They are, in short **xerophytic [drought tolerant]**, a word used to describe the drought-resistant plants in an environment deficient in moisture.

Tropical Deciduous Biome [Monsoon Climate]

- Unlike equatorial wet climate, monsoon climate is characterized by **distinct wet and dry seasons** associated with **seasonal reversal of winds**.
- **Floods** in wet season and **droughts** in dry season are common.
- Usually there are three seasons namely **summer, winter and rainy** season.



Temperature

- Monthly mean temperatures **above 18 °C.**
- Temperatures range from 30-45° C in summer.
- In winters, temperature range is 15-30° C with mean temperature around 20-25° C.

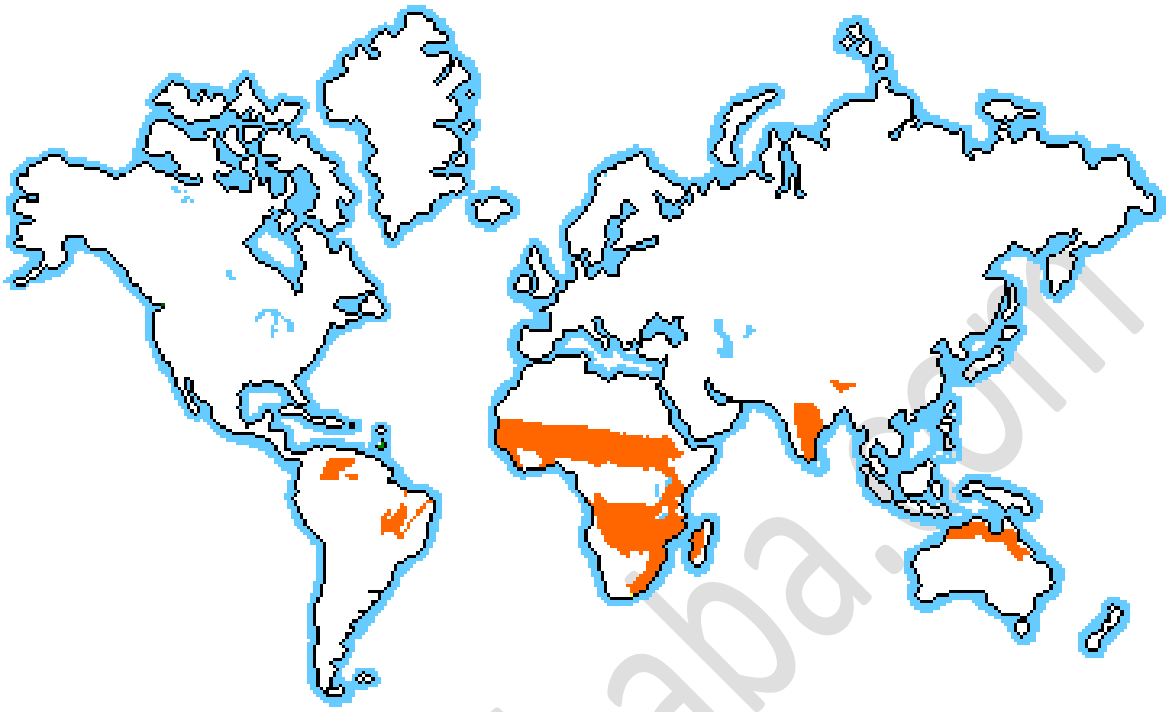
Precipitation

- Annual mean rainfall ranges from 200-
- 250 cm. In some regions it is around 350 cm.
- Places like **Cherrapunji & Mawsynram** receive an annual rainfall of about **1000 cm.**

Tropical Monsoon Forests

- Also known as **drought-deciduous**
- **forest; dry forest; dry-deciduous forest; tropical deciduous forest.**
- **Teak, neem, bamboos, sal, shisham, sandalwood, khair, mulberry** are some of the important species found here.

Savanna or Tropical Wet and Dry Biome



- This type of biome has alternate wet and dry seasons similar to monsoon climate but has **considerably less annual rainfall**.
- Also, there is **no distinct rainy season** like in monsoon climate. [Only two seasons – winter and summer. **Rains occur in summer**].
- Floods and droughts are common.
- Vegetation, wildlife and human life are quite different from monsoon climate regions.

Rainfall

- Mean annual rainfall ranges from **80 – 160 cm** [Rainfall decreases with distance from equator].

Temperature

- Mean annual temperature is **greater than 18° C.**
- The monthly temperature hovers between 20° C and 32° C for lowland stations.

Natural Vegetation of Savanna Climate

- The savanna landscape is typified by **tall grass and short trees**.
- The grasslands are also called as ***'bush-veld'.***
- The trees are **deciduous**, shedding their leaves in the cool, dry season to prevent

excessive loss of water through transpiration, e.g. acacias.

- Trees usually have **broad trunks**, with water-storing devices to survive through the prolonged drought.
- Many trees are umbrella shaped, exposing only a narrow edge to the strong winds.
- In true savanna lands, the grass is **tall and coarse**, growing 6 to 12 feet high. The **elephant grass** may attain a height of even 15 feet.
- Grasses appear greenish and well-nourished in the rainy season but turns yellow and dies down in the dry season that follows.
- As the rainfall diminishes towards the deserts the savanna merges into thorny scrub.

Animal Life of the Savanna

- There are two main groups of animals in the savanna, the grass-eating herbivorous animals and the fleshing-eating carnivorous animals.
- The herbivorous include the zebra, antelope, giraffe, deer, gazelle; elephant etc. [most of the National geographic and Animal Planet documentaries on wild animals are shot in savanna regions] and carnivorous animals include the lion, tiger, leopard, hyena, panther, jaguar, jackal etc.
- Species of reptiles and mammals including crocodiles, alligators, and giant lizards live together with the larger rhinoceros and hippopotamus in rivers and marshy lakes.

Tropical Rain Forest Biome

- Also known as '**The Hot, Wet Equatorial Climate**', '**Equatorial Rainforest Climate**'.
- The regions are generally referred as **'Equatorial Rainforests', 'Equatorial Evergreen Forests', 'Tropical Moist Broadleaf Forest', 'Lowland Equatorial Evergreen Rainforest'.**

Temperature

- Temperature is **uniform** throughout the year.
- The mean monthly temperatures are always around **27° C** with very little variation.
- **There is no winter**. [Typical to Equatorial Rainforest Climate]

Precipitation

- Precipitation is heavy and **well distributed throughout the year**.
- Annual average is always above **150 cm**. In some regions the annual average may be as high as 250 – 300 cm.

Equatorial Vegetation

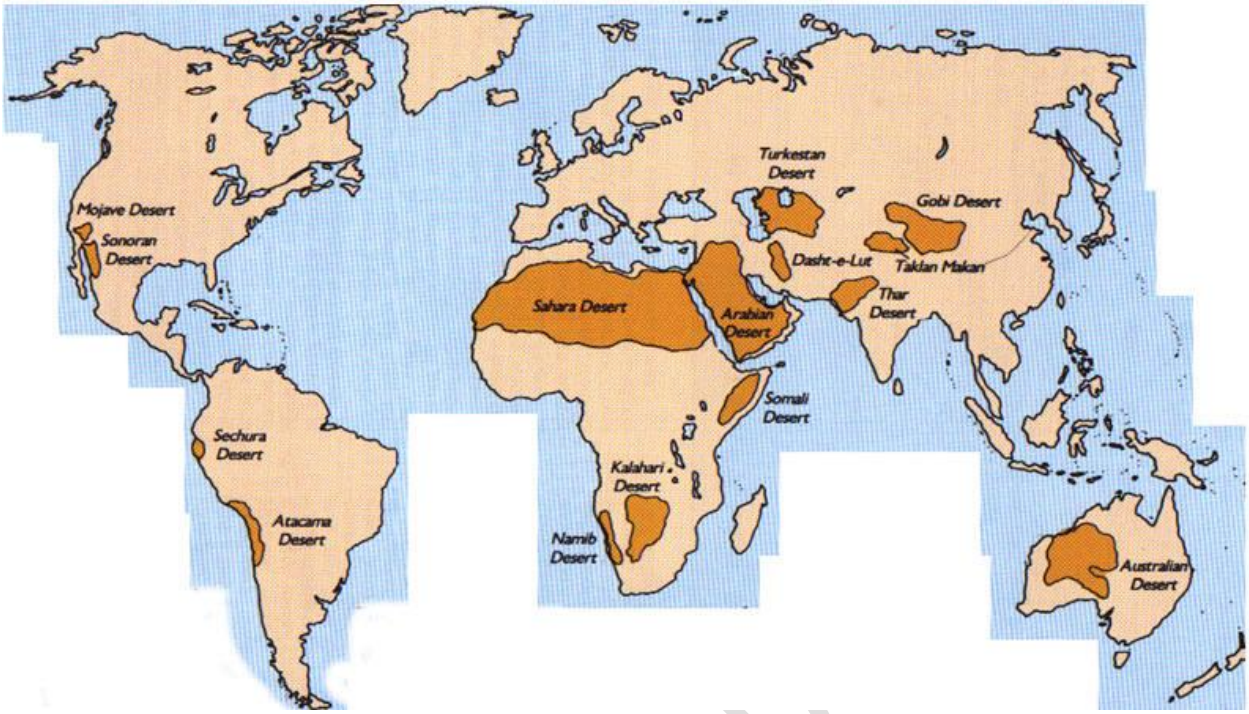
- High temperature and abundant rainfall support a luxuriant **tropical rain forest**.
- In the Amazon lowlands, the forest is so dense that it is called **'selvas'**. [selvas: A dense tropical rainforest usually having a cloud cover (**dense canopy**)]
- Unlike the temperate regions, the **growing season here is all the year round**-seeding, flowering, fruiting and decaying do not take place in a seasonal pattern.
- The equatorial vegetation comprises a multitude of evergreen trees that yield ***tropical hardwood, e.g. mahogany, ebony, dyewoods etc.***
- In the coastal areas and brackish swamps, **mangrove forests** thrive.
- All plants struggle upwards (most **ephiphytes**) for sunlight resulting in a peculiar layer arrangement [Canopy].

Epiphyte

- (Commensalism – Epiphyte benefits without troubling the host) **-** An epiphyte is a plant that grows harmlessly upon another plant (such as a tree) and derives its moisture and nutrients from the air, rain, and sometimes from debris accumulating around it.

Desert Biome

- Deserts are regions where **evaporation exceeds precipitation.**
- There are mainly two types – hot like the **hot deserts** of the Saharan type and temperate as are the **mid-latitude deserts** like the Gobi.



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Hot Deserts

- They include the biggest **Sahara Desert**
- (3.5 million square miles), **Great Australian Desert, Arabian Desert, Iranian Desert, Thar Desert, Kalahari** and **Namib Deserts**.
- In North America, the desert extends from Mexico into U.S.A. and is called by different names at different places, e.g. the **Mohave, Sonoran, Californian** and **Mexican Deserts.**
- In South America, the **Atacama or Peruvian Desert** is the **driest** of all deserts with less than 2 cm of rainfall annually.

Mid-Latitude Deserts

- The temperate deserts are rainless because of either **continentiality or rain-shadow effect.** [**Gobi desert** is formed due to **continentiality** and **Patagonian desert** due to **rain-shadow effect**]
- Amongst the mid-latitude deserts, many are found on plateau and are at a considerable distance from the sea. These are **Ladakh, The Kyzyl Kum, Turkestan, Taklimakan and Gobi deserts of Central Asia, drier portions of the Great Basin Desert of the western United States** and **Patagonian Deserts of Argentina etc.**
- The Patagonian Desert is more due to its rain-shadow position on the leeward side of the lofty Andes than to continentiality.

Rainfall (Both Hot and Cold deserts)

- Deserts, whether hot or mid-latitude have an annual precipitation of **less than 25 cm.**

Temperature of Hot deserts

- There is no cold season in the hot deserts and the average summer temperature is high around 30°C.
- The highest temperature recorded is **57.77° C in 1922 at A1 Azizia, Libya.**

Desert Vegetation

- The predominant vegetation of both hot and mid-latitude deserts is **xerophytic** or drought-resistant.
- This includes the cacti, thorny bushes, long-rooted wiry grasses and scattered dwarf acacias.
- Trees are rare except where there is abundant ground water to support clusters of **date palms.**
- Most desert shrubs have long roots and are well spaced out to gather moisture, and search for ground water. Plants have few or no leaves and the foliage is either **waxy, leathery, hairy or needle-shaped** to reduce the loss of water through transpiration.
- The seeds of many species of grasses and herbs have **thick, tough skins** to protect them while they lie dormant.

Indian Biomes – Indian Forest Types

- Classification of Natural Vegetation of India is primarily based on spatial and annual variations in rainfall. Temperature, soil and topography are also considered.

Annual rainfall (in cms)	Types of Vegetation
200 or more	Evergreen Rain forests
100 to 200 cm	Monsoon Deciduous forests
50 to 100 cm	Drier deciduous or tropical savanna
25 to 50 cm	Dry thorny Scrub (Semi - Arid)
Below 25 cm	Desert (Arid)

- Temperature is the major factor in Himalayas and other hilly regions with an elevation of more than 900 meters.
- As the temperature falls with altitude in the Himalayan region the vegetal cover changes with altitude from **tropical to sub-tropical, temperate and finally alpine.**
- Soil is an equally determining factor in few regions. **Mangrove forests, swamp forests** are some of the examples where soil is the major factor.
- Topography is responsible for certain minor types e.g. **alpine flora, tidal forests, etc..**
- India's vegetation can be divided into 5 main types and 16 sub-types as given below.

A. Moist Tropical Forests

1. Tropical Wet Evergreen
2. Tropical Semi-Evergreen
3. Tropical Moist Deciduous
4. Littoral and Swamp

B. Dry Tropical Forest

1. Tropical Dry Evergreen
2. Tropical Dry Deciduous
3. Tropical Thorn

C. Montane Sub-tropical Forests

1. Sub-tropical broad leaved hill
2. Sub-tropical moist hill (pine)
3. Sub-tropical dry evergreen

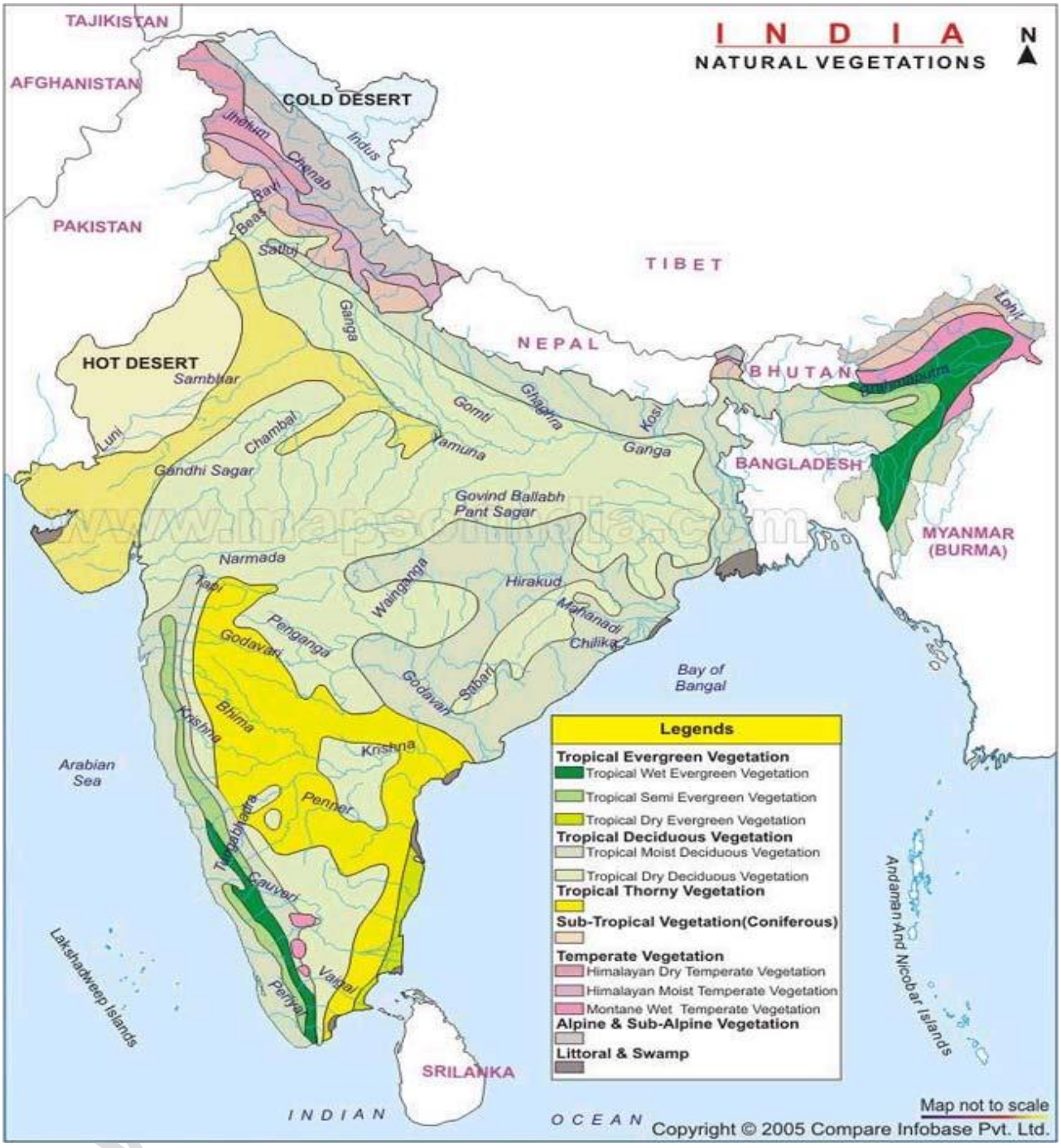
D. Montane Temperate Forests

1. Montane Wet Temperate
2. Himalayan Moist Temperate
3. Himalayan Dry Temperate

E. Alpine Forests

1. Sub-Alpine
2. Moist Alpine scrub
3. Dry Alpine scrub

Forest type in India	% of total area
Tropical Moist deciduous	37
Tropical dry deciduous	28
Tropical wet Evergreen	8
Subtropical moist	6
Tropical semi evergreen	4
Rest below – 4%	



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Moist Tropical Forests

1. Tropical Wet Evergreen
2. Tropical Semi-Evergreen
3. Tropical Moist Deciduous
4. Littoral and Swamp

Tropical Wet Evergreen Forests or Rain Forests

Climatic Conditions

- Annual rainfall exceeds 250 cm.
- The annual temperature is about 25°-27°C
- The average annual humidity exceeds 77 per cent.
- The dry season is distinctly short.

Characteristics

- Evergreen: Due to high heat and high humidity, the trees of these forests do not shed their leaves together.
- **Trees are Mesosphytic**: **Plants adopted to neither too dry nor too wet type climate.**

What are mesophytes?

- Unlike **hydrophytic plants**, such as water lily or pondweed, that grow in saturated soil or water, or **xerophytic plants**, such as cactus, that grow in extremely dry soil, mesophytes are ordinary plants that **exist between the two extremes.**
- Mesophytic environments are marked by average to hot temperatures and soil that is **neither too dry nor too wet.**
- Lofty: The trees often reach 45 – 60 metres in height.
- Thick Canopy: From the air, the tropical rain forest appears like a thick canopy of foliage, broken only where it is crossed by large rivers or cleared for cultivation.
- All plants struggle upwards (most **ephiphytes**) for sunlight resulting in a peculiar layer arrangement. The entire morphology looks like a green carpet when viewed from above.
- Less undergrowth: The sun light cannot reach the ground due to thick canopy. The undergrowth is formed mainly of bamboos, ferns, climbers, orchids, etc.

Distribution

- Western side of the Western Ghats (500 to 1370 meters above sea level).

Timber

- Hardwood: The timber of these forests is fine-grained, hard and durable.
- It has high commercial value but it is highly challenging to exploit due **to dense undergrowth, absence of pure stands and lack of transport facilities.**
- The important species of these forests are **mahogany, mesua, white cedar, jamun, canes, bamboo** etc.

Tropical Semi-Evergreen Forests

- They are **transitional forest** between tropical wet evergreen forests and tropical deciduous forests.
- They are comparatively drier areas compared to tropical wet evergreen forests.

Climatic Conditions

- Annual rainfall is 200-250 cm.
- Mean annual temperature varies from 24°C to 27°C.
- The relative humidity is about 75 per cent.
- The dry season is not short like in tropical evergreen forests.

Distribution

- Western coast
- Assam
- Lower slopes of the EasternHimalayas
- Odisha and Andamans.

Characteristics

- The semi-evergreen forests are less dense.
- They are more gregarious (living in flocks or colonies – more pure stands) than the wet evergreen forests.
- These forests are characterized by many species.
- Trees usually have **buttressed trunks with abundant epiphytes.**
- The important species are **laurel, rosewood, mesua, thorny bamboo – Western Ghats, white cedar, Indian chestnut, champa, mango**, etc. – Himalayan region.

Timber

- Hardwood: Similar to that in tropical
- evergreen forests except that these forests are less dense with **more pure stands** (timber industry here is better than in evergreen forests).

Tropical Moist Deciduous Forests

Climatic Conditions

- Annual rainfall 100 to 200 cm.
- Mean annual temperature of about 27°C
- The average annual relative humidity of 60 to 75 per cent.
- Spring (between winter and summer) and summer are dry.

Characteristics

- The trees drop their leaves during the spring and early summer when sufficient moisture is not available.
- The general appearance is bare in extreme summers (April-May).
- Tropical moist deciduous forests present irregular top storey [25 to 60 m].
- Heavily buttressed trees and fairly complete undergrowth.
- These forests occupy a much larger area than the evergreen forests but large tracts under these forests have been cleared for cultivation.

Distribution

- Belt running along the Western Ghats surrounding the belt of evergreen forests.
- A strip along the Shiwalik range including terai and bhabar from 77° E to 88° E.
- Manipur and Mizoram.
- Hills of eastern Madhya Pradesh and Chhattisgarh.
- Chota Nagpur Plateau.
- Most of Odisha.
- Parts of West Bengal and
- Andaman and Nicobar Islands.

Timber

- These provide valuable timer like **Teak.**
- The main species found in these forests are **teak, sal, laurel, rosewood, amla, jamun, bamboo, etc.**
- It is **comparatively easy to exploit these forests due to their high degree of gregariousness (more pure stands).**

Littoral and Swamp Forests

- They can survive and grow both in fresh as well as **brackish water**.

Brackish Water: *The mixture of seawater and fresh water in estuaries is called brackish water and its salinity can range from 0.5 to 35 ppt).*

- Occur in and around the deltas, estuaries and creeks prone to **tidal influences (delta or tidal forests).**
- Littoral (relating to or on the shore of the sea or a lake) forests occur at several places along the coast.
- Swamp forests are confined to the deltas of the Ganga, the Mahanadi, the Godavari, the Krishna and the Cauvery.
- Dense mangroves occur all along the coastline in sheltered estuaries, tidal creeks, backwaters, salt marshes and mudflats. It provides useful fuel wood.
  The most pronounced and the densest is the **Sunderban in the Ganga delta** where the predominant species is Sundri (Heriteera).

Timber

- It provides hard and durable timber which is used for construction, building purposes and making boats.
- The important species found in these forests are **Sundri, agar, rhizophora, screw pines, canes and palms**, etc.

Dry Tropical Forests

1. Tropical Dry Evergreen
2. Tropical Dry Deciduous
3. Tropical Thorn

Tropical Dry Evergreen Forests

Distribution

- Along the coasts of Tamil Nadu.

Climatic Conditions

- Annual rainfall of 100 cm [mostly from the north-east monsoon winds in October – December].
- Mean annual temperature is about 28°C.
- The mean humidity is about 75 per cent.
- The growth of evergreen forests in areas of such low rainfall is a bit strange.

Characteristics

- Short statured trees, up to 12 m high, with complete canopy.
- Bamboos and grasses not conspicuous.
- The important species are **jamun, tamarind, neem**, etc.
- Most of the land under these forests has been cleared for agriculture or **casuarina plantations.**

Casuarina plantation

- It resembles feathery conifer in general appearance.
- They are rapid-growing, carefree species for sites and climates as varied as coastal sand dunes, high mountain slopes, hot humid tropics, and semi-arid regions.
- They have the ability to **fix atmospheric nitrogen**. It grows 15 to 25 metres in height on an average.

Distribution

- Casuarina is the most popular farm forestry in the states of Andhra Pradesh, Tamil Nadu, West Bengal, Odisha, Maharashtra, Gujarat, and Karnataka.

Benefits

- Reduces damage in the event of natural calamities.
- Line planting in the coastal areas helps in controlling the wind force.
- It is also used for tourism promotion in view of its ornamental appearance.
- It provides top quality firewood.
- The wood is suitable for paper pulp and useful raw material for the manufacture of paper for writing, printing, and wrapping.
- It is got some serious medicinal values as well.

Wasteland development

- The characteristics which make it a suitable species for wasteland development include adaptability to wide range of habitats, fast growth, salt tolerant, drought resistant, ability to reclaim land and stabilize sand dunes.
  Intercrops such as groundnut, cucumber, watermelons, sesamum, and pulses can also be raised along with the plantation.

Tropical Dry Deciduous Forests

Climatic Conditions

- Annual rainfall is 100-150 cm.

Characteristics

- These are similar to moist deciduous forests and shed their leaves in dry season.
- The major difference is that they can grow in areas of comparatively less rainfall.
- They represent a transitional type -moist deciduous on the wetter side and thorn forests on the drier side.

- They have closed but uneven canopy.
- The forests are composed of a mixture of a **few species** of deciduous trees rising up to a height of 20 meters.
- Undergrowth: Enough light reaches the ground to permit the growth of grass and climbers.

Distribution

- They occur in an irregular wide strip
- Running from the foot of the Himalayas to Kanyakumari except in Rajasthan, Western Ghats and West Bengal.
- The important species are **teak, axle wood, rosewood, common bamboo, red sanders, laurel, satinwood,** etc.
- Large tracts of this forest have been cleared for agricultural purposes.
- These forests have suffered from over grazing, fire, etc.

Tropical Thorn Forests

Climatic Conditions

- Annual rainfall less than 75 cm.
- Humidity is less than 50 per cent.
- Mean temperature is 25°-30°C.

Characteristics

- The trees are low (6 to 10 metres maximum) and widely scattered.
- Acacias and Euphorbias are very prominent.
- The Indian wild date is common. Some grasses also grow in the rainy season.

Distribution

- Rajasthan, south-western Punjab,
- Western Haryana, Kachchh and neighbouring parts of Saurashtra.
- Here they degenerate into desert type in the Thar desert.
- Such forests also grow on the leeside of the Western Ghats covering large areas of Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil Nadu.
- The important species are **neem, babul, cactii**, etc.

Montane Sub-Tropical Forests

1. Sub-tropical broad leaved hill
2. Sub-tropical moist hill (pine)
3. Sub-tropical dry evergreen

Sub-tropical Broad-leaved Hill Forests

Climatic conditions

- Mean annual rainfall is 75 cm to 125 cm.
- Average annual temperature is 18°-21°C.
- Humidity is 80 per cent.

Distribution

- Eastern Himalayas to the east of 88°E longitude at altitudes varying from 1000 to 2000 m.

Characteristics

- Forests of **evergreen species**.
- Commonly found species are **evergreen oaks, chestnuts, ash, beech, sals and pines**.
- Climbers and epiphytes [a plant that grows non-parasitically on a tree or other plant] are common.
- These forests are not so distinct in the southern parts of the country. They occur only in the **Nilgiri and Palni hills** at 1070-1525 metres above sea level.
- It is a "stunted rain-forest" and is **not so luxuriant** as the true tropical evergreen.
- The higher parts of the Western Ghats such as Mahabaleshwar, the summits of the Satpura and the Maikal Range, highlands of Bastar and Mt. Abu in the Aravali Range carry sub-types of these forests.

Sub-tropical Moist Pine Forests

Distribution

- Western Himalayas between 73°E and 88°E longitudes at elevations between 1000 to 2000 metres above sea level.
- Some hilly regions of Arunachal Pradesh, Manipur, Naga Hills and Khasi Hills.

Timber

- **Chir or Chil** is the most dominant tree which forms pure stands.
- It provides **valuable timber** for furniture, boxes and buildings.
- It is also used for producing resin and turpentine.

Sub-tropical Dry Evergreen Forests

Distribution

- Found in the Bhabar, the Shiwaliks and the western Himalayas up to about 1000 metres above sea level.

Climatic Conditions

- Annual rainfall is 50-100 cm (15 to 25 cm in December-March).
- The summers are sufficiently hot and winters are very cold.

Characteristics

- Low scrub forest with small evergreen stunted trees and shrubs.
- Olive, acacia modesta and pistacia are the most predominant species.

Montane Temperate Forests

1. Montane Wet Temperate
2. Himalayan Moist Temperate
3. Himalayan Dry Temperate

Montane Wet Temperate Forests

Climatic Conditions

- Grows at a height of 1800 to 3000 m above sea level
- Mean annual rainfall is 150 cm to 300 cm
- Mean annual temperature is about 11°C to 14°C and the
- Average relative humidity is over 80 per cent.

Distribution

- Higher hills of Tamil Nadu and Kerala, in the Eastern Himalayan region.

Characteristics

- These are closed **evergreen forests**. Trunks have large girth.
- Branches are clothed with mosses, ferns and other epiphytes.
- The trees rarely achieve a height of more than 6 metres.

- **Deodar, Chilauni, Indian chestnut, birch, plum, machilus, cinnamomum, litsea, magnolia, blue pine, oak, hemlock,** etc. are important species.

Himalayan Moist Temperate Forests

Climatic Conditions

- Annual rainfall varies from 150 cm to 250 cm

Distribution

- Occurs in the temperate zone of the Himalayas between 1500 and 3300 metres.
- Cover the entire length of this mountain range in Kashmir, Himachal Pradesh, Uttarakhand, Darjeeling and Sikkim.

Characteristics

- Mainly composed of **coniferous species.**
- Species occur in mostly pure strands.
- Trees are 30 to 50 m high.
- **Pines, cedars, silver firs, spruce**, etc. are most important trees.
- They form high but fairly open forest with shrubby undergrowth including oaks, rhododendrons and some bamboos.

Timber

- It provides fine wood which is of much use for construction, timber and railway sleepers.

Himalayan Dry Temperate Forests

Climatic Conditions

- Precipitation is below 100 cm and is mostly in the form of snow.

Characteristics

- **Coniferous forests with xerophytic shrubs** in which **deodar, oak, ash, olive**, etc are the main trees.

Distribution

- Such forests are found in the inner
- Dry ranges of the Himalayas where south-west monsoon is very feeble.

- Such areas are in Ladakh, Lahul, Chamba, Kinnaur, Garhwal and Sikkim.

Alpine Forests

- Altitudes ranging between 2,900 to 3,500.
- These forests can be divided into: (1) sub-alpine; (2) moist alpine scrub and (3) dry alpine scrub.
- The sub-alpine forests occur lower alpine scrub and grasslands.
- It is a mixture of coniferous and broad-leaved trees in which the coniferous trees attain a height of about 30 m while the broad leaved trees reach only 10 m.
- **Fir, spruce, rhododendron**, etc. are important species.
- The moist alpine scrub is a low evergreen dense growth of rhododendron, birch etc. which occurs from 3,000 meters and extends up to snowline.
- The dry alpine scrub is the uppermost limit of scrub xerophytic, dwarf shrubs, over 3,500 meters above sea level and found in dry zone. Juniper, honeysuckle, artemesia etc. are important species.

Grassland Ecosystem in India

- The grasslands are found where rainfall is about **25-75 cm** per year.
- Grasslands are generally found in temperate climates [Steppe Grasslands – tree less]. In India, they are found mainly in the **high Himalayas**.
- The rest of India's grasslands are mainly composed of savannas [Tropical grasslands – trees like **khetri**, acacias, shrubs, cacti intersperse (scatter among or between other things) here and there].
- The major difference between Indian steppes and savannas is that all the forage (food for horses and cattle) in the steppe is provided only during the brief wet season whereas in the savannas forage is largely from grasses that not only grow during the wet season but also from the smaller amount of regrowth in the dry season.

Types of Grasslands in India

Semi-arid zone

- It covers the northern portion of Gujarat, Rajasthan (excluding Aravallis), western Uttar Pradesh, Delhi and Punjab.
- The topography is broken up by hill spurs and sand dunes.

Dry sub humid zone

- It covers the whole of peninsular India (except Nilgiri).

Moist sub humid zone

- It covers the Ganga alluvial plain in Northern India.
- The topography is level, low lying and ill-drained.
- The common trees and shrubs are Acacia arabica

Themeda

- This extends to the humid montane regions and moist sub-humid areas of Assam, Manipur, West Bengal, Uttar Pradesh, Punjab, Himachal Pradesh and Jammu and Kashmir.
- It is derived from the humid forests on account of shifting cultivation and sheep grazing.

Economic importance of Grasslands

- The livestock wealth plays a crucial role in Indian life. It is a major source of fuel, draught power, nutrition and raw material for village industries.
- Grassland biomes are important to maintain the population of livestock such as horse, mule, ass, cow, pig, sheep, goat, buffalo, camel, deer, zebra, etc.
- This huge mass of livestock needs fodder for sustenance but there is not enough of it. Only about 13 million hectares in the country are classified as permanent grazing lands. But they exist in a highly degraded state.

- **Indian Grasslands and Fodder Research Institute is at Jhansi**
- **Central Arid Zone Research institute is at Jodhpur.**

Impact of grazing

- Due to heavy grazing the mulch cover of the soil reduces and the soil is readily invaded by xerophytic plants.
- Increased areas of bare soil creates a new habitat for burrowing animals such as mice, jack-rabbits, gophers, prairie dogs, locusts etc., which render large areas of forage lands sterile.
- Soil surface is heavily trampled by cattle leading to pulverized (reduce to fine particles) top soil which is easily washed away by rain.
- Soil trampled by cattle in wet season creates puddling which reduce the percolation of

water. This leads to quick water runoff and the rate of soil erosion increases.

- Reduced percolation also lowers the ground water table leading to water scarcity and drought in dry season.
- Wind erosion becomes intense due to bare soil and this slowly leads to desertification of grasslands.
- These changes contribute to the reduction of energy flow, and the disruption of the periodicity of the primary producers.
- It results in a breakdown of the biogeochemical cycles of water, carbon and nitrogen.

Role of fire

- Fire plays an important role in the management of grasslands.
- Under moist conditions fire favors grass over trees, whereas in dry conditions fire is often necessary to maintain grasslands against the invasion of desert shrubs. Burning increases, the forage yields (burning of grasses and shrubs adds lot of nutrients to the soil).

Desert Ecosystem

- Deserts are formed in regions with **less than 25 cm** of annual rainfall.
- At high altitudes and at greater distance from the equator the deserts are cold and near the equator and at low altitudes in tropics they are hot.
- The perennial plant species like bush, cactus, fetrocactus are scattered throughout the desert biomes.
- Where soils are suitable, irrigation can convert deserts into some of the most productive agricultural lands.
- As the large volume of water passes through the irrigation system, salts may be left behind that will gradually accumulate over the years until they become limiting.

Adaptation

Desert plants conserve water by following methods -

- They are mostly shrubs.
- They have deep roots. Root system
- Spread over large area.
- Their epidermal layers are made up of
- Thick cuticle.
- Leaves are absent or reduced in size.
- In some plants leaves are modified into thorns or spines that can carry out photosynthesis.

- Leaves and stem are succulent (having thick fleshy leaves or stems adapted to storing water) and water storing.
- In some plants even the stem contains chlorophyll for photosynthesis.
- The seeds germinate only during the short rainy season.

Desert animals

- They are fast runners.
- They are nocturnal in habit to avoid the
- Sun's heat during day time.
- They conserve water by excreting
- Concentrated urine.
- Animals and birds usually have long
- Legs to keep the body away from the hot ground.
- Lizards are mostly insectivorous and can live without drinking water for several days.
- Herbivorous animals get sufficient water from the seeds which they eat.
- A few species of nocturnal rodents can live in the desert without drinking water.

Indian Desert — Thar desert (hot)

- The climate of this region is characterized by excessive drought, the rainfall being scanty and irregular.
- The winter rains of northern India rarely penetrate into the region.
- The cold season starts from about the middle of November to the middle of March.
- This season is characterized by extreme variations of temperature and the temperature is frequently below freezing point at night.
- During April to June the heat are intense, frequent scorching winds prevail with great desiccating effect.
- The relative humidity of the atmosphere is always low.
- The climate is hostile to all vegetation, only plants and animals possessing special adaptations being able to establish themselves.

Flora

- The proper desert plants may be divided into two main groups.
    - Depending directly upon on rain and
    - Those depending on the presence of subterranean water.
- The first group consists of two types:
    - The '**ephemerals**' and
    - The '**rain perennials**'.
- The ephemerals are delicate annuals, apparently free from any **xerophilous adaptations**, having slender stems and root-systems and often large flowers.

- They appear almost immediately after rain, develop flowers and fruits in an incredibly short time, and die as soon as the surface layer of the soil dries up.
- The rain perennials are visible above the ground only during the rainy season, but have a perennial underground stem.

Fauna

- It is home to some of India's most magnificent grasslands and sanctuary for a charismatic bird, the **Great Indian Bustard**.
- Among the mammal fauna, the **blackbuck, wild ass, chinkara, caracal, sandgrouse** and desert fox inhabit the open plains, grasslands, and saline depressions.
- The nesting ground of **Flamingoes** and the only known population of Asiatic Wild Ass lies in the remote part of **Great Rann, Gujarat**.
- It is the migration flyway used by cranes and flamingos.

Indian Cold Desert/Temperate Desert

- Cold desert of India includes areas of Ladakh, Leh and Kargil of Kashmir and Spiti valley of Himachal Pradesh and some parts of northern Uttaranchal and Sikkim.
- These arid areas are not affected by the Indian monsoons because they lie in the rain-shadow of the Himalayan mountain systems.
- Characterized by extreme cold weather and denuded terrain they are not suitable for plant growth.
- Isolated, scattered and over grazed herbaceous shrubs are found. Grazing period is less than 3-4 months.
- The flora and fauna is unique to the area. **Oak, pine, deodar, birch and rhododendron** are the important trees and bushes found there. Major animal includes **yaks, dwarf cows, and goats.**

Characteristics

- Severe arid conditions – Dry Atmosphere
- Temperature less than 0^0 C for most of the period drops to -50^0 C during winter.
- Mean annual rainfall less than 40 cm.
- Heavy snowfall occurs between November and March.
- Soil type - sandy to sandy loam.
- Soil pH - neutral to slight alkaline.
- Soil nutrient - Poor organic matter content.
- Soil has low water retention capacity.
- Wind erosion is more common.
- Narrow growing period, mostly during the summer.
- Due to aforesaid extreme cold conditions, growth of vegetation is slow and of stunted nature.

Desertification

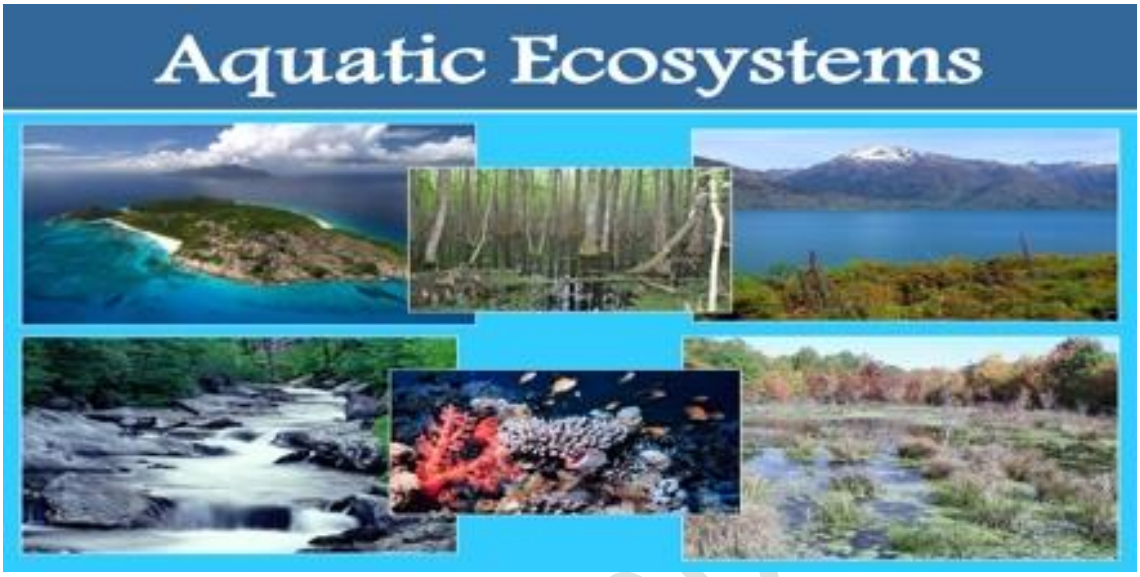
- It is the destruction of the biological potential of the land which can ultimately lead to desert like conditions.
- In arid and semiarid regions, the restoration of the fragile ecosystem is very slow, and issues like deforestation, mining enhances the desertification.
- Desertification is a main problem faced by desert adjoining areas, which stretches across parts of Rajasthan, Gujarat, Punjab and Haryana.
- The cause of this process is not climatic changes, droughts, etc. but human actions.
- Increase in population and lack of alternative employment opportunities have left the people living in the Thar Desert with no choice but to continue grazing cattle even in its inhospitable conditions.

Control measures

- India as a signatory to **United Nations Convention to Combat Desertification (UNCCD)** has submitted National Reports to UNCCD since 2000.
- The **National Action Programme for Combating Desertification** was prepared in 2001 to take appropriate action in addressing the problems of desertification.
- Some of the major programmes currently implemented that address issues related to land degradation and desertification are
    1. Integrated Watershed Management Programme (IWMP),
    2. National Afforestation Programme (NAP),
    3. National Mission for Green India (GIM),
    4. The Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS),
    5. Soil Conservation in the Catchment of River Valley Project and Flood Prone River,
    6. National Watershed Development Project for Rained Areas (NWDPRA),
    7. Desert Development Programme (DDP)
    8. Fodder and Feed Development Scheme-component of Grassland Development including Grass Reserves
    9. Command Area Development and Water Management (CADWM) programme etc.

AQUATIC ECOSYSTEM

Aquatic Ecosystems

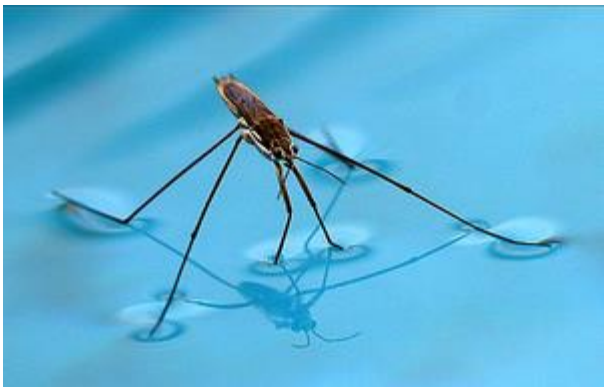


- Aquatic ecosystems refer to plant and animal communities occurring in water bodies. Aquatic ecosystems are classified on the basis of salinity into following types:
- ***Fresh water ecosystems*** — Water on land which is continuously cycling and has low salt content (always less than 5 ppt) is known as fresh water. There are two types of fresh water ecosystems: (i) Static or still water (**Lentic**) ecosystems e.g. pond, lake, bogs and swamps. (ii) Running water (**Lotic**) ecosystems e.g. springs, mountain brooks, streams and rivers.
- ***Marine ecosystems*** — the water bodies containing salt concentration equal to or above that of sea water (i.e., 35 ppt or above). Eg: shallow seas and open ocean.
- ***Brackish water ecosystems*** — these water bodies have salt content in between 5 to 35 ppt. e.g. estuaries, salt marshes, mangrove swamps and forests.

Aquatic Organisms

The aquatic organisms are classified on the basis of their zone of occurrence.

- ***Neuston:*** These organisms live at the air-water interface e.g. floating plants. Some organisms spend most of their lives on top of the air-water interface such as water striders, while others spend most of their time just beneath the air-water interlace and obtain most of their food within the water.



- E.g., beetles and back-swimmers.

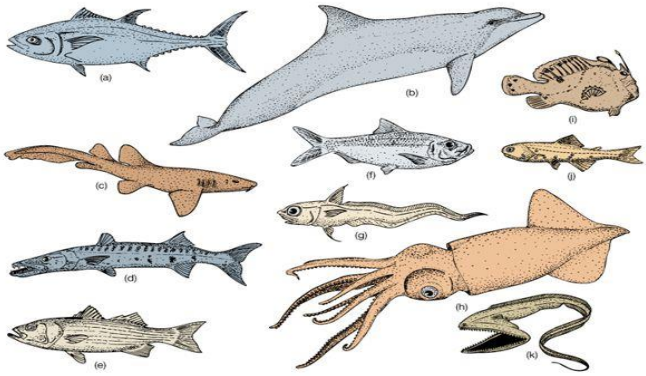
- ***Periphyton:*** These are organisms which remain attached to stems and leaves of rooted plants or substances emerging above the bottom mud such as sessile algae.

- ***Plankton:*** Microscopic floating organisms such as algae, diatoms, protozoans and larval forms are called plankton. This group includes both microscopic plants like algae (phytoplankton) and animals like crustaceans and protozoans (zooplankton).

- The locomotory power of the planktons is limited so that their distribution is controlled, largely, by currents in the aquatic ecosystems.
- ***Nekton:*** This group contains powerful swimmers that can overcome the water currents.

Nekton

Organisms capable of swimming against a current



- The animals range in size from the swimming insects to the largest blue whale.
- ***Benthos:*** The benthic organisms are those found living in the **bottom** of the water mass.

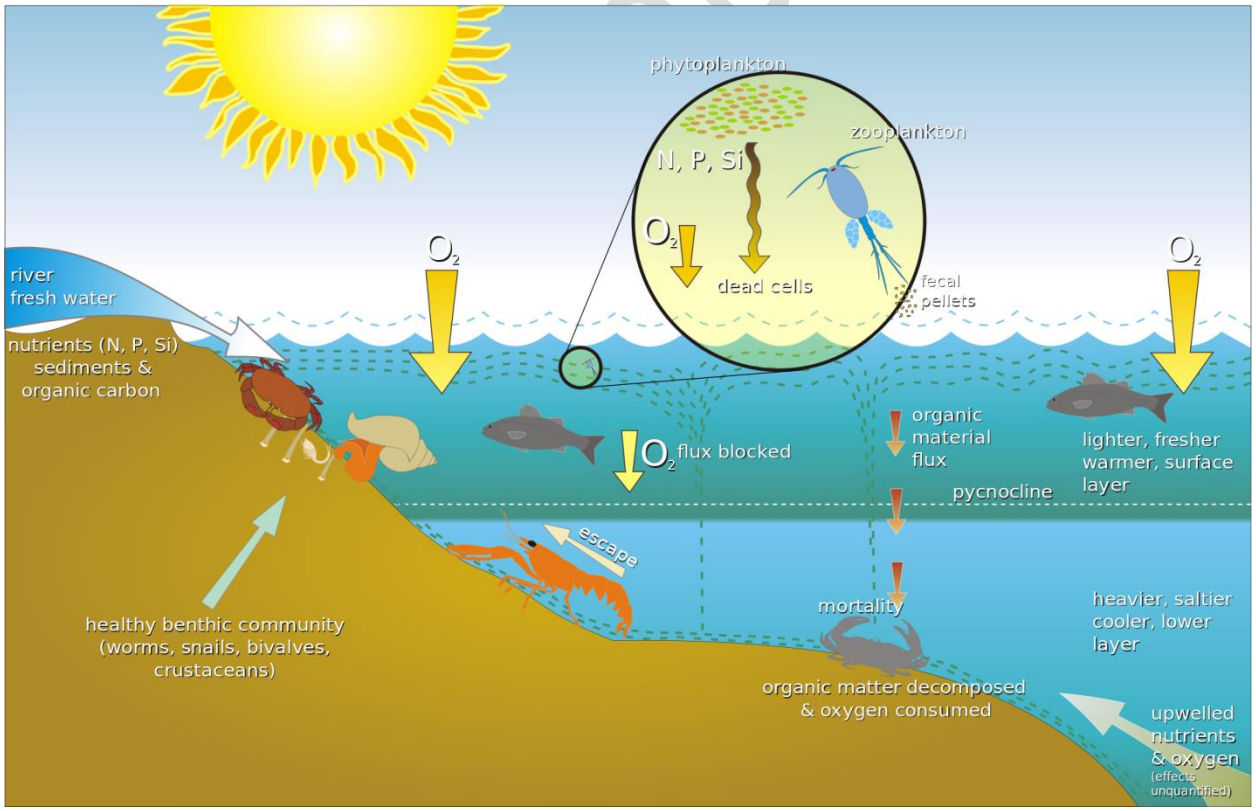


Figure 1 Benthos

High resolution – click here

Factors Limiting the Productivity of Aquatic Habitats

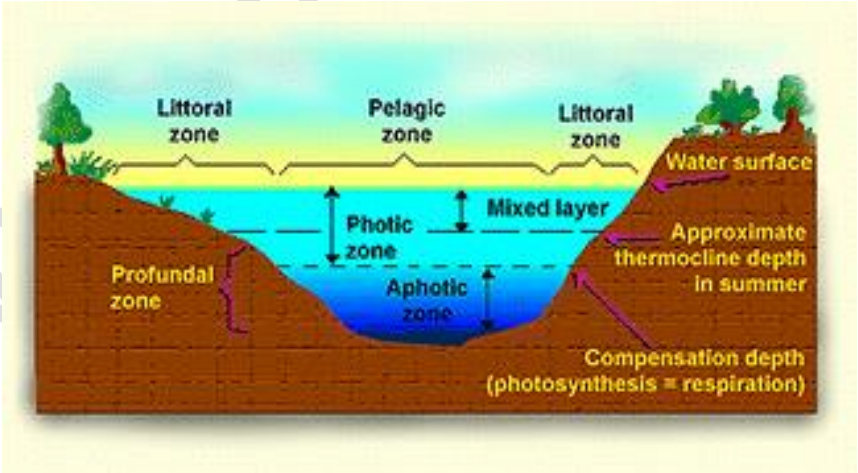
Sunlight and oxygen are the most important limiting factors of the aquatic ecosystems while temperature and humidity are limiting factors of the terrestrial ecosystem.

Sunlight

- Sunlight penetration rapidly diminishes as it passes down the column of water.
- The depth to which light penetrates a lake determines the extent of plant distribution.
- Suspended particulate matters such as clay, silt, phytoplankton, etc. make the water turbid.
- Turbidity limits the extent of light penetration and the photosynthetic activity in a significant way.
- Based on light penetration and plant distribution they are classified as photic and aphotic zones.

Photic zone

- Open water zone (or photic zone) – In this zone sunlight supports photosynthetic algae, and the species that feed upon them.
- Photic (or "euphotic") zone is the portion that extends from the lake surface down to where the light level is 1% of that at the surface. The depth of this zone depends on the transparency of water.
- It is the upper layer of the aquatic ecosystems within which photosynthetic activity is confined. Both photosynthesis and respiration activity takes place.



Aphotic zone

- The lower layers of the aquatic ecosystems, where light penetration and plant growth are restricted form the aphotic zone (**profundal zone**). Only respiration activity takes place in this zone.

- Aphotic zone extends from the end of the photic zones to bottom of the lake.

Dissolved oxygen

- In fresh water the average concentration of dissolved oxygen is 10 parts per million or 10 ppm by weight. This is 150 times lower than the concentration of oxygen in an equivalent volume of air.
- Oxygen enters the aquatic ecosystem through the air water interface and by the photosynthetic activities of aquatic plants.
- Dissolved oxygen escapes the water body through air-water interface and through respiration of organisms (fish, decomposers, zooplanktons, etc.).
- The amount of dissolved oxygen retained in water is also influenced by temperature. **Oxygen is less soluble in warm water**. **Warm water also enhances decomposer activity**. Therefore, increasing the temperature of a water body increases the rate at which oxygen is depleted from water.
- When the dissolved oxygen level falls below 3-5 ppm, many aquatic organisms are likely to die.

Winterkill

- An ice layer on the top of a water body can effectively cut off light. Photosynthesis stops but respiration continues in such water body. Thus in shallow lakes, the oxygen get depleted. Fish die, but we won't know it until the ice melts and we find floating fish. This condition is known as winterkill.

Transparency

- Transparency affects the extent of light penetration.
- Suspended particulate matters such as clay, silt, phytoplankton, etc. make the water turbid.
- Consequently, it limits the extent of light penetration and the photosynthetic activity in a significant way.

Temperature

- Water temperature changes slowly than air temperature because of higher specific heat.
- Since water temperatures are less subject to change, the aquatic organisms have **narrow temperature tolerance limit**.
- As a result, even small changes in water temperature are a great threat to the survival

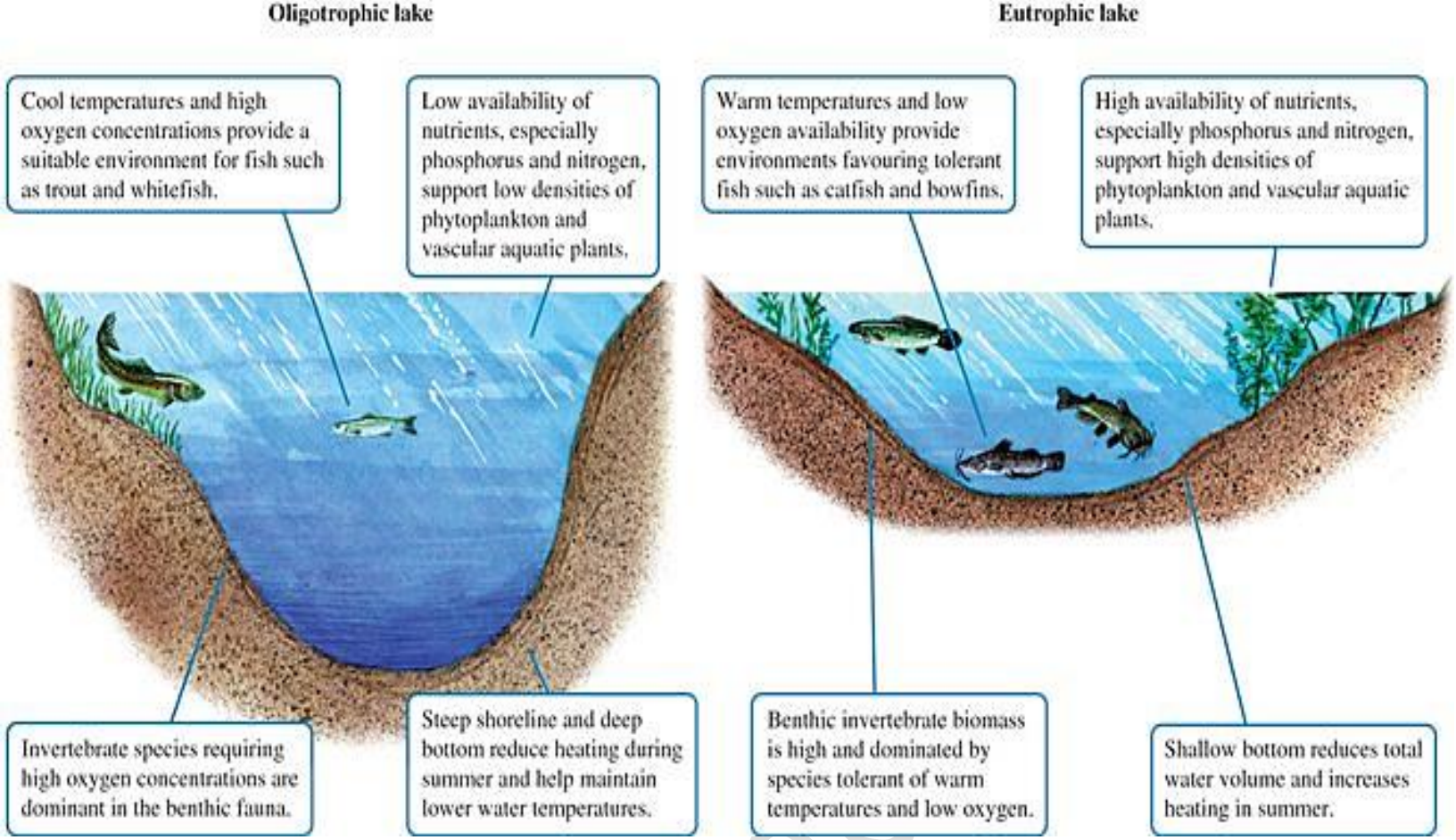
of aquatic organisms when compared to the changes in air temperatures in the terrestrial organisms.

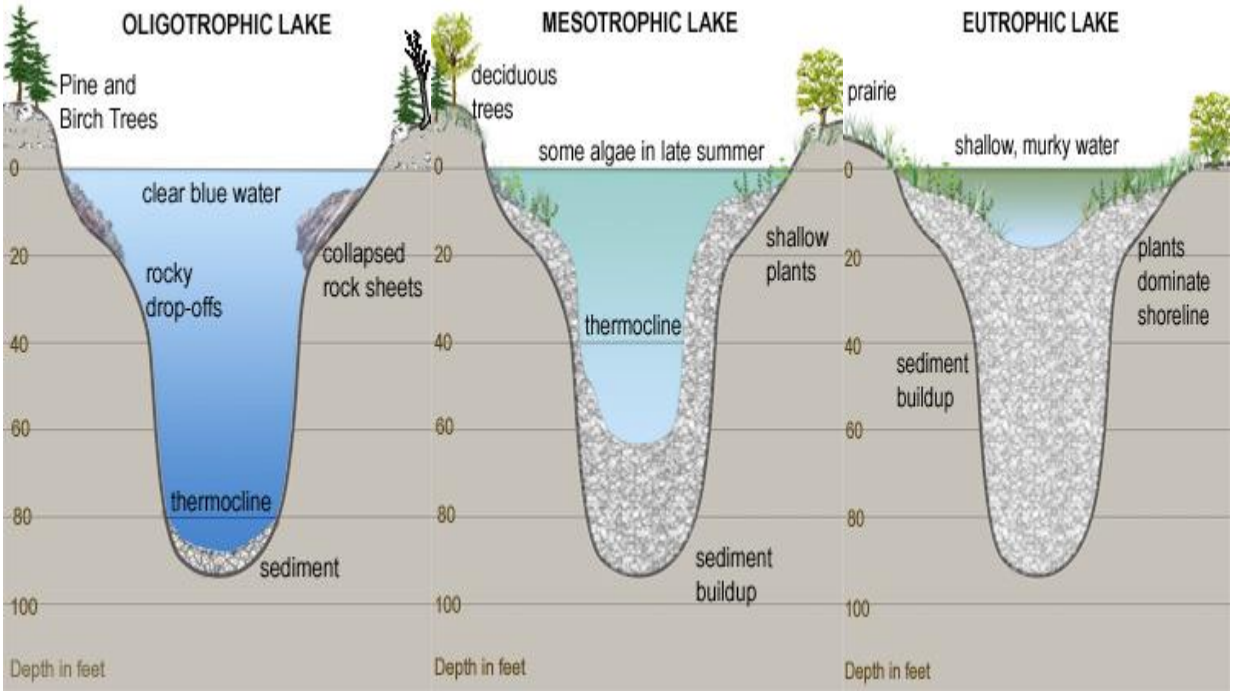
Lake Ecology

- Anybody of standing water, generally large enough in area and depth is known as lake.
- The largest lake in the world is Lake Superior in North America. Lake Baikal in Siberia is the deepest. Chilka lake of Orissa is largest lake in India.
- Three main zones can be differentiated in a lake -
    1. Peripheral zone (littoral zone) with shallow water.
    2. Open water beyond the littoral zone where water is quite deep.
    3. Benthic zone (bottom) or the floor of the lake.

Ageing of Lakes

- Lakes receive their water from surface runoff (sometimes also groundwater discharge) and along with it various chemical substances and mineral matter eroded from the land.
- Over periods spanning millennia, ageing occurs as the lakes accumulate mineral and organic matter and gradually, get filled up.
- The nutrient-enrichment of the lakes promotes the growth of algae, aquatic plants and various fauna. This process is known as natural **'eutrophication'**.
- Similar nutrient enrichment of lakes at an accelerated rate is caused by human activities (discharge of wastewaters or agricultural runoff) and the consequent ageing phenomenon is known as **'cultural eutrophication'**.
- On the basis of their nutrient content, lakes are categorized as **Oligotrophic** (very low nutrients), **Mesotrophic** (moderate nutrients) and **Eutrophic** (highly nutrient rich).
- Vast majority of lakes in India are either eutrophic or mesotrophic because of the nutrients derived from their surroundings or organic wastes entering them.


Oligotrophic lake
Eutrophic lake
Cool temperatures and high oxygen concentrations provide a suitable environment for fish such as trout and whitefish.
Low availability of nutrients, especially phosphorus and nitrogen, support low densities of phytoplankton and vascular aquatic plants.
Warm temperatures and low oxygen availability provide environments favouring tolerant fish such as catfish and bowfins.
High availability of nutrients, especially phosphorus and nitrogen, support high densities of phytoplankton and vascular aquatic plants.
Invertebrate species requiring high oxygen concentrations are dominant in the benthic fauna.
Steep shoreline and deep bottom reduce heating during summer and help maintain lower water temperatures.
Benthic invertebrate biomass is high and dominated by species tolerant of warm temperatures and low oxygen.
Shallow bottom reduces total water volume and increases heating in summer.


OLIGOTROPHIC LAKE
Pine and Birch Trees
clear blue water
rocky drop-offs
collapsed rock sheets
thermocline
sediment
0
20
40
60
80
100
Depth in feet
MESOTROPHIC LAKE
deciduous trees
some algae in late summer
shallow plants
thermocline
sediment buildup
0
20
40
60
80
100
Depth in feet
EUTROPHIC LAKE
prairie
shallow, murky water
plants dominate shoreline
sediment buildup
0
20
40
60
80
100
Depth in feet

Lakes in India

- In India, natural lakes (relatively few) mostly lie in the Himalayan region, the floodplains of Indus, Ganga and Brahmaputra.
- In the semi-arid and arid regions of western and peninsular India, tens of thousands of water bodies have been constructed over millennia.
- Lake 'Sudarshan' in Gujarat's Girnar area was perhaps the oldest man-made lake in India, dating back to 300 BC.
- Lakes are also classified on the basis of their water chemistry. Based on the levels of salinity, they are known as Freshwater, Brackish or Saline lakes (similar to that of classification of aquatic ecosystem).
- On the basis of their nutrient content, they are categorized as Oligotrophic (very low nutrients), Mesotrophic (moderate nutrients) and Eutrophic (highly nutrient rich).
- Vast majority of lakes in India are either eutrophic or mesotrophic because of the nutrients derived from their surroundings or organic wastes entering them.

Figure 2 'Sudarshan' lake

4.2.3. General Characteristics of Oligotrophic and eutrophic Lakes

Type of lake			
Sl.no	Parameter	Oligotrophic	Eutrophic
1.	Aquatic plant production	Low	High
2.	Aquatic animal production	Low	High
3.	Aquatic plant nutrient flux	Low	High
4.	Oxygen in the hypolimnion (bottom layer)	Present	Absent
5.	Depth	Tend to be deeper	Tend to be shallower
6.	Water quality for domestic & industrial uses	Good	Poor
7.	Total salts or conductance	Usually lower	Sometimes higher
8.	Number of plant and animal species	Many	Fewer

Removal of the nutrients from a lake

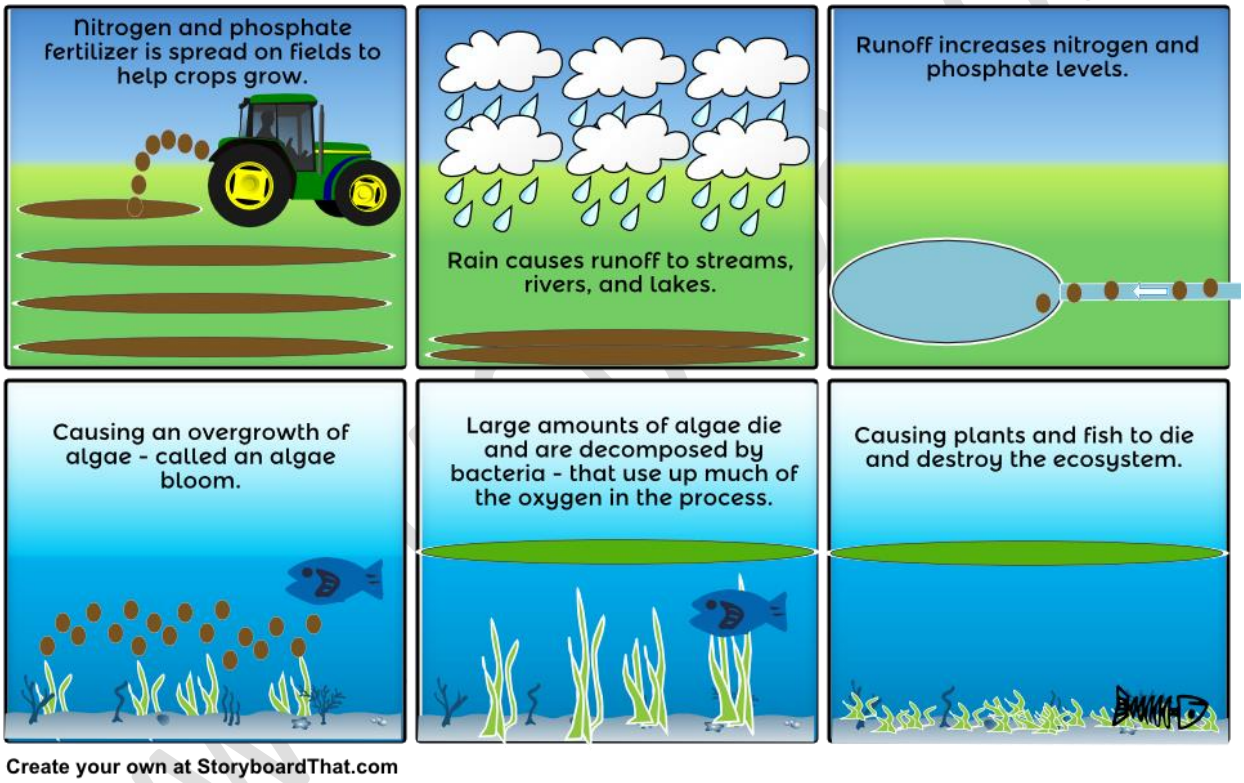
- Flushing with nutrient-poor waters.
- Deep water abstraction.
- On-site P-elimination by flocculation/flotation with water backflow, or floating Plant NESSIE with adsorbents.
- On-site algae removal by filters and P-absorbers.
- On-site algae skimming and separator thickening.
- Artificial mixing / Destratification (permanent or intermittent). ·
- Harvest of fishes and macrophytes.
- Sludge removal.

Eutrophication – Algal Bloom

- Eutrophic water body: it is a body of water rich in nutrients and so supporting a dense plant population, the decomposition of which kills animal life by depriving it of oxygen.
- Eutrophication is the response to the addition of nutrients such as **nitrates** and **phosphates** naturally or artificially, fertilizing the aquatic ecosystem.
- **Algal blooms** are the consequence of Eutrophication.
- The growth of green algae which we see in the lake surface layer is the physical identification of an Eutrophication.
- Eutrophication occurs naturally due to deposition of nutrients [such as in depositional environments] carried by flood waters. It takes over centuries for eutrophication to occur naturally.
- Similar nutrient enrichment of lakes at an accelerated rate is caused by human activities [discharge of wastewaters or agricultural runoff, Combustion of fossil fuel (produces gases —nitrogen oxides), growing urban population in the coastal areas) and the consequent phenomenon is known as **'cultural eutrophication'**. It takes only decades.
- Phytoplankton (algae and blue-green bacteria) thrive on the excess nutrients and their population explosion covers almost entire surface layer. This condition is known as **algal bloom**.
- Oxygen in aquatic ecosystem is replenished by photosynthetic aquatic plants. Algal Blooms restrict the penetration of sunlight resulting in **death of aquatic plants**, and hence restricts the replenishment of oxygen.
- The oxygen level is already depleted due to the population explosion of phytoplankton.
- Phytoplanktons are **photosynthetic during day time** adding oxygen to aquatic ecosystem. But **during nights, they consume far more oxygen** as they respire aggressively. i.e. Algal blooms accentuate the rate of oxygen depletion as the population of phytoplankton is very high.
- The primary consumers like small fish are killed due to oxygen deprivation caused by algal blooms.
- Death of primary consumers adversely affects the food chain and leads to the destruction of higher life forms.
- Further, more **oxygen is taken up by microorganisms during the decomposition process** of dead algae, plants and fishes. Due to reduced oxygen level, the remaining fishes and other aquatic organisms also die. All this eventually leads to degradation of aquatic ecosystem.
- The new anaerobic conditions [absence of oxygen] created promote growth of bacteria such as **Clostridium botulinum** which produces **toxins** deadly to aquatic organisms, birds and mammals.

Effects of Eutrophication

- ***Loss of fresh water lakes:*** Eutrophication eventually creates detritus layer in lakes and produces successively **shallower** depth of surface water. Eventually the water body is reduced into marsh whose plant community is **transformed** from an aquatic environment to recognizable **terrestrial** ecosystem. [Lakes are one of the major sources of fresh water]
- ***New species invasion:*** Eutrophication may cause the ecosystem competitive by transforming the normal limiting nutrient to abundant level. This cause shifting in species composition of ecosystem.
- ***Toxicity:*** Some algal blooms when died or eaten, release **neuro & hepatotoxins** which can kill aquatic organism & pose threat to humans. E.g. **Shellfish poisoning**.



- ***Loss of coral reefs:*** Occurs due to decrease in water transparency (increased turbidity).
- Affects navigation due to increased turbidity; creates colour (yellow, green, red), smell and water treatment problems; increases biomass of inedible toxic phytoplankton, benthic and epiphytic algae and bloom of gelatinous zooplankton.

Mitigation of Eutrophication

Checking water pollution is the ultimate solution to eutrophication.

- Treating Industrial effluents domestic sewage to remove nutrient rich sludge through waste water processing.
- Riparian buffer: Interfaces between a flowing body of water and land created near the waterways, farms, roads, etc. in an attempt to filter pollution. Sediments and nutrients are deposited in the buffer zones instead of deposition in water [Wetlands, estuaries are natural riparian buffers].
- Increase in efficiency of nitrogen & phosphorous fertilizers and using them in adequate levels.
- Nitrogen testing & modeling: N-Testing is a technique to find the optimum amount of fertilizer required for crop plants. It will reduce the amount of nitrogen lost to the surrounding area.
- Encouraging organic farming.
- Reduction in nitrogen emission from vehicles and power plants.

Harmful Algal Blooms

- Algae or phytoplankton are microscopic organisms that can be found naturally in coastal waters.
- They are major producers of oxygen and food for many of the animals that live in these waters.

- When environmental conditions are favorable for their development, these cells may multiply rapidly and form high numbers of cells and this is called an algal bloom.
- Water temperature has also been related to the occurrence of algal blooms, with unusually **warm water being conducive to blooms**.
- A bloom often results in a color change in the water. Algal blooms can be any color, but the most common ones are red or brown. These blooms are commonly referred to as **red or brown tides**.
- Most algal blooms are not harmful but some produce toxins and do affect fish, birds, marine mammals and humans. The toxins may also make the surrounding air difficult to breathe. These are known as Harmful Algal Blooms (HABs).

Use of Algae

- Most species of algae or phytoplankton serve as the energy producers at the base of the food web, without which higher life on this planet would not exist.

Red Tide

- Red tide is a common name for a phenomenon known as an algal bloom (large concentrations of aquatic microorganisms) when it is caused by a few species of dinoflagellates and the bloom takes on a red or brown color.
- Blooms can appear greenish, brown, and even reddish orange depending upon the type of organism, the type of water, and the concentration of the organisms.
- The term "red tide" is a misnomer because blooms are not always red, they are not associated with tides, they are usually not harmful, and some species can be harmful or dangerous at low cell concentrations that do not discolor the water.

Causes of these blooms

- When several colonies start combining rapidly when conditions such as nutrient concentrations, salinity and temperature are optimal.
- Nutrient enrichment and warm waters.
- **Nutrient enrichment of water** - especially phosphates and nitrogen, is often the result of pollution from nonpoint sources and can cause algal blooms.
- **Water temperature** - unusually warm water is conducive to blooms.

HABs danger to fish and humans

- Depletes oxygen in water and lead to low dissolved oxygen levels.

How it depletes oxygen?

- When masses of algae die and decompose, the decaying process can deplete oxygen in the water, causing the water to become so low in oxygen.
- When oxygen levels become too low, fish suffocate and die.the death of fishes further deplete oxygen.
- Some algae species in blooms produce potent neurotoxins that can be transferred through the food web where they affect and even kill the higher forms of life such as zooplankton, shellfish, fish, birds, marine mammals, and even humans that feed either directly or indirectly on them.

HAB's an environmental hazard?

- Harmful Algal Blooms are considered an environmental hazard because these events can make people sick when contaminated **shellfish or finfish** are eaten, or when people breathe aerosolized HAB toxins near the beach.
- HAB events adversely affect commercial and recreational fishing, tourism, and valued habitats, creating a significant impact on local economies and the livelihood of coastal residents.

HABs and Climate Change

- Because the growth, toxicity, and distribution of harmful algal bloom (HAB) species are all tied to the environment, changes in climate can change the occurrence, severity, and impacts of HAB events.

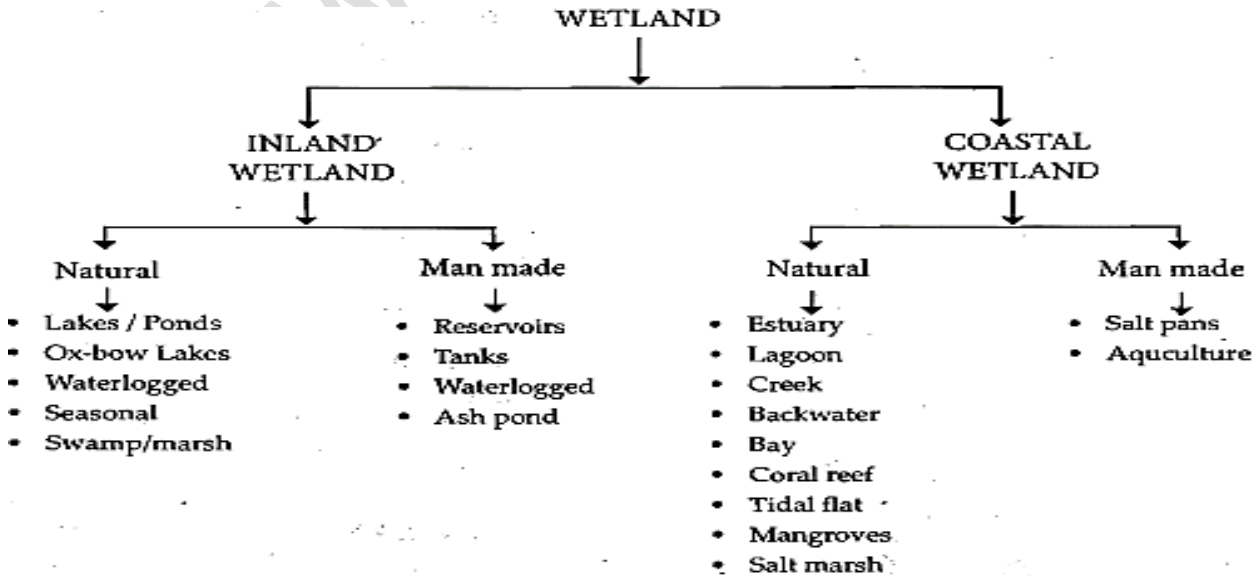
Wetland Ecosystem

- A **wetland** is a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct **ecosystem**.
- Wetlands are **transition zones** between terrestrial and aquatic ecosystems. E.g. Mangroves, lake littorals (marginal areas between highest and lowest water level of the lakes), floodplains (areas lying adjacent to the river channels beyond the natural levees and periodically flooded during high discharge in the river) and other marshy or swampy areas.
- These habitats experience periodic flooding from adjacent deep water habitats and therefore support plants and animals specifically adapted to such shallow flooding or water logging.

India's wetland

- **Waterlogged soil**, adapted plant life (**hydrophytes**) and **hydric soils (not enough O2**) are the chief characteristics of wetlands.
- India has totally 27,403 wetlands, of which 23,444 are inland wetlands and 3,959 are coastal wetlands.
- Wetlands occupy 18.4% of the country's area of which 70% are under **paddy cultivation**.
- Natural wetlands in India range from high altitude wetlands in Himalayas; flood plains of the major river systems; saline and temporary wetlands of the arid and semi-arid regions; coastal wetlands such as **lagoons, backwaters, estuaries, mangroves**, swamps and coral reefs, and so on.

Wetland's classification



Functions of Wetlands

- Habitat to aquatic plants and animals and also to numerous species of birds, including migratory species.
- Filtration of sediments and nutrients from surface water.
- Nutrients recycling, water purification, floods mitigation
- Maintenance of stream flow
- Ground water recharging
- Provide drinking water, fish, fodder, fuel, etc.
- Control rate of runoff in urban areas
- Buffer shorelines against erosion
- Comprise an important resource for sustainable
- Tourism, recreation and cultural heritage

Reasons for depletion

- Conversion of lands for agriculture
- Overgrazing
- Removal of sand from beds
- Aqua culture, Habitat Destruction and Deforestation
- Pollution - Domestic waste, Agricultural runoff, Industrial effluents
- Climate change

Mitigation

- It is the replacement of unavoidably lost wetland resources with created or restored wetlands, with the goal of replacing as fully as possible the functions and public benefits of the lost wetland.
- Survey and demarcation
- Protection of natural regeneration
- Artificial regeneration
- Protective measures, Afforestation (percentage survival to be indicated)
- Weed control
- Soil conservation measures & afforestation
- Wildlife conservation
- Removal of encroachments
- Eutrophication abatement
- Environmental awareness

Distinction from Lakes

- Ministry of Environment, forest and climate change doesn't differentiate between lakes and wetlands.
- The National Lake Conservation Programme (NLCP) considers lakes as standing water bodies which have a minimum water depth of 3 m, generally cover a water spread of more than ten hectares, and have no or very little aquatic vegetation (macrophytes).
- Wetland has excessive growth of macrophytes (both submerged and free-floating) which affects the water quality adversely and interferes with the utilization of the water body.
- Marginal aquatic vegetation (wetlands), inhabiting waterlogged soils, checks erosion.
- Wetlands (generally less than 3 m deep over most of their area) are usually rich in nutrients (derived from surroundings and their sediments) and have abundant growth of aquatic macrophytes.
- They support high densities and diversity of fauna, particularly birds, fish and macro invertebrates, and therefore, have high value for biodiversity conservation. These shallow lakes are rightfully categorized as wetlands.
- Lakes are generally less important when compared to wetland from the viewpoint of ecosystem and biodiversity conservation.

National Wetlands Conservation Programme (NWCP)

- NWCP was implemented in the year 1985-86.
- Under the programme, 115 wetlands (Annexure) have been identified by the Ministry which requires urgent conservation and management interventions.

Aim

- Conservation of wetlands to prevent –
    - Further degradation
    - Ensuring of wise use of wetlands for the benefit of local communities and overall conservation of biodiversity.

Objectives

- To lay down policy guidelines for conservation and management of wetlands in the country.
- to undertake intensive conservation measures in priority wetlands
- To monitor implementation of the programme.

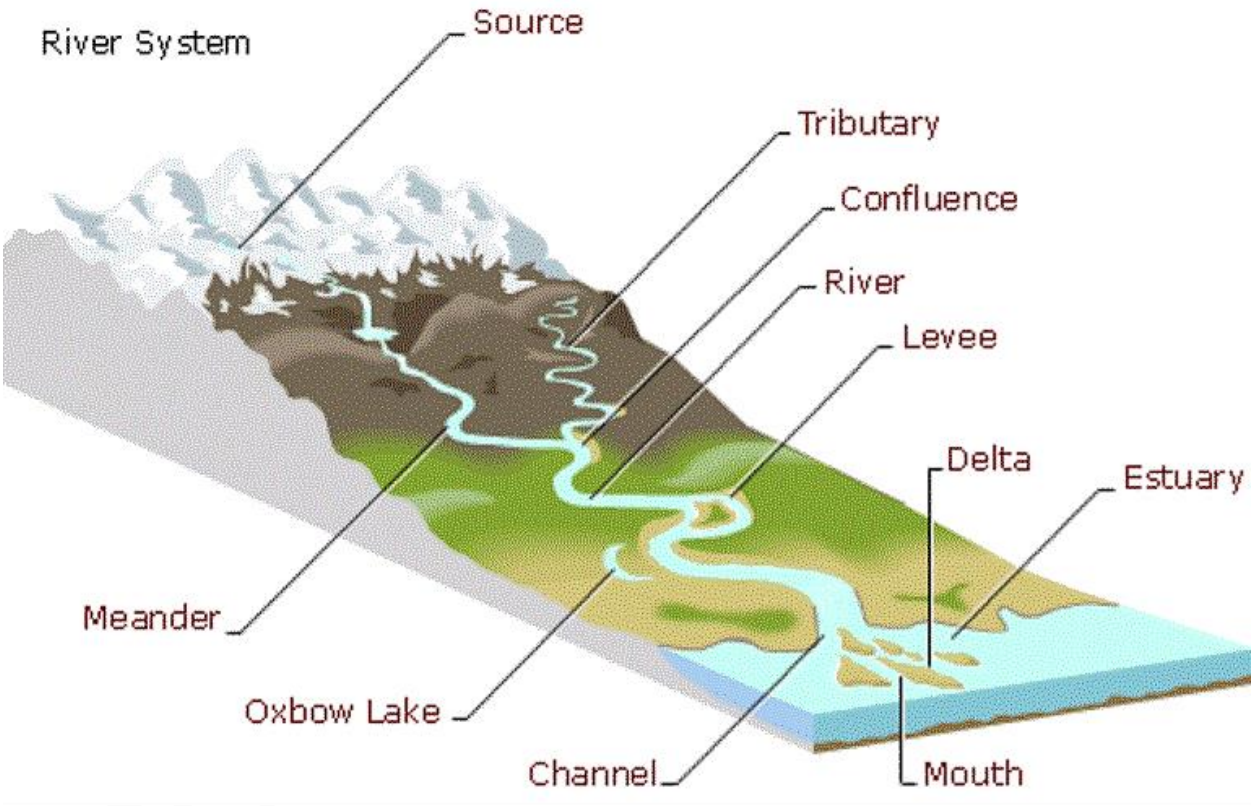
- To prepare an inventory of Indian wetlands.

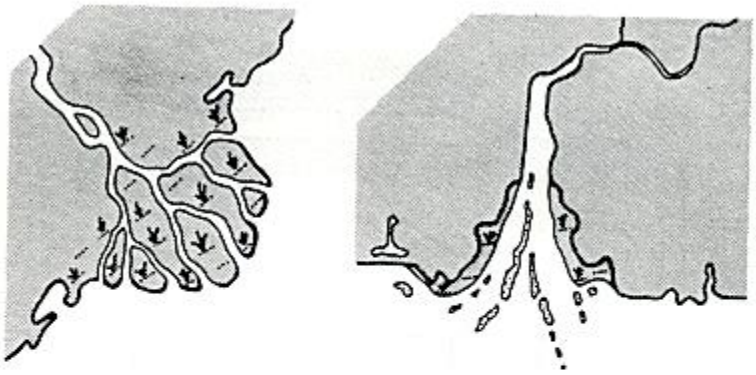
Criteria for Identification of Wetlands of National Importance

- Same as those prescribed under the 'Ramsar Convention on Wetlands' and are as given below:
- Sites containing representative, **rare or unique wetland types**
  (i) If it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region
- Criteria based on **species and ecological communities**
  (ii) If it supports vulnerable, endangered, or critically endangered species; or threatened ecological communities.
  (iii) If it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
  (iv) If it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
- Specific criteria based on **water birds**
  (v) If it regularly supports 20,000 or more water birds.
  (vi) If it regularly supports 1% of the individuals in a population of one species or subspecies of water birds.
- Specific criteria based on **fish**
  (vii) If it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
  (viii) If it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend. Specific criteria based on water/life and culture
  (ix) If it is an important source of food and water resource, increased possibilities for recreation and eco-tourism, improved scenic values, educational opportunities, conservation of cultural heritage (historic or religious sites).

Estuarine Ecosystem

- An estuary is a place where a river or a stream opens into the sea (mouth of the river).
- It is a partially enclosed coastal area of brackish water (salinity varies between 0-35 ppt) with one or more rivers or streams flowing into it, and with a free connection to the open sea.
- At the estuaries, fresh water carrying fertile silt and runoff from the land mixes with the salty sea water.
- Estuaries form a **transition zone (ecotone)** between river environments and maritime environments.
- Examples of estuaries are **river mouths, coastal bays, tidal marshes, lagoons and deltas**.





DELTA

- large sediment yield
- stable or rising coast
- sea level declining
- low tidal wave

ESTUARY

- low sediment yield
- subsiding coast
- sea level rising
- high tidal wave
- original channel formed by glaciers or formerly larger rivers

- Estuaries are formed due to rise in sea level, movement of sand and sandbars, glacial processes and tectonic processes.
- All the plants and animals in the estuaries are subjected to variations in salinity to which they are adapted (osmoregulation).
- Estuaries are greatly influenced by tidal action. They are periodically washed by sea water once or twice a day based on the number of tides.
- In some narrow estuaries, **tidal bores** are significant. Tidal bores cause great damage to the estuarine ecology.

Importance of Estuaries

- They are the **most productive** (more productive than wetlands) water bodies in the world because of the mixing of fresh water and saline water zone where marine organisms of both the ecosystems meet.

*Ecotone regions (transitional zones) like **mangroves, wetlands, estuaries, grasslands** etc. have far greater productivity compared to natural ecosystems like forest ecosystem, ocean ecosystem, pond ecosystem, riverine ecosystem, desert ecosystem etc. This is because of the wide ranging species from the adjacent ecosystems being present in the ecotone.*

- An estuary has **very little wave action**, so it provides a calm refuge from the open sea and hence becomes ideal for the survival of numerous aquatic species.
- Estuaries are **most heavily populated areas** throughout the world, with about 60% of

the world's population living along estuaries and the coast.

- The vast mangrove forests on the sea ward side of an estuary act as barrier for the costal habitat **to check the wind speed during cyclones** and high velocity landward winds.
- Precipitation of clay and alluvium particles in estuarine region is high because of the exposure to saline water (saline water precipitates fine alluvium).
- Estuaries **store and recycle Nutrients,** traps sediment and form a **buffer** between coastal catchments and the marine environment.
- They also absorb, trap and detoxify pollutants, acting as a **natural water filter**.
- Estuaries with their wetlands, creeks, lagoons, mangroves and sea-grass beds are rich in natural resources including fisheries.
- They are deep and well protected from marine transgressions and hence they are ideal locations for the construction of **ports and harbours**.
- The banks of estuarine channels form a **favored location for human settlements**, which use the estuaries for fishing and commerce, but nowadays also for dumping civic and industrial waste.

Differences between Lagoon and Estuary

- A lagoon is a stretch of salt water separated from the sea by a low sandbank or coral reef.
- Example - Backwaters in Kerala are mostly lagoons where sea water flows inwards through a small inlet that is open towards the sea.
- The main difference between lagoons and estuaries is in the flow dynamics of the water bodies: in estuaries, the water flows fast and strong, while in lagoons the water is shallower and flows sluggishly.
- Estuaries are usually deeper than lagoons. Also, lagoons mostly don't have any fresh water source while the estuaries have at least one. Lagoons more saline than estuaries.
- Lagoons are formed due to fall in sea levels (coastline of emergence. E.g. Kerala Coast) whereas estuaries are mostly formed due to rise in sea levels (coastline of submergence. E.g. Konkan coast)

Try to find estuary and lagoon in this diagram

Estuarine Vegetation

- Only certain types of plants and animals specially adapted to the "brackish" estuarine waters flourish in the estuaries.
- Factors influencing the growth and distribution of organism in an estuary are - its salinity and the amount of flooding.
- Estuaries support diverse habitats, such as mangroves, salt marshes, seagrass, mudflats etc.
- Estuaries are very dynamic and productive ecosystems since the river flow, tidal range and sediment distribution is continuously changing in them.
- In general the phytoplankton's of estuaries are diatoms, dinoflagellates, green algae, blue-green algae.
- Towards the sea coast of the estuaries there are large algae and sea grasses. Near the mouth of the rivers and deltas there are mangrove forests.
- Estuaries are homes to all kind of terrestrial or land-based plants and animals, such as wood storks, pelicans, coniferous and deciduous trees and butterflies.
- Estuaries are also homes to unique aquatic plants and animals, such as sea turtles, sea lions, sea catfish, saltworts, eelgrass, saltgrasses, cordgrasses, sea grass, sedge, bulrush etc.

Figure 3 sea turtle

Figure 4 saltwort

Figure 5 eelgrass

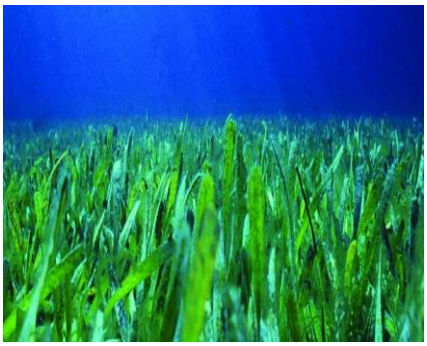


Figure 6 salt grasses *Figure 7 seagrass* *Figure 8 Bulrush*

India Estuarine Ecosystem

- The Country has 14 major, 44 mediums and 162 minor rivers drains into the sea through various estuaries.
- Major estuaries occur in the **Bay of Bengal**. Many estuaries are locations of some of the major seaports.
- Most of the India's major estuaries occur on the east coast. In contrast, the estuaries on the west coast are **smaller** (In environmental studies, deltas are considered as sub sections of estuaries).
- Two typical examples of estuaries on the west coast are the **Mandovi** and **Zuari estuaries**.

Issues of Indian Estuarine ecosystem

- Modifications of the estuarine catchments results in changes in water flow in various estuaries, either far in excess or much lower than required.
- Example - Hooghly, Narmada, Krishna, Godavari, Pulicat etc.
- Pollution through industries and combined city sewage discharge.
- Recreational boating and fishing.
- Navigation, dredging and shipping (e.g. Hooghly)
- Expansion of urban and rural settlements, mining & industries, agriculture and dumping of solid wastes.
- Over exploitation of target fish stock due to increased demand.
- Reclaiming the fringed areas for intensive aquaculture in pens.
- Obstructing the migratory routes of fish and prawn recruitment (e.g., Chilka, Pulicat)
- Polluting the environment through feeding of stocked fish and prawn in pens (Chilka)
- Destruction of biodiversity through prawn seed collection and operation of small meshed nets (e.g., Hooghly, Chilka, Pulicat)
- Submergence of catchment areas due to rise in water level.

Mangroves

- Mangroves represent a characteristic littoral (near the sea shore) forest ecosystem.
- These are **mostly evergreen** forests that grow in sheltered low lying coasts, estuaries, mudflats, tidal creeks backwaters (coastal waters held back on land), marshes and lagoons of tropical and subtropical regions.
- Mangroves **grow below the high water level of spring tides**. The best locations are where **abundant silt** is brought down by rivers or on the backshore of accreting sandy beaches.
- Since mangroves are located between the land and sea they represent the best example of ecotone.
- Mangroves are shrubs or small trees that grow in coastal saline or brackish water.
- Mangroves are salt tolerant trees, also called **halophytes**, and are adapted to life in harsh coastal conditions.

- Mangrove vegetation facilitates **more water loss**. Leaves are thick and contain salt secreting glands. Some block absorption of salt at their roots itself.
- They contain a **complex salt filtration system** and complex root system to cope with salt water immersion and wave action.
- They are adapted to the **low oxygen (anoxic)** conditions of waterlogged mud.
- They produce **pneumatophores (blind roots)** to overcome respiration problem in the anaerobic soil conditions.
- Mangroves occur worldwide in the tropics and subtropics, mainly between latitudes 25° N and 25° S.
- They require high solar radiation to filter saline water through their roots. This explains why mangroves are confined to only tropical and sub- tropical coastal waters.
- Mangroves occur in a variety of configurations. Some species (e.g. **Rhizophora**) send arching **prop roots** down into the water. While other (e.g. **Avicennia**) sends **vertical "Pneumatophores"** or air roots up from the mud.
- Adventitious roots which emerged from the main trunk of a tree above ground level

are called **stilt roots**.

- Mangroves exhibit **Viviparity** mode of reproduction. i.e. seeds germinate in the tree itself (before falling to the ground).
- This is an adaptive mechanism to overcome the problem of germination in saline water.

Importance of Mangroves

- Mangroves are highly productive ecosystems and the trees may vary in height from 8 to 20 m. They protect the shoreline from the effect of cyclones and tsunamis.
- Mangroves act as a filter trapping suspended mud and sand carried by rivers which leads to delta formations around estuaries.
- They are breeding and spawning ground for many commercially important fishes.
- They moderate monsoon tidal flows.
- Prevents costal soil erosion.
- Enhance the natural recycling of nutrients.
- It supports numerous flora, avifauna and wild life.
- Supplies wood, fire wood, medicinal plants and edible plants to local people

Mangrove profile in India

Sunderban

- Largest single block of tidal holophytic mangroves of the world.
- Major species of Sunderbans - Herritiera fames, Rhizophora spp., Bruguiera spp., Ceriops decandra, Sonneratia spp. and Avicennia spp., Nypa fruticans are found along the creeks.
- It is famous for the Royal Bengal Tiger and crocodiles.

Mangroves of Bhitarkanika

- It is the second largest mangrove forest in the Indian sub-continent
- High concentration of typical mangrove species and high genetic diversity.

- Mangrove swamps occur in profusion in the intertidal mudflats on both sides of the creeks in the Godavari-Krishna deltaic regions of Andhra Pradesh.
- **Mangroves of Pichavaram and Vedaranyam** - degraded because of construction of aquaculture ponds and salt pans.
- **West coast of India** has mostly scrubby and degraded mangroves along the intertidal

region of estuaries and creeks in Maharashtra, Goa and Karnataka.

- **Kerala coast** - is very sparse and thin.
- **Gujarat (north-west coast)** - mangroves Avicennia marine, Avicennia officinalis and Rhizophora mucronata are found mainly in Gulf of Kachchh and the Kori creek.
- Mangroves are of scrubby type with stunted growth, forming narrow, discontinuous patches on soft clayey mud.
- The condition of the mangroves is improving especially in the Kori creek region, which is a paleodelta of the Indus River.
- In size, mangroves range from bushy stands of dwarf mangroves found in Gulf of Kuchchh, to taller stands found in the Sunderbans.

Coral Reefs

- Coral reefs are built by and made up of thousands of tiny animals—**coral "polyps"**—that are related to **anemones and jellyfish.**

- Polyps are **shallow water organisms** which have a soft body covered by a **calcareous skeleton**. The polyps extract calcium salts from sea water to form these hard skeletons.
- The polyps live in colonies fastened to the rocky sea floor.
- The tubular skeletons grow upwards and outwards as a cemented calcareous rocky mass, collectively called **corals.**
- When the coral polyps die, they shed their skeleton [coral] on which new polyps grow.
- The cycle is repeated for over millions of years leading to accumulation of layers of corals [shallow rock created by these depositions is called **reef**].
- These layers at different stages give rise to various marine landforms. One such important landform is called **coral reef.**
- Coral reefs over a period of time transform or evolve into **coral islands (Lakshadweep).**
- The corals occur in different forms and colors, depending upon the **nature of salts** or constituents they are made of.
- Small marine plants **(algae)** also deposit calcium carbonate contributing to coral growth.

Coral Reef Relief Features

- **Fringing reef, barrier reef** and **atoll (coral islands are formed on atolls)** are the most important relief features.

Fringing Reefs (Shore Reefs)

- Fringing reefs are reefs that **grow directly from a shore**. They are located very **close** to land, and often form a **shallow lagoon** between the beach and the main body of the reef.
- A fringing reef runs as a narrow belt [1-2 km wide]. This type of reef grows from the deep sea bottom with the seaward side sloping steeply into the deep sea. Coral polyps do not extend outwards because of **sudden and large increase in depth**.

Figure 9 Island with fringing reef off Yap, Micronesia

- The fringing reef is by far the ***most common*** of the three major types of coral reefs, with numerous examples in all major regions of coral reef development.
- Fringing reefs can be seen at the New Hebrides Society islands off Australia and off the southern coast of Florida.

Barrier Reefs

Figure 10 Fringing reef

- Barrier reefs are **extensive linear reef** complexes that **parallel a shore**, and are separated from it by **lagoon**.
- This is the **largest (in size, not distribution)** of the three reefs, runs for hundreds of kilometres and is several kilometres wide. It extends as a broken, irregular ring around the coast or an island, running almost parallel to it.
- Barrier reefs are **far less common** than fringing reefs or atolls, although examples can be found in the tropical Atlantic as well as the Pacific.
- The **1200-mile long Great Barrier Reef** off the NE coast of Australia is the world's largest example of this reef type.
- The GBR is not actually a single reef as the name implies, but rather a very large complex consisting of **many reefs**.

Atolls

- An atoll is a roughly circular (annular) oceanic reef system surrounding a large (and **often deep) central lagoon**.
- The lagoon has a depth 80-150 meters and may be joined with sea water through a number of channels cutting across the reef.
- Atolls are located at **great distances** from deep see platforms, where the submarine features may help in formation of atolls, such as a **submerged island or a volcanic cone** which may reach a level suitable for coral growth.
- An atoll may have any one of the following three forms-
    1. **true atoll—a circular reef enclosing a lagoon with no island;**
    2. **an atoll surrounding a lagoon with an island;**
    3. **a coral island or an atoll island which is, in fact, an atoll reef, built by the process of erosion and deposition of waves with island crowns formed on them.**
- Atolls are **far more common in the Pacific** than any other ocean.
- The **Fiji atoll** and the Funafuti atoll in the Ellice/Island are well known examples of atolls.
- A large number of atolls also occur in the **Lakshadweep Islands.**
- In the South Pacific, most atolls occur in mid-ocean. Examples of this reef type are common in **French Polynesia**, the **Caroline and Marshall Islands**, **Micronesia**, and the **Cook Islands.**
- The Indian Ocean also contains numerous atoll formations. Examples are found in the **Maldives** and **Chagos island groups,** the **Seychelles,** and in the **Cocos Island group**.

Functions of Coral Reefs

- Corals are called the **rainforests of the ocean** because of their high biodiversity and productivity.
- Coral reefs are natural protective barriers against erosion and storm surge.
- The coral animals are highly adapted for capturing plankton from the water, thereby capturing nutrients.
- Largest biogenic calcium carbonate producer on earth.
- They provide **substrate for mangroves**.
- Coral reefs provide habitat for a large variety of animals and plants.

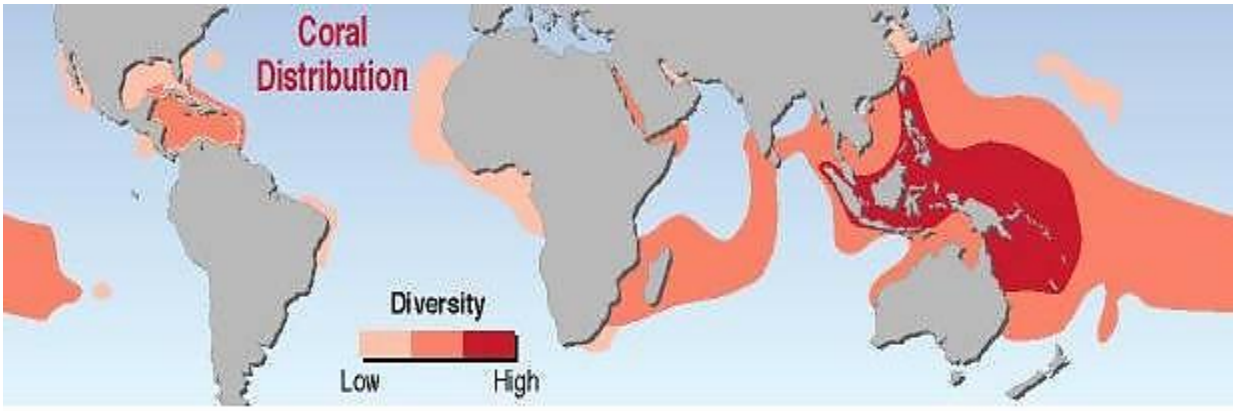
Ideal Conditions for Coral Growth

- **Stable climatic conditions:** Corals are highly susceptible to quick changes. They grow in regions where climate is significantly stable for a long period of time.
- **Perpetually warm waters:** Corals thrive in **tropical waters** [between 30°N and 30°S latitudes, temperature of water is around 20°C] where diurnal and annual temperature ranges are very narrow.

[Explain why coral reefs are absent on west coast of tropical continents? Because of Cold Ocean Currents – corals like warm waters and hate cold waters]

- **Shallow water:** Coral require fairly good amount of **sunlight** to survive. The ideal depths for coral growth are 45 m to 55 m below sea surface, where there is abundant sunlight available.
- **Clear salt water:** Clear salt water is suitable for coral growth, while both fresh water and highly saline water are harmful.
- **Abundant Plankton:** Adequate supply of oxygen and microscopic marine food, called **plankton [phytoplankton]**, is essential for growth. As the plankton is more abundant on the **seaward side**, corals grow rapidly on the seaward side.
- **Little or no pollution:** Corals are highly fragile and are vulnerable to climate change and pollution and even a minute increase in marine pollution can be catastrophic.

Distribution of Coral Reefs



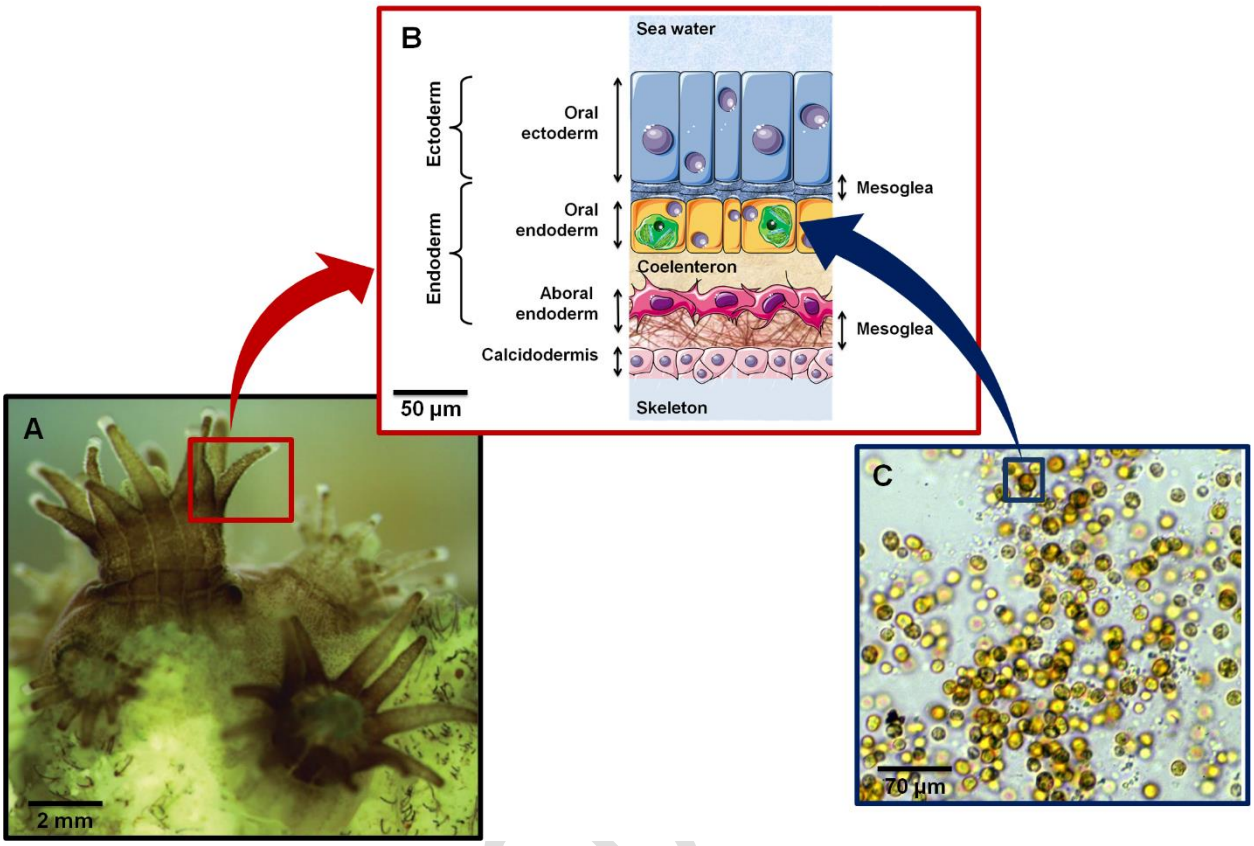
Corals and Zooxanthellae

- Many invertebrates, vertebrates, and plants live in close association with corals, with **tight resource coupling and recycling**, allowing coral reefs to have extremely high productivity and biodiversity, such that they are referred to as **'the Tropical Rainforests of the Oceans'.**
- Scleractinian corals build skeletons of calcium carbonate **sequestered** from the water.
- Scleractinian corals come under **Phylum Cnidaria**, and they receive their nutrient and energy resources in two ways.
    1. They use the traditional cnidarian strategy of capturing tiny planktonic organisms with their tentacles (All about Phylum Cnidaria is given in NCERT).
    2. Having a symbiotic relationship with a **single cell algae** known as **ZOOXANTHELLAE.**

- Zooxanthellae are **autorophic [prepare their own food] microalgaes** belonging to various taxa in the **Phylum Dinoflagellata.**
- **Coral = Phylum Cnidaria.**

Zooxanthellae = Phylum Dinoflagellata.

Symbiotic Relationship between Corals and ZOOXANTHELLAE



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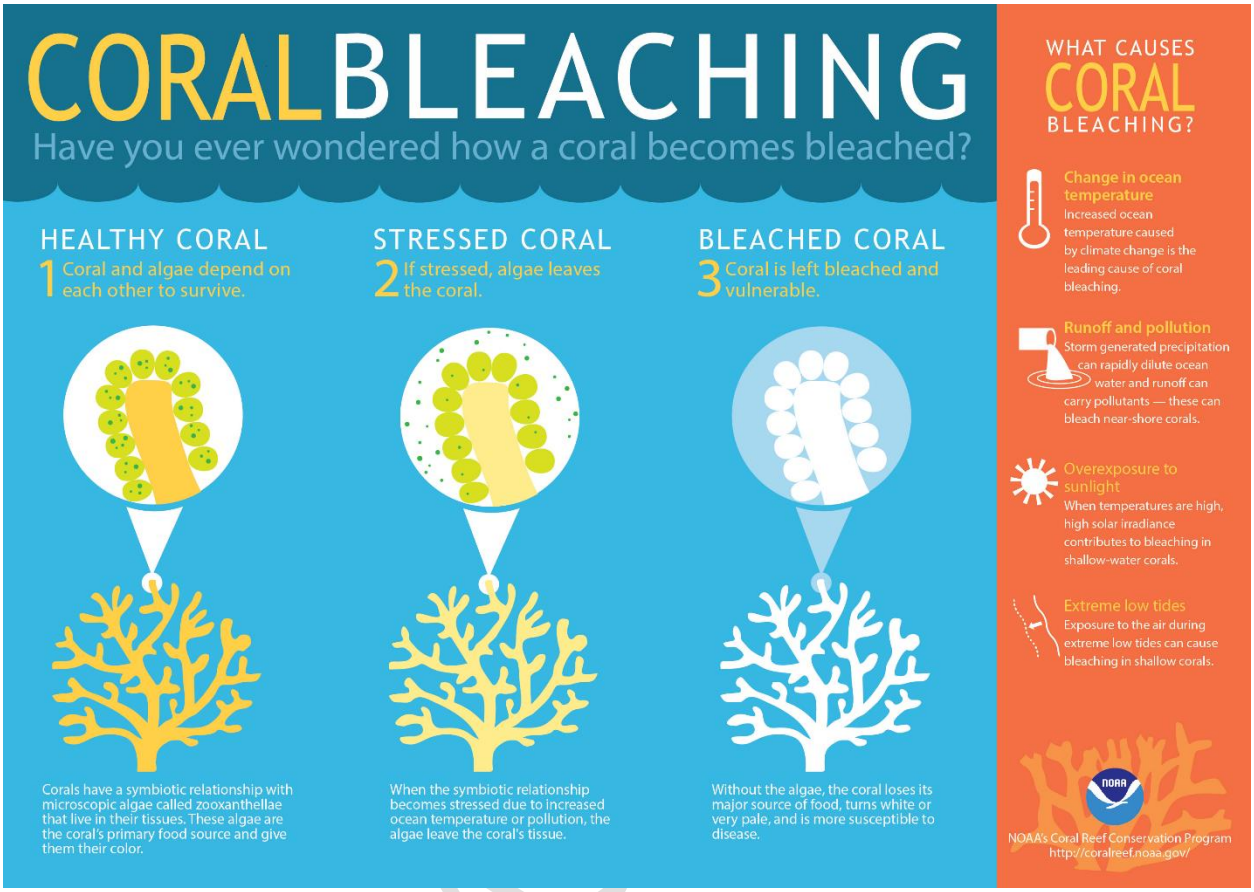
- Zooxanthellae live symbiotically within the coral polyp tissues and **assist the coral in nutrient production through its photosynthetic activities**.
- These activities provide the coral with **fixed carbon compounds for energy, enhance calcification, and mediate elemental nutrient flux.**
- The host coral polyp in return provides its zooxanthellae with a **protected environment** to live within, and a **steady supply of carbon dioxide** for its photosynthetic processes.
- The symbiotic relationship allows the slow growing corals to compete with the faster growing multicellular algae. The corals can feed by day through **photosynthesis** and by night through **predation**.
- **The tissues of corals themselves are actually not the beautiful colors of the coral reef, but are instead clear. The corals receive their coloration from the ZOOXANTHELLAE living within their tissues.**

Coral Bleaching or Coral Reef Bleaching



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- Disturbances affecting coral reefs include anthropogenic and natural events.
- Recent accelerated coral reef decline is related mostly to anthropogenic impacts **(overexploitation, overfishing, increased sedimentation and nutrient overloading).**
- Natural disturbances which cause damage to coral reefs include **violent storms, flooding, high and low temperature extremes, El Nino Southern Oscillation (ENSO) events, sub aerial exposures, predatory outbreaks and epizootics.**
- Coral reef bleaching is a common **stress response** of corals to many of the various disturbances mentioned above.
- Bleaching occurs when
    1. **the density of zooxanthellae decline and/or**
    2. **the concentration of photosynthetic pigments within the zooxanthellae fall. [it is no more useful for the coral and the coral will bleach it]**
- When corals bleach they commonly **lose 60-90% of their zooxanthellae** and each zooxanthellae may **lose 50-80% of its photosynthetic pigments**.
- If the **stress-causing** bleaching is not too severe and if it decreases in time, the affected corals usually regain their symbiotic algae within several weeks or a few months.
- If zooxanthellae loss is prolonged, i.e. if the stress continues and depleted zooxanthellae populations do not recover, the coral host eventually dies.

Coral Bleaching may also be Beneficial

- Recent research has revealed that corals that are consistently exposed to low levels of stress may develop some kind of **resistance to bleaching**.

Ecological Causes of Coral Bleaching

Temperature

- Coral species live within a relatively narrow temperature margin, and **anomalously low and high sea temperatures [corals are absent on the west coast of tropical temperate continents because of the cold currents]** can induce coral bleaching.
- Bleaching events occur during sudden temperature drops accompanying intense upwelling episodes [El-Nino], seasonal cold-air outbreaks.
- Most reefs recovered, with low levels of coral deaths, but damage has been severe at places.
- This is an instance of coral reefs' susceptibility to increased water temperatures combined with **OCEAN ACIDIFICATION.**
- While the rising temperatures have increased the frequency and intensity of bleaching, acidification has **reduced corals calcifying ability.**
- Small temperature increase over many weeks or large increase (3-4 °C) over a few days will result in **coral dysfunction.**

- Coral bleaching has occurred mostly during the summer seasons or near the end of a protracted warming period.
- They are reported to have taken place during times of **low wind velocity, clear skies, calm seas and low turbidity.** The conditions favor localized heating and high ultraviolet (UV) radiation.
- UV radiation readily penetrates clear sea waters. The corals actually contain UV-absorbing compounds which can block potentially damaging UV radiation. But rising temperatures mean reduction in the concentration of these UV absorbing compounds in corals.

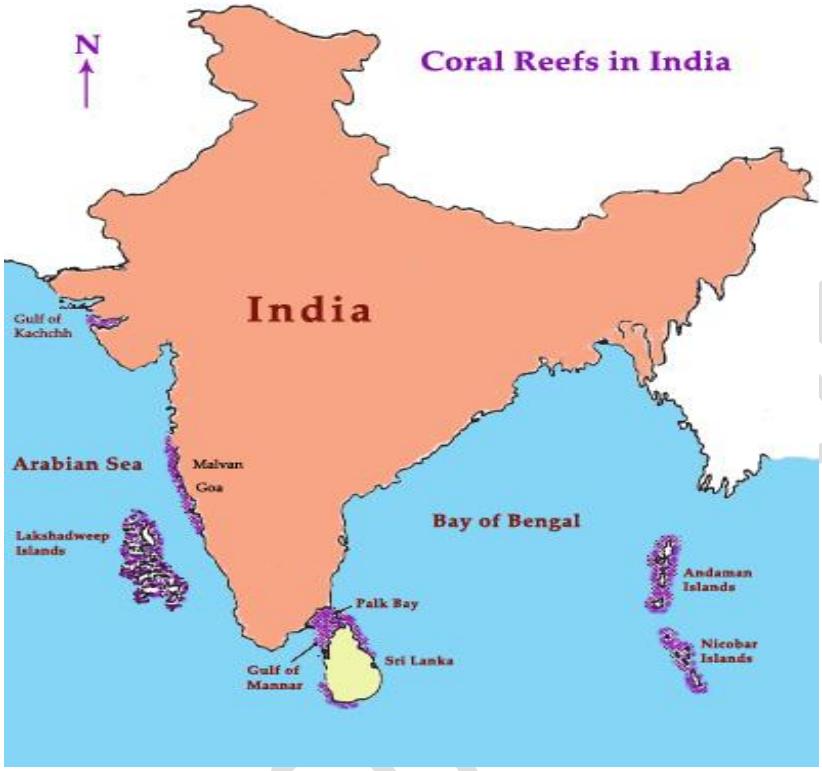
Sub aerial Exposure

- Sudden exposure of reef flat corals to the atmosphere during events such as extreme low tides, ENSO-related sea level drops or tectonic uplift can potentially induce bleaching.
- The consequent exposure to high or low temperatures, increased solar radiation, desiccation, and sea water dilution by heavy rains could all play a role in zooxanthellae loss, but could also very well lead to coral death.

Fresh Water Dilution

- Rapid dilution of reef waters from storm-generated precipitation and runoff has been demonstrated to cause coral reef bleaching.
- Generally, such bleaching events are rare and confined to relatively small, near shore areas.

Coral reef distribution in India



1. **Andaman and Nicobar Islands**
   - Situated in the Bay of Bengal, exclusively fringing reefs of about 500 islands, most of these islands have a healthy biodiversity.
   - Andaman and Nicobar Islands, Gulf of Kutch and Gulf of Mannar are regions where there is not significant freshwater intrusion. But Sunderbans are the mouth of Ganga-Brahmaputra river system and hence there is no coral reef formation there.
2. **Gulf of Kutch**
   - Exclusively consists of fringing reefs. The reefs are relatively less developed due to large range of temperature and high salinity. The harbours have less biodiversity. The entire Gulf of Kutch is also known as a marine national park.
3. **Gulf of Mannar**
   - Fringing reefs with a chain of 21 islands from Rameswaram in the north to Thoothukudi (Tuticorin) in the south. This part of the gulf forms part of the Gulf of Mannar biosphere reserve.
4. **Lakshadweep**
   - Exclusively coral atolls with 36 islands, of which 10 are inhabited. The islands range from less than 1 km (0.62 mi) to about 9 km (5.6 mi) in length, and do not exceed 2 km (1.2 mi) in width.

5. **Others**
   - Tarkarli in Malwan, Maharashtra is a smaller reef. Angria Bank is a coral reef off Vijaydurg in Maharashtra. There is a coral reef in Netrani Island in Karnataka.

Please read this page – Must read

- Coral reefs don't form in areas where there is significant intrusion of fresh water and cold water.
- Most of the mighty Indian Rivers flow into Bay of Bengal and hence coral reefs are absent on the east coast of India.
- Coral reefs are also absent on west coast of Africa (Benguela Current), South America (Peruvian or Humboldt Current), Europe (Canaries Current) and other continents due to cold currents.

Xenobiotics

- When corals are exposed to high concentrations of chemical contaminants like copper, herbicides and oil, coral bleaching happens.

Epizootics

- **Pathogen** induced bleaching is different from other sorts of bleaching.
- Most coral diseases cause patchy or whole colony death and sloughing of soft tissues, resulting in a white skeleton (not to be confused with bleached corals).

Spatial and temporal range of coral reef bleaching

- Nearly all of the world's major coral reef regions (Caribbean/ western Atlantic, eastern Pacific, central and western Pacific, Indian Ocean, Arabian Gulf, Red Sea) experienced some degree of coral bleaching and mortality during the 1980s.
- Prior to the 1980s, most mass coral moralities were related to non-thermal disturbances such as storms, aerial exposures during extreme low tides, and Acanthaster outbreaks.
- Coral bleaching accompanied some of the mortality events prior to the 1980s during periods of elevated sea water temperature, but these disturbances were geographically isolated and restricted to particular reefs zones.
- In contrast, many of the coral bleaching events observed in the 1980s occurred over large geographic regions and at all depths.

Cold Water Corals

- Cold-water corals inhabit deep, cold water.
- The United Nations Environment Programme (UNEP) reports that there are more cold-water coral reefs worldwide than tropical reefs.
- There are only about 6 different coral species associated in building with these reefs. The largest cold-water coral reef is the Rost Reef off Norway.

Initiatives to Protect Marine and Coastal Environments

1. Coastal Ocean Monitoring and Prediction System (COMAPS)

- Being implemented from 1991.
- Assesses the health of coastal waters and facilitates management of pollution-related issues.

2. Land Ocean Interactions in the Coastal Zone (LOICZ)

- Launched in 1995.
- Investigates the effects of global change on the coastal zone.
- Aims to develop, on a scientific basis, the integrated management of coastal environments.

3. Integrated Coastal and Marine Area Management (ICMAM)

- Launched in 1998.
- Aims at integrated management of coastal and marine areas.
- Model plans for Chennai, Goa and Gulf of Kutch being prepared.

4. Society of Integrated Coastal Management (SICOM)

- Launched in 2010.
- Major national initiative to protect coastal ecosystems.
- A professional body with experts in various aspects of coastal science and management was created.

5. Institutions for Coastal Management

- The Notification on Coastal Regulation Zone (CRZ), 1991 (as amended from time to time) aims at protecting coastal stretches in India.
- India has created institutional mechanisms such as National Coastal Zone Management Authority (NCZMA) and State Coastal Zone Management Authority (SCZMA) for enforcement and monitoring of the CRZ Notification.
- These authorities have been delegated powers under Section 5 of the Environmental (Protection) Act, 1986 to take various measures for protecting and improving the quality of the coastal environment and preventing, abating and controlling environmental pollution in coastal areas.

ENVIRONMENTAL POLLUTION

Pollution

Pollution is the introduction of contaminants into the natural environment that cause adverse change. **Pollution** can take the form of chemical substances or energy, such as noise, heat or light.

Pollutants

- Pollutants, the components of **pollution**, can be either foreign substances/energies or naturally occurring contaminants.
- Example - smoke from industries and automobiles, chemicals from factories, radioactive substances from nuclear plants, sewage of houses and discarded household articles are the common pollutants.
- Pollution may be of the following types: Air pollution, Noise pollution, Water pollution, Soil pollution, Thermal pollution and Radiation pollution.
- In order to control environmental pollution, the Government of India has passed the **Environment (Protection) Act, 1986** to protect and improve the quality of our environment (air, water and soil).

Air Pollution

- Air pollution may be defined as the presence of any solid, liquid or gaseous substance including **noise** and **radioactive radiation** in the atmosphere in such concentration that may be directly and/or indirectly injurious to humans or other living organisms, property or interferes with the normal environmental processes. An ever increasing use of fossil fuels in power plants, industries, transportation, mining, construction of buildings, stone quarries had led to air pollution.
- Fossil fuels contain small amounts of **nitrogen** and **sulphur**. Burning of fossil fuels like coal (thermal power plants) and petroleum (petroleum refineries) release different **oxides of nitrogen and sulphur** into the atmosphere.
- These gases react with the water vapour present in the atmosphere to form sulphuric acid and nitric acid. The acids drop down with rain, making the rain acidic. This is called **acid rain**.
- Acid rain corrodes the marble monuments like Taj Mahal. This phenomenon is called as **"Marble cancer"**.
- Other kinds of pollutants are **chlorofluorocarbons (CFCs)** which are used in **refrigerators, air conditioners and as pressurizing agents in aerosol sprays**. CFCs damage the ozone layer of the atmosphere.

- The combustion of fossil fuels also increases the amount of suspended particles in air. These suspended particles could be unburnt carbon particles or substances called hydrocarbons.
- Presence of high levels of all these pollutants causes visibility to be lowered, especially in cold weather when water also condenses out of air. This is known as **smog** and is a visible indication of air pollution.

Classification of Pollutants

- According to the form in which they persist after release into the environment.
- ***Primary pollutants:*** These persist in the form in which they are added to the environment e.g. DDT, plastic.
- ***Secondary Pollutants:*** These are formed by interaction among the primary pollutants. For example, **peroxyacetyl nitrate (PAN)** is formed by the interaction of **nitrogen oxides** and **hydrocarbons**.

According to their existence in nature

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

Particulate pollutants

- Particulate matters suspended in air are dust and soot released from the industrial chimneys. Their size ranges from 0.001 to 500 micrometers (µm) in diameter.
- Particles less than 10 µm float and move freely with the air current. Particles which are more than 10 µm in diameter settle down. Particles less than 0.02 µm form persistent aerosols.
- Major source of SPM (suspended particulate matter) are vehicles, power plants, construction activities, oil refinery, railway yard, market place, industries, etc.
- According to Central Pollution Control Board (CPCB), particulate size 2.5 µm or less in diameter (**PM 2.5**) are responsible for causing the greatest harm to human health.
- These fine particulates can be inhaled deep into the lungs and can cause breathing and respiratory symptoms, irritation, inflammations and **pneumoconiosis** – a disease of the lungs due to inhalation of dust, characterized by inflammation, coughing, and fibrosis.

Fly ash

- Fly ash is ejected mostly by thermal power plants as byproducts of coal burning operations.
- Fly ash pollutes air and water and may cause heavy metal pollution in water bodies.
- Fly ash affects vegetation as a result of its direct deposition on leaf surfaces or indirectly through its deposition on soil.
- Fly ash in the air slowly settles on leaves and crops in fields in areas near to thermal power plants and lowers the plant yield.
- Fly ash is now being used for making **bricks** and as a **land fill** material.

Composition

- Fly ash particles are oxide rich and
- Consist of silica, alumina, oxides of iron, calcium, and magnesium and *toxic heavy metals* like **lead, arsenic, cobalt,** and **copper**.
- Major oxides are present are **Aluminium silicate** (in large amounts), **silicon dioxide (SiO2)** and **calcium oxide (CaO)**.

Advantages

- Cement can be replaced by fly ash up to 35%, thus reducing the cost of construction, making roads, etc.
- Fly ash bricks are light in weight and offer high strength and durability.
- Fly ash is a better fill material for road embankments and in concrete roads.
- Fly ash can be used in **reclamation of wastelands**.
- Abandoned mines can be filled up with fly ash.
- Fly ash can increase the crop yield and it also enhances water holding capacity of the land.

Policy measures of MoEF

- The Ministry of Environment and Forests has made it mandatory to use Fly Ash based products in all construction projects, road embankment works and low lying land filling works within 100 kms radius of Thermal Power Station and mine filling power plants as byproducts of coal burning operations.

Nanoparticles – NPs

- Nanoparticles are particle with dimensions comparable to $1/10^9$ of a meter
- Major natural processes that release NPs in the atmosphere are forest fires, volcanic eruptions, weathering, dust storms from desert etc.
- Naturally occurring NPs are quite heterogeneous in size and can be transported over thousands of kilometres and remain suspended in the air for several days.
- Nanotechnology has a global socioeconomic value, with applications ranging from electronics to biomedical uses (delivering drugs to target sites).
- Man-made NPs are unknowingly or purposely released in the environment during various industrial and mechanical processes.

Effects of Nanoparticles on the environment

After release in the environment, NPs will accumulate in various environmental matrices such as air, water, soil and sediments including wastewater sludge.

- NPs in the environment influences dust cloud formation, environmental hydroxyl radical concentration, ozone depletion, or stratospheric temperature change.

Effect of NNPs on dust cloud formation

- NNPs are thought to play an important role in dust-clouds formation after being released into the environment as they coagulate and form dust cloud.
- Dust cloud formation decreases sun light intensity.

Asian brown clouds impact on Himalayan glaciers

- Asian brown clouds carry large amounts of soot and black carbon (NPs) which are deposited on the glaciers.
- This could lead to higher absorption of the sun's heat and potentially contributing to the increased melting of glaciers.

NPs and ozone depletion

- The nanoparticles have greater chemical reactivity. They can result in increased production of reactive oxygen species (ROS), including free radicals like Cl^-.
- Radicals like Cl^- destroy ozone.
- In chemistry, a radical (a free radical) is an atom, molecule, or ion that has unpaired valence electrons.

Effect of NPs on stratospheric temperature

- NPs in the troposphere interact with molecular hydrogen accidentally released from hydrogen fuel cells and other sources.
- Molecular hydrogen along with NPs moves up to the stratosphere, resulting in the abundance of water vapor in the stratosphere.
- This will cause stratospheric cooling due to formation stratospheric clouds (mostly ice crystals).
- Stratospheric clouds destroy ozone.

Major Gaseous Air Pollutants, Their Sources & Effects

Carbon monoxide (CO)

- Carbon monoxide (CO) is a colorless, odorless, tasteless and highly toxic gas that is slightly less dense than air. It is **short-lived** (stay only few months) in the atmosphere.
- Carbon monoxide is produced from the exhaust of internal combustion engines and from incomplete combustion of various other fuels. Iron smelting also produce carbon monoxide as a byproduct.
- It forms when there is not enough oxygen to produce carbon dioxide (CO2).
- In the presence of oxygen, carbon monoxide burns with a blue flame, producing carbon dioxide.
- Worldwide, the largest source of carbon monoxide is natural in origin, due to photochemical reactions in the troposphere.
- Other natural sources of CO include volcanoes, forest fires, and other forms of combustion.

Health Effects

- Carbon monoxide poisoning is the most common type of fatal air poisoning.
- It is toxic to hemoglobin animals (including humans) when encountered in concentrations above about 35 ppm.
- It is also produced in normal animal metabolism in low quantities.
- It combines with hemoglobin to produce **carboxyhemoglobin**, which usurps the space in hemoglobin that normally carries oxygen.

Environmental Effects

- In the atmosphere, it is spatially
- Variable and short lived, having a role in the formation of **ground-level ozone** (tropospheric ozone) and can elevate concentrations of **methane**.

- Carbon monoxide reacts with hydroxyl radical (-OH) to produce peroxy radical. Peroxy radical reacts with nitrogen oxide (NO) to form nitrogen dioxide (NO2) and hydroxyl radical. **NO2 gives O3 via photolysis** (separation of molecules by the action of light).

Carbon dioxide (CO2)

- Colorless and odorless gas vital to life on Earth. It is heavier than air.
- Natural sources include volcanoes, hot springs and geysers, and it is freed from carbonate rocks by dissolution in water and acids.
- Because carbon dioxide is soluble in water, it occurs naturally in groundwater, rivers and lakes, in ice caps and glaciers and also in seawater.

Effects on Health

- CO2 is an asphyxiant gas (asphyxia →a condition arising when the body is deprived of oxygen, causing unconsciousness or death.).
- Concentrations of 7% may cause suffocation, even in the presence of sufficient oxygen, manifesting as dizziness, headache, and unconsciousness.

Effects on Environment

- Carbon dioxide is an important greenhouse gas. Burning of carbon-based fuels since the industrial revolution has led to **global warming**.
- It is also a major cause of **ocean acidification** because it dissolves in water to form **carbonic acid**.

Name Of Pollutant	Sources	Health Effects
Sulphur Oxides	Thermal power plants and industries	Eye and throat irritation, cough, allergies, impairs enzyme function in respiratory system. Reduces exchange of gases from lung surface.
Nitrogen Oxides	Thermal power plant, industries and vehicles	Irritation and inflammation of lungs, breathlessness, impairs enzyme function in respiratory system and causes bronchitis and asthma.
Suspended Particulate Matter (SOM)	Vehicular emissions and burning of fossil fuels	Lung irritation reduces development of RBC and cause pulmonary malfunctioning.
Carbon Monoxide	Vehicular emissions and burning of fossil fuels	Difficulty in breathing, severe headaches, irritation to mucous membrane, unconsciousness and death
Carbon Dioxide	Burning of fossil fuels	Impairs reflexes, judgment and vision, severe headaches and heart strain.
Smog	Industries and vehicular pollution	Respiratory problems and intense irritation to the eyes.
Ozone	Automobile emissions	Breathlessness, asthma, wheezing, chest pain, emphysema and chronic bronchitis.
Chlorofluorocarbons	Refrigerators, sprays, emissions from jets	Depletion of stratospheric ozone layer, global warming.
Hydrocarbons	Burning of fossil fuels	Carcinogenic effect on lungs, kidney damage, hypertension, respiratory distress, irritation of eyes, nose and throat, asthma, bronchitis and impairs enzyme function in respiratory system.
Tobacco Smoke	Cigarettes, cigars etc.	Chronic bronchitis, asthma and lung cancer, irritation of eyes, nose and throat.
Mercury	Industries	Nervous disorders, insomnia, memory loss, excitability, irritation, tremor, gingivitis and minamata disease.

Lead	Leaded petrol emissions	Damage to brain and central nervous system, kidneys and brains, impaired intelligence and interference with development of RBCs.
Cadmium	Industries	Affects the heart
Silica dust	Silicon quarries	Silicosis affects the lungs
Cotton dust	Cotton textile factories	Byssinosis involves destruction of lung tissues, chronic cough, bronchitis and emphysema.
Asbestos dust	Asbestos mining, asbestos sheet manufacturing	Asbestosis which involves severe respiratory problems and may lead to cancer.
Radioactive pollutants	Cosmic rays, x-rays, beta rays, radon and radium	Destroy living tissues and blood cells; affect cell membrane and cell enzyme functions, leukemia, and permanent genetic changes.
Coal dust and particles	Coal mines	Black lung cancer, pulmonary fibrosis which lead to respiratory failure.

Chlorofluorocarbons (CFCs)

- Chlorofluorocarbons (CFCs) are used in refrigerators, air conditioners and aerosol sprays.
- Since the late 1970s, the use of CFCs has been heavily regulated and phased out under Montreal Protocol because of their destructive effects on the ozone layer.
- The **Montreal Protocol** on Substances that Deplete the Ozone Layer (a protocol to the **Vienna Convention for the Protection of the Ozone Layer**) is an **international treaty** designed to protect the ozone layer by phasing out the production of numerous substances including CFCs which are responsible for ozone depletion.

Ozone (O_3)

- It occurs naturally in the stratosphere. Here it absorbs harmful ultraviolet rays of the sun.
- However, at the ground level, it is a pollutant (**Greenhouse gas**) with highly toxic effects.
- Vehicles and industries are the major source of ground-level ozone emissions.
- **Carbon monoxide, Nitrogen dioxide** etc. play a major role in converting O_2 to O_3.
- Ozone makes our eyes itchy, and watery. It lowers our resistance to cold and pneumonia.

Nitrogen oxide (NOx)

- NOx is a generic term for the various nitrogen oxides produced during combustion.
- They are produced mainly in **internal combustion engines** and **coal burning power plants**. They are produced naturally by **lightening**.

[Oxygen and nitrogen do not react at ambient temperatures. But at high temperatures they produce various oxides of nitrogen. Such temperatures arise inside an internal combustion engine or a power station boiler]

- **Agricultural fertilization** and the **use of nitrogen fixing plants** also contribute to atmospheric NOx, by promoting nitrogen fixation by microorganisms.
- **NOx (contributes to global cooling)** should not be confused with **nitrous oxide (N2O)**, which is a **greenhouse gas** and has many uses as an oxidizer.

Effects on Health and Environment

- They are believed to aggravate asthmatic **conditions** and create many respiratory health issues, especially in children.
- The reduction of NOx emissions is one of the most important technical challenges facing **biodiesel**.
- NOx gases react to form **smog** and **acid rain** as well as being central to the formation of **tropospheric ozone**.
- When NOx and volatile organic compounds (VOCs) react in the presence of sunlight, they form **photochemical smog**.
- Mono-nitrogen oxides eventually form nitric acid when dissolved in atmospheric moisture, forming a component of acid rain.
- NOx emissions cause **global cooling** through the formation of -OH radicals that **destroy methane molecules**, countering the effect of greenhouse gases.

Sulphur dioxide (SO2)

- It is a toxic gas with a pungent, irritating smell. It contributes to **acid rain** formation.
- It is released naturally by volcanic activity. It is abundantly available in the atmosphere of **Venus**.
- Sulfur dioxide is primarily produced for sulfuric acid manufacture.
- Inhaling sulfur dioxide is associated with increased respiratory symptoms and disease, difficulty in breathing, and premature death. It also weakens the functioning of certain nerves.

It is also produced by

- **Burning coal in thermal power plants and diesel fuels**.
- Some industrial processes, such as production of paper and smelting of metals.
- Reactions involving hydrogen sulphide (h2s) and oxygen.
- The roasting of sulfide ores such as pyrite, sphalerite, and cinnabar (mercury sulfide). Pollutants

Volatile organic compounds (VOCs)

- Volatile Organic Compounds (VOCs) are a large group of **carbon-based** chemicals that easily **evaporate** at room temperature.
- For example, **formaldehyde**, which evaporates from paint, has a boiling point of only –19 °C. Formaldehyde causes irritation to the eyes and nose and allergies.
- The main indoor sources are perfumes, hair sprays, furniture polish, glues, air fresheners, moth repellents, wood preservatives, and other products.
- Health effect - imitation of the eye, nose and throat, headaches, nausea and loss of coordination.
- Long term - suspected to damage the liver and other parts of the body.

Benzene and Ethylene

- Benzene is a natural constituent of crude oil and is one of the elementary petrochemicals.
- Because benzene has a **high octane number**, it is an important component of gasoline.
- Benzene increases the **risk of cancer** and other illnesses. Benzene is a notorious cause of **bone marrow failure**.
- Ethylene is widely used in the chemical industry. Much of this production goes toward **polyethylene**, a widely used plastic containing polymer chains of ethylene units in various chain lengths.
- Ethylene is also an important **natural plant hormone**, used in agriculture to force the **ripening of fruits**.
- Ethylene is of low toxicity to humans and exposure to excess ethylene cause adverse health effects like headache, drowsiness, dizziness and unconsciousness.
- Ethylene is not but **Ethylene oxide is a carcinogen**.

Tobacco Smoke

- Tobacco smoke generates a wide range of harmful chemicals and is **carcinogenic** (cancer causing).
- Health effect - burning eyes, nose, and throat irritation to cancer, bronchitis, severe asthma, and a decrease in lung function.

Biological pollutants

- It includes pollen from plants, mite, and hair from pets, fungi, parasites, and some bacteria.
- Most of them are allergens and can cause asthma, hay fever, and other allergic diseases.

Asbestos

- Asbestos refers to a set of six naturally occurring silicate **fibrous minerals** — chrysotile, crocidolite, amosite, anthophyllite, tremolite, and actinolite.
- It is now known that prolonged inhalation of asbestos fibers can cause serious and fatal illnesses including **lung cancer, mesothelioma,** and **asbestosis** (a type of pneumoconiosis).

Radon

- It is a gas that is emitted naturally by the **soil**. Due to modern houses having poor ventilation, it is confined inside the house and causes lung cancers.

Smog

- Smog = **smoke + fog (smoky fog)** caused by the burning of large amounts of **coal, vehicular emission** and **industrial fumes** (Primary pollutants).
- Smog contains soot particulates like **smoke, sulphur dioxide, nitrogen dioxide** and other components.
- At least two distinct types of smog are recognized: **sulfurous smog** and **photochemical smog**.

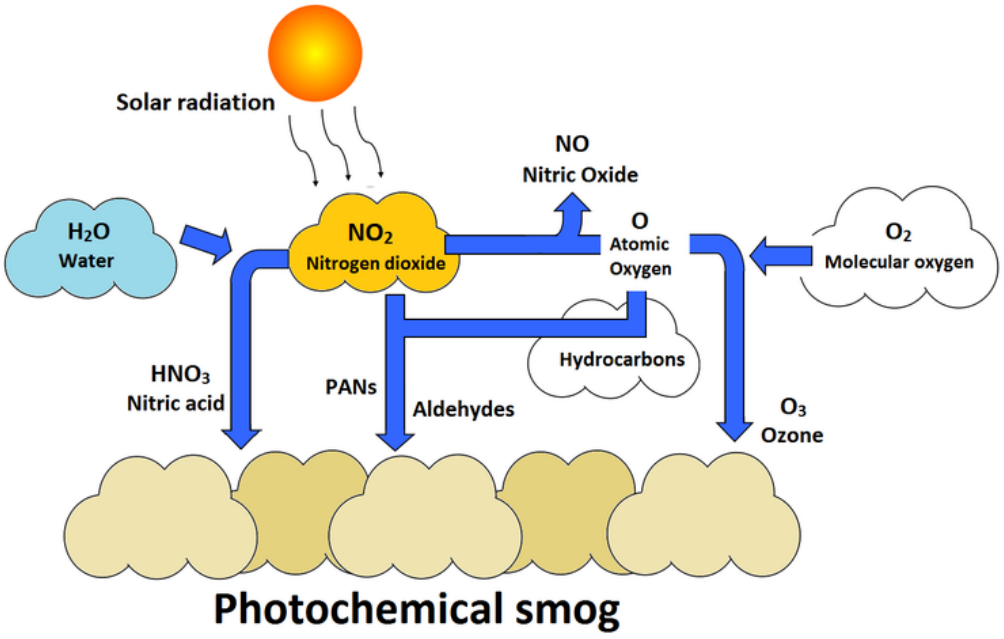
Primary and Secondary Pollutants

- A primary pollutant is an air pollutant emitted directly from a source.
- A secondary pollutant is not directly emitted as such, but forms when other pollutants (primary pollutants) react in the atmosphere.
- Examples of a secondary pollutant include **ozone**, which is formed when
    1. **hydrocarbons (HC) and nitrogen oxides (NOx) combine in the presence of sunlight;**
    2. **NO combines with oxygen in the air; and**
- Acid rain is another example for secondary pollutant. Acid rain is formed when sulfur dioxide or nitrogen oxides react with water

Sulfurous smog

- Sulfurous smog is also called **"London smog,"** (first formed in London).
- Sulfurous smog results from a high concentration of **Sulfur Oxides** in the air and is caused by the use of **sulfur-bearing fossil fuels, particularly coal and diesel** (Coal was the mains source of power in London during nineteenth century. The effects of coal burning were observed in early twentieth century).
- This type of smog is aggravated by **dampness** and a **high concentration of suspended particulate matter** in the air.

Photochemical Smog



- Photochemical smog is also known as **"Los Angeles smog".**
- Photochemical smog occurs most prominently in urban areas that have large numbers of **automobiles** (**Nitrogen oxides** are the primary emissions).
- When pollutants such as **nitrogen oxides** (primary pollutant) and **volatile organic compounds** (primary pollutant) react together in the presence of **SUNLIGHT**, **OZONE** (Secondary pollutant) and peroxyacetyl nitrate (PAN) (Secondary pollutant) are formed.
- **Nitrogen oxides + Sunlight + Hydrocarbons = Ozone (Ozone in stratosphere it is beneficial, but near the earth's surface it results in global warming as it is a greenhouse gas) + PAN**

Atmospheric oxidant production:

1. $NO + VOC \longrightarrow NO_2$ (nitrogen dioxide)
2. $NO_2 + UV \longrightarrow NO + O$ (nitric oxide + atomic oxygen)
3. $O + O_2 \longrightarrow O_3$ (ozone)
4. $NO_2 + VOC \longrightarrow$ PAN, etc. (peroxyacetyl nitrate)

Net results:

$NO + VOC + O_2 + UV \longrightarrow O_3$, PAN, and other oxidants

- Photochemical **(summer smog)** is formed when the primary pollutant NO2 reacts with secondary pollutants 03 and peroxyacetyl nitrate in the presence of sunlight.
- The resulting smog causes a light brownish coloration of the atmosphere, reduced visibility, plant damage, irritation of the eyes, and respiratory distress.

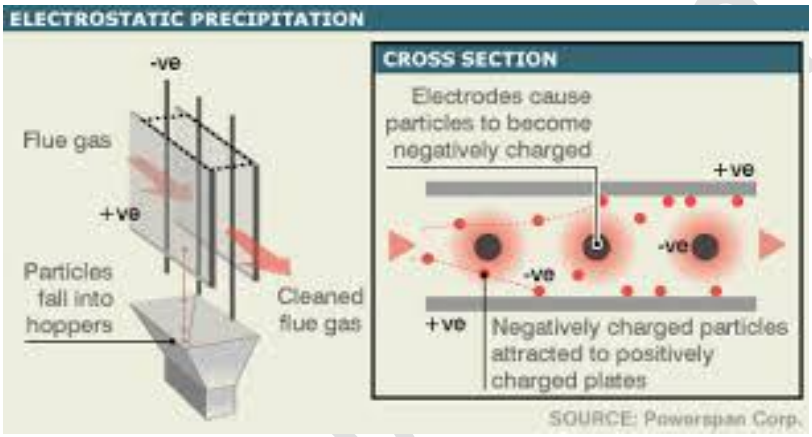
Haze

- Haze is traditionally an atmospheric phenomenon where dust smoke and other dry particles obscure the clarity of the sky (there is no condensation in haze. Smog is similar to haze but there is condensation in smog).
- Sources for haze particles include farming (ploughing in dry weather), traffic, industry, and wildfires.

Effects of Smog

- The **atmospheric pollution** levels of Los Angeles, Beijing, Delhi, Mexico City and other cities are increased by **inversion** that traps pollution close to the ground.
- It is usually highly toxic to humans and can cause severe sickness, shortened life or death.
- Smog is a combination of airborne particulate matter, like soot, and invisible toxic gases including **ozone (O3), carbon monoxide (CO), sulfur dioxide (SO2)**, which are **carcinogens (cancer causing agents).**
- Temperature inversions are accentuated and **precipitation is reduced**.
- Smog related Haze lowers visibility.

Electrostatic Precipitators (ESP)



- There are several ways of removing particulate matter; the most widely used method is electrostatic precipitation, which can remove over 99 per cent particulate matter present in the exhaust from a thermal power plant.
- The emanating dust is charged with ions and the ionized particulate matter is collected on an oppositely charged surface.
- An electrostatic precipitator has electrode wires that are maintained at several thousand volts, which produce a **corona** that releases **electrons**.
- These electrons attach to dust particles giving them a net negative charge. The collecting plates are grounded (relatively positive charge) and attract the charged dust particles.
- The velocity of air between the plates must be low enough to allow the dust to fall.
- The particles are removed from the collection surface by occasional shaking or by rapping the surface.
- ESPs are used in boilers, furnaces, and many other units of thermal power plants, cement factories, steel plants, etc.

Government Initiative

National Air Quality Monitoring Programme

- Central Pollution Control Board (CPCB) has been executing a nationwide programme of ambient air quality monitoring known as National Air Quality Monitoring Programme (NAMP).
- The National Air Quality Monitoring Programme (NAMP) is undertaken
    - to determine status and trends of ambient air quality;
    - to ascertain the compliance of NAAQS;
    - to identify non-attainment cities;
    - to understand the natural process of cleaning in the atmosphere; and
    - to undertake preventive and corrective measures.

National Ambient Air Quality Standards (NAAQS)

- The NAAQS have been revisited and revised in November 2009 for 12 pollutants, which include
    - sulphur dioxide (S02),
    - nitrogen dioxide (NO2),
    - particulate matter having micron
    - (PM10),
    - particulate matter having size
    - less than 2.5 micron (PM2.5),
    - ozone,
    - lead,
    - carbon monoxide (CO),
    - arsenic,
    - nickel,
    - benzene,
    - ammonia, and
    - benzopyrene.

National Air Quality Index (AQI)

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0-50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51-100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101-150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151-200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201-300	Health alert: everyone may experience more serious health effects.
Hazardous	> 300	Health warnings of emergency conditions. The entire population is more likely to be affected.

- Launched by the Environment Ministry
- Initiative under **'Swachh Bharat'.**

AQI

- It helps the common man to judge the air quality within his vicinity.
- Index constituted as a part of Government's mission to improve the culture of cleanliness.

Difference between old and new

- While the earlier measuring index was limited to three indicators, the current measurement index had been made quite comprehensive by the addition of more parameters.

Previously who measured Air pollution

- Central Pollution Control Board along with State Pollution Control Boards has been operating **National Air Monitoring Program (NAMP)**.

Why is AQI necessary

- Quality of data from some cities remains weak and the standards set for pollutants fall short of World Health Organization recommendations.
- The pollution related analysis using vast number of complex parameters was

complicated for the common man to understand.

Categories of air pollution under AQI

- There are six AQI categories, namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe.

Pollutants considered

- It is determined on the basis of concentration of 8 pollutants (PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb).

Alternatives

- Government is disincentivising use of private vehicles through **congestion charging.**
- The National Green Tribunal has ordered that diesel vehicles over 10 years old not ply on Delhi roads.
- Odd even formula.
- Making city roads friendly to bicycle users.
- Promoting rooftop solar power as an alternative to coal power.

Water Pollution

- Water pollution is the addition/presence of undesirable substances to/in water such as organic, inorganic, biological, radiological, heat, which degrades the quality of water so that it becomes unfit for use'.
- Water pollution is caused by a variety of human activities such as industrial, agricultural and domestic.
- Natural sources of pollution of water are soil erosion, leaching of minerals from rocks and decaying of organic matter.

Point and non-point sources of pollution

- Rivers, lakes, seas, oceans, estuaries and ground water sources may be polluted by point or non-point sources.
- When pollutants are discharged from a specific location such as a drain pipe carrying industrial effluents discharged directly into water body it represents point source pollution.
- In contrast non-point sources include discharge of pollutants from diffused sources or from a larger area such as run off from agricultural fields, grazing lands, construction sites, abandoned mines and pits, roads and streets.

Causes of Water Pollution

Sewage Water

- Sewage water includes discharges from houses, commercial and industrial establishments connected to public sewerage system.
- The sewage contains human and animal excreta, food residues, cleaning agents, detergents and other wastes.
- Domestic and hospital sewage contain many undesirable pathogenic microorganisms, and its disposal into water without proper treatment.
- ***Putrescibility*** *is the process of decomposition of organic matter present in water by microorganisms using oxygen.*

Dissolved Oxygen (DO) – Biological Oxygen Demand (BOD) – Chemical oxygen demand (COD)

DO

- Presence of organic and inorganic wastes in water decreases the dissolved Oxygen (DO) content of the water.
- Water having DO content below 8.0 mg/L may be considered as contaminated. Water having DO content below. 4.0 mg/L is considered to be highly polluted.
- DO content of water is important for the survival of aquatic organisms. A number of factors like surface turbulence, photosynthetic activity, O2 consumption by organisms and decomposition of organic matter are the factors which determine the amount of DO present in water.
- The higher amounts of waste increase the rates of decomposition and O2 consumption, thereby decreases the DO content of water.

BOD

- The demand for O2 is directly related to increasing input of organic wastes and is expressed as biological oxygen demand (BOD) of water.
- Water pollution by organic wastes is measured in terms of Biochemical Oxygen Demand (BOD).
- *BOD is the amount of dissolved oxygen needed by bacteria in decomposing the organic wastes present in water. It is expressed in milligrams of oxygen per litre of water.*
- The *higher value of BOD indicates low DO content of water*. Since BOD is **limited to biodegradable materials** only. Therefore, it is not a reliable method of measuring pollution load in water.

COD

- Chemical oxygen demand (COD) is a slightly better mode used to measure pollution load in water.
- COD measures the amount of oxygen in parts per million required to oxidize **organic (biodegradable and non-biodegradable)** and **oxidizable inorganic** compounds in the water sample.

Industrial Wastes

- The industries discharge several inorganic and organic pollutants, which may prove highly toxic to the living beings.

- Discharge of waste water from industries like petroleum, paper manufacturing, metal extraction and processing, chemical manufacturing, etc., that often contain toxic substances, notably, heavy metals (defined as elements with density > 5 g/cm3 such as **mercury, cadmium, copper, lead, arsenic** etc.) and a variety of organic compounds.

Type of Industry	Inorganic pollutants	Organic pollutant
Mining	Mine Wastes: Chlorides, various metals, ferrous sulphate, sulphuric acid, hydrogen sulphide, ferric hydroxide, surface wash offs, suspended solids, chlorides and heavy metals.	
Iron and Steel	Suspended solids, iron cyanide, thiocyanate, sulphides, oxides of copper, chromium, cadmium, and mercury.	Oil, phenol and neptha
Chemical Plants	Various acids and alkalies, chlorides, sulphates, nitrates of metals, phosphorus, fluorine, silica and suspended particles.	Aromatic compounds solvents, organic acids, nitro compound dyes, etc.
Pharmaceutical	-	Proteins, carbohydrates, organic solvent intermediate products, drugs and antibiotics
Soap and Detergent	Tertiary ammonium compounds alkalies	Flats and fatty acids, glycerol, polyphosphates, sulphonated hydrocarbons.
Food processing	-	Highly putrescible organic matter and pathogens
Paper and Pulp	Sulphides, bleaching liquors.	Cellulose fibres, bark, woods sugars organic acids.

Agricultural Sources

- Agricultural runoff contains dissolved salts such as **nitrates, phosphates, ammonia** and other nutrients, and toxic metal ions and organic compounds.
- Fertilizers contain major plant nutrients such as **nitrogen, phosphorus** and **potassium**.
- Excess fertilizers may reach the ground water by leaching or may be mixed with surface water of rivers, lakes and ponds by runoff and drainage.
- Pesticides include insecticides, fungicides, herbicides, nematicides, rodenticides and soil fumigants. They contain a wide range of chemicals such as **chlorinated hydrocarbons (CHCs. E.g. DDT, Endosulfan etc.), organophosphates, metallic salts, carbonates, thiocarbonates, derivatives of acetic acid** etc. Many of the pesticides are non-degradable and their residues have long life.

- The animal excreta such as dung, wastes from poultry farms, piggeries and slaughter houses etc. reach the water though run off and surface leaching during rainy season.

Thermal and Radiation Pollution

- Power plants – thermal and nuclear, chemical and other industries use lot of water for cooling purposes and the used hot water is discharged into rivers, streams or oceans.
- Discharge of hot water may increase the temperature of the receiving water by 10 to 15 °C above the ambient water temperature. This is thermal pollution.
- Increase in water temperature **decreases dissolved oxygen** in water which adversely affects aquatic life.
- Unlike terrestrial organisms, aquatic organisms are adopted to a uniform steady temperature of environment. Sudden rise in temperature kills fishes and other aquatic animals.
- Discharge of hot water in water body affects feeding in fishes, increases their metabolism and affects their growth. Their swimming efficiency declines. Running away from predators or chasing prey becomes difficult. Their resistance to diseases and parasites decreases.
- One of the best methods of reducing thermal pollution is to store the hot water in cooling ponds, allow the water to cool before releasing into any receiving water body
- Nuclear accidents near water bodies or during natural calamities like tsunami and earthquakes pose the risk of radiation leakage (radiation exposure) into water bodies. E.g. Fukushima Daiichi nuclear disaster. *Radiation exposure causes **mutations in DNA** of marine organisms. If those mutations are not repaired, the cell may turn cancerous.*
- ***Radioactive iodine** tends to be absorbed by the thyroid gland and can cause thyroid cancer.*

Oil Spills

- Oil spills are most glaring of all oceanic pollution.
- The most common cause of oil spill is leakage during marine transport and leakage form underground storage tanks. Oil spill could occur during off shore oil production as well.

Impact of oil spill on marine life

- Oil being lighter than water covers the water surface as a thin film cutting off oxygen to floating plants and other producers.
- Within hours of oil spill, the fishes, shellfish, plankton die due to suffocation and metabolic disorders.
- Birds and sea mammals that consume dead fishes and plankton die due to poisoning. Death of these organisms severely damages marine ecosystems.

The new technique of using the bacteria to get rid of oil spill has been called **"Oil Zapping".** Oil Zapping is a bio-remediation technique involving the use of 'oil zapping' bacteria.

Impact of oil spills on terrestrial life

- Bays, estuaries, shores, reefs, beaches particularly near large coastal cities or at the mouth of rivers are relatively more susceptible to the hazards of oil spills.
- A number of coastal activities, especially recreational such as bathing, boating, angling, diving, rafting is affected. As a result, tourism and hotel business in the coastal areas suffers seriously.

Invasive species

- Plants of **water hyacinth** are the world's most problematic aquatic weed, also called '**Terror of Bengal**'.
- They grow abundantly in eutrophic water bodies, and lead to an imbalance in the ecosystem dynamics of the water body.
- They cause havoc by their excessive growth leading to stagnation of polluted water.

Underground water pollution

- In India at many places, the ground water is threatened with contamination due to seepage from industrial and municipal wastes and effluents, sewage channels and agricultural runoff.
- Pollutants like fluorides, **uranium**, heavy metals and nutrients like nitrates and phosphates are common in many parts of India.

Marine pollution

- Oceans are the ultimate sink of all natural and manmade pollutants.
- Rivers discharge their pollutants into the sea.
- The sewerage and garbage of coastal cities are also dumped into the sea.
- The other sources of oceanic pollution are navigational discharge of oil, grease, detergents, sewage, garbage and radioactive wastes, off shore oil mining, oil spills.

Effects of Water Pollution

Effects of Water Pollution on Human Health

- Domestic and hospital sewage contain many undesirable pathogenic microorganisms, and its disposal into water without proper treatment may cause outbreak of serious diseases, such as, amoebiasis dysentery, typhoid, jaundice, cholera, etc.
- Metals like **lead, zinc, arsenic, copper, mercury** and **cadmium** in industrial waste waters adversely affect humans and other animals.
- **Arsenic pollution** of ground water has been reported from West Bengal, Orissa, Bihar, Western U.P. Consumption of such arsenic polluted water leads to accumulation of arsenic in the body parts like blood, nails and hairs causing skin lesions, rough skin, dry and thickening of skin and ultimately **skin cancer**.
- Mercury compounds in waste water are converted by bacterial action into extremely toxic **methyl mercury**, which can cause numbness of limbs, lips and tongue, deafness, blurring of vision and mental derangement.
- Pollution of water bodies by mercury causes **Minamata** (neurological syndrome) disease in humans and **dropsy** in fishes.
- Lead causes **lead poisoning** (Lead interferes with a variety of body processes and is toxic to many organs and tissues). The compounds of lead cause anaemia, headache, loss of muscle power and bluish line around the gum.
- Cadmium poisoning causes cancer of lungs and liver and **Itai – Itai** disease (a painful disease of bones and joints, causes softening of the bones and kidney failure) etc.
- Water contaminated with cadmium can cause **itai itai disease** also called ouch-ouch disease (a painful disease of bones and joints) and cancer of lungs and liver.

Effects of Water Pollution on Environment

- Micro-organisms involved in biodegradation of organic matter in sewage waste consume lot of oxygen, and make water oxygen deficient killing fish and other aquatic creatures.
- Presence of large amounts of nutrients in water results in **algal bloom** [excessive growth of planktonic (free-floating) algae [Harmful Algal Blooms and **Eutrophication** are explained in the previous post]. This leads to **ageing of lakes**.
- A few toxic substances, often present in industrial waste waters, can undergo biological magnification (Bio-magnification) in the aquatic food chain. This phenomenon is well-known for **mercury** and **DDT**.
- High concentrations of DDT disturb calcium metabolism in birds, which causes thinning of eggshell and their premature breaking, eventually causing decline in bird populations.
- Thermal wastewater eliminates or reduces the number of organisms sensitive to high temperature, and may enhance the growth of plants and fish in extremely cold areas but, only after causing damage to the indigenous flora and fauna.

- Aquatic organisms take up pesticides from water which get into the food chain and move up the food chain. At higher trophic level they get concentrated and may reach the upper end of the food chain [**Bio-magnification** explained in 'Trophic Levels'].

Effects of Water Pollution on Aquatic Ecosystem

- Polluted water reduces Dissolved Oxygen (DO) content, thereby, eliminates sensitive organisms like plankton, molluscs and fish etc.
- However a few tolerant species like **Tubifex (annelid worm)** and some insect larvae may survive in highly polluted water with low DO content. Such species are recognized as **indicator species** for polluted water.
- **Biocides, polychlorinated biphenyls (PCBs)** and **heavy metals** directly eliminate sensitive aquatic organisms.
- Hot waters discharged from industries, when added to water bodies, lowers its DO content.

Water-borne diseases

A. Bacterial diseases:

Disease	Causative organism	Mode of spread	Symptoms
Typhoid	*Salmonella typhi*	Contaminated food, water, milk, unwashed raw vegetables and flies	Continuous fever which increases day by day Temperature higher in evening than morning, body ache, headache and constipation. Haemorrhage from an ulceration in small intestine
Cholera	*Vibrio cholerae*	Water or food contaminated by bacteria from stools of cholera patient	Painless diarrhoea , vomiting, 30-40 stools per day which soon becomes typically watery and colourless with flakes of mucous floating in them
Bacterial Diaorhoea	*Shigella* spp.	Contaminated food, water and by direct personal contact	Diarrhoea, with blood and dysentry mucous in the stools along with severe gripping pain in the abdomen. Stools not too frequent (4-10 per day), faecal matter scanty. Patient looks ill
Leptospirosis	*Leptospira*	Rodents primary hosts-carry organisms in kidneys. Infection by wading or swimming in water contaminated with rodent urine	Fever, pain in legs, nausea, vomiting are common, congestion of the conjunctival blood vessels around corneas of the eyes

B. Viral diseases:

Infective Hepatitis	*Hepatitis virus*	Food and water contaminated with virus in stools	Loss of appetite, nausea, vomiting and diarrhoea, accompanied with fever. Urine dark coloured. Eye and skin appear yellow

C. Protozoan diseases:

Amoebic dysentery	*Entamoeba histolytica*	Ingestion of cysts in food and water	Abdominal discomfort and diarrhoea, with or without blood or mucous in stools, fever, chills and gripping pain in abdomen
Diarrhoea	*Giardia (=Lamblia) intestinalis*	Food or water contaminated with faeces having cysts	Intestinal disorders leading to epigastric pain, abdominal discomfort, loss of appetite, headache and loose bowels

D. Helminth diseases:

Bilharzia	*Schistosoma* spp	Cercaria larvae of flukes in water penetrate skin of persons wading in water	Allergy-like itch, rash, aches, fever, eosinophilia etc. When infection heavy, eggs may block arterioles of lungs cardio-pulmonary water causing schistosomiasis and may lead to congestive heart failure
Guinea worm	*Dracunculus medinensis*	Unfiltered water	Blister near the ankle, causing allergy and aches

E. Vector borne diseases related with water:

Diseases transmitted by mosquitoes-

Disease	Causative Organisms	Vector	Hosts	Symptoms
Malaria	*Plasmodium* sp	Female Anopheles (primary or final hosts)	Man (inter-mediate hosts)	Shivering, chills and sweating. As chills subside body temperature rises as high as 106° F. When temperature comes down patient sweats profusely and becomes comfortable until next attack which takes place at regular intervals
Filaria (Elephantiasis)	*Wuchereria (=filaria)*	*Culex fatigans*	Man (final hosts)	Enlargement of limbs and scrotum
Dengue	Barbo - virus	*Aedes aegypti*	Man (reservoir)	Sudden onset of moderately high fever, excruciating joint pain, intense pain behind eyes, a second rise in temp following brief remission, reduction in neutrophilic white blood cells

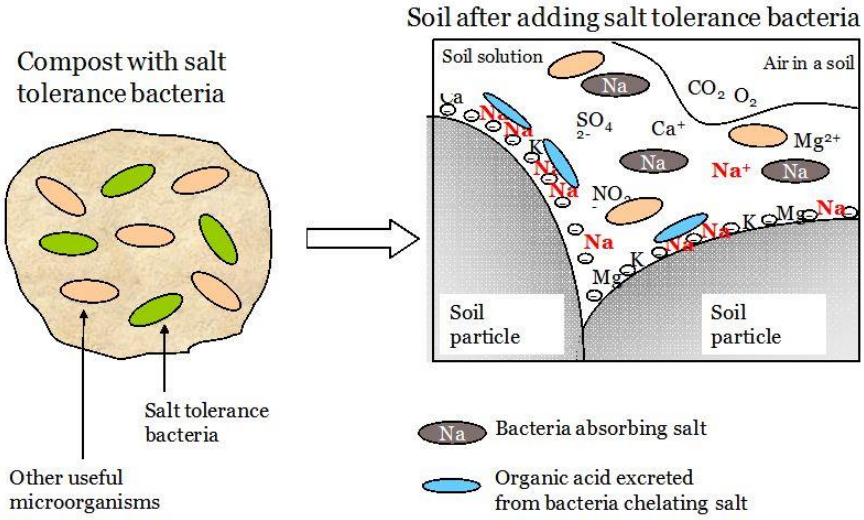
Water Pollution Control Measures

- Realizing the importance of maintaining the cleanliness of the water bodies, the Government of India has passed the **Water (Prevention and Control of Pollution) Act, 1974** to safeguard our water resources.
- An ambitious plan to save the river, called the **Ganga Action Plan** was launched in 1985. It aimed to reduce the pollution levels in the river. However, the increasing population and industrialization have already damaged this mighty river beyond repair.
- In India, the **Central Pollution Control Board (CPCB)**, an apex body in the field of water quality management, has developed a concept of "designated best use".
- Accordingly, the water body is designated as A, B, C, D, E on the basis of
    - **pH,**
    - **dissolved oxygen, mg/1**
    - **BOD, (200C) mg/l**
    - **total coliform (MPN/100ml)**
    - **free ammonia mg/l,**

- **electrical conductivity etc.**

- The CPCB, in collaboration with the concerned State Pollution Control Boards, has classified all the water bodies including coastal waters in the country according to their “designated best uses”.
- This classification helps the water quality managers and planners to set water quality targets and identify needs and priority for water quality restoration programmes for various water bodies in the country.
- The famous **Ganga Action Plan** and subsequently the **National River Action Plan** are results of such exercise.
- **Riparian buffers:** A riparian buffer is a vegetated area (a "buffer strip") near a stream, usually forested, which helps shade and partially protect a stream from the impact of adjacent land uses. It plays a key role in increasing water quality in associated streams, rivers, and lakes, thus providing environmental benefits.
- Treatment of sewage water and the industrial effluents before releasing it into water bodies. Hot water should be cooled before release from the power plants.
- Excessive use of fertilizers and pesticides should be avoided. Organic farming and efficient use of animal residues as fertilizers can replace chemical fertilizers.
- **Water hyacinth** (an **aquatic weed, invasive species**) can purify water by taking some toxic materials and a number of heavy metals from water.
- Oil spills in water can be cleaned with the help of **bregoli** — a by-product of paper industry resembling saw dust, oil zapper, microorganisms.
- It has been suggested that we should plant **eucalyptus** trees all along sewage ponds. These trees absorb all surplus wastewater rapidly and release pure water vapor into the atmosphere.

Bioremediation



- Bioremediation is the use of microorganisms (bacteria and fungi) to degrade the environmental contaminants into less toxic forms.
- The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere and brought to the contaminated site.
- The process of bioremediation can be monitored indirectly by measuring the **Oxidation Reduction Potential or redox** in soil and groundwater, together with pH, temperature, oxygen content, electron acceptor/donor concentrations, and concentration of breakdown products (e.g. carbon dioxide)

In situ bioremediation

- In situ — it involves treatment of the contaminated material at the site.
- **Bioventing:** supply of air and nutrients through wells to contaminated soil to stimulate the growth of indigenous bacteria. It is used for simple hydrocarbons and can be used where the contamination is deep under the surface.
- **Biosparging:** Injection of air under pressure below the water table to increase groundwater oxygen concentrations and enhance the rate of biological degradation of contaminants by naturally occurring bacteria
- **Bioaugmentation:** Microorganisms are imported to a contaminated site to enhance degradation process.
- Using bioremediation techniques, TERI has developed a mixture of bacteria called '**Oilzapper and Oilivorous-S**' which degrades the pollutants of oilcontaminated sites, leaving behind no harmful residues. This technique is not only environment friendly, but also highly cost-effective.

Ex situ bioremediation

- Ex situ — involves the removal of the contaminated material to be treated elsewhere.
- **Land farming:** contaminated soil is excavated and spread over a prepared bed and periodically tilled until pollutants are degraded. The goal is to stimulate indigenous biodegradative microorganisms and facilitate their aerobic degradation of contaminants.
- **Biopiles:** it is a hybrid of land farming and composting. Essentially, engineered cells are constructed as aerated composted piles. Typically used for treatment of surface contamination with petroleum hydrocarbons.
- **Bioreactors:** it involves the processing of contaminated solid material (soil, sediment, sludge) or water through an engineered containment system.
- **Composting:** Composting is nature's process of recycling decomposed organic materials into a rich soil known as compost.

Advantages and Disadvantages of bioremediation

Advantages of bioremediation

- Useful for the complete destruction of a wide variety of contaminants.
- The complete destruction of target pollutants is possible.
- Less expensive.
- Environment friendly.

Disadvantages of bioremediation

- Bioremediation is limited to those compounds that are **biodegradable**. Not all compounds are susceptible to rapid and complete degradation.
- Biological processes are often highly specific.
- It is difficult to extrapolate from bench and pilot-scale studies to full-scale field operations.
- Bioremediation often takes longer time than other treatment process.

Phytoremediation

- Phytoremediation is use of **plants** to remove contaminants from soil and water. Natural phytoremediation is carried out by mangroves, estuarine vegetation and other wetland vegetation.
- **Phytoextraction/phytoaccumulation**: plants accumulate contaminants into the roots and aboveground shoots or leaves.
- **Phytotransformation/phytodegradati on**: uptake of organic contaminants from soil,

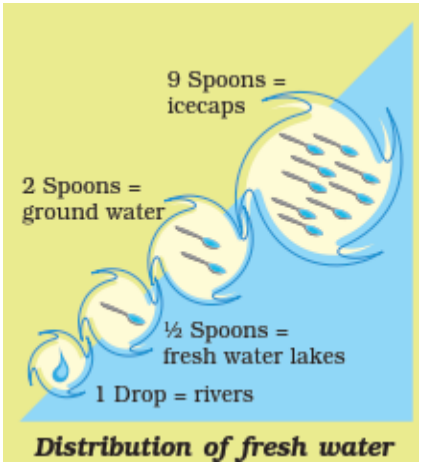
and their transformation to more stable, less toxic, less mobile form.

- **Phytostabilization**: plants reduce the mobility and migration of contaminated soil. Leachable constituents are adsorbed and bound into the plant structure.
- **Rhizodegradation**: breakdown of contaminants through the activity existing in the rhizosphere (region of soil in the vicinity of plant roots). This activity is due to the presence of proteins and enzymes produced by the plants or by soil organisms such as bacteria, yeast, and fungi.
- **Rhizofiltration:** water remediation technique that involves the uptake of contaminants by plant roots. Rhizofiltration is used to reduce contamination in natural wetlands and estuary areas (E.g. Mangroves).
- **Mycoremediation**: fungi are used to decontaminate the area.
- **Mycofiltration**: using fungal mycelia to filter toxic waste and microorganisms.
- The bacterium **Deinococcus radiodurans** has been used to detoxify toluene and ionic mercury which are released from radioactive nuclear waste.

Ground Water

- ***Titbit: 22 March is celebrated as the world water day.***
- ***General Assembly of the United Nations proclaimed the period 2005 – 2015 as the International Decade for action on "Water for life"***

Oceans	:	97.3	Saline Water
Ice-caps	:	02.0	Fresh Water
Ground water	:	0.68	
Fresh water lakes	:	0.009	
Inland seas and salt lakes	:	0.009	
Atmosphere	:	0.0019	
Rivers	:	0.0001	
		100.00	



Distribution of fresh water

- The moisture in the soil indicates the presence of water underground.
- If we dig deeper and deeper, we would reach a level where all the space between particles of soil and gaps between rocks are filled with water. The upper limit of this layer is called the water table.
- The water table may be at a depth of less than a metre or may be several metres below the ground. The water found below the water table is called groundwater.
- The process of seeping of water into the ground is called infiltration.

- At places the groundwater is stored between layers of hard rock below the water table. This is known as an aquifer.
- The rainwater can be used to recharge the groundwater. This is referred to as water harvesting.
- ***Mahatma Gandhi said: "No one need to wait for anyone else to adopt a humane and enlightened course of action."***

Groundwater Contaminants and Their Effects

Nitrates

- Dissolved nitrates commonly contaminate groundwater.
- Excess nitrate in drinking water reacts with hemoglobin to form non-functional **methaemoglobin**, and impairs oxygen transport. This condition is called **methaemoglobinemia** or **blue baby syndrome**.
- **Methemoglobin is a form of the oxygencarrying metalloprotein hemoglobin. Methemoglobin cannot bind oxygen, unlike oxyhemoglobin.**
- High level of nitrates may form carcinogens and can accelerate eutrophication in surface waters.

Pathogens

Poor hygiene of wells may cause pathogenic contamination. Water seepage from solid waste dumps and municipal drains may also cause pathogenic contamination.

Trace metals

- Include **lead, mercury, cadmium, copper, chromium** and **nickel**. These metals can be toxic and carcinogenic.

Arsenic

- Seepage of industrial and mine discharges, fly ash ponds of thermal power plants can lead to metals in groundwater.
- In India and Bangladesh [Ganges Delta], millions of people are exposed to groundwater contaminated with high levels of arsenic, a highly toxic and dangerous pollutant.
- Chronic exposure to arsenic causes **black foot disease**. It also causes diarrhoea, peripheral neuritis, hyperkeratosis and also lung and skin cancer.

Organic compounds

- Seepage of agricultural runoff loaded with organic compounds like pesticides and may cause pesticide pollution of ground water.

Fluoride

- Excess fluoride in drinking water causes **neuromuscular disorders, gastro-intestinal problems, teeth deformity, hardening of bones and stiff and painful joints (skeletal fluorosis)**.
- Fluorisis is a common problem in several states of the country due to intake of high fluoride content water.
- Fluorides cause dental fluorisis, stiffness of joints (particularly spinal cord) causing humped back.
- Pain in bones and joint and outward bending of legs from the knees is called Knock-Knee syndrome.
- High concentration of fluoride ions is present in drinking water in 13 states of India. The maximum level of fluoride, which the human body can tolerate is 1.5 parts per million (mg/L of water). Long term ingestion of fluoride ions causes fluorosis.

Major Water Issues of India

Water scarcity

- Due to un-even distribution of rainfall in time and space and ever-increasing demand of water for agricultural, industrial and domestic activities, the water resources are over-exploited. This is resulting in shrinking or even drying up of many water bodies for considerable periods in a year.
- Reducing demands by optimum use, minimization of wastage, efforts to reduce the percolation and evaporation losses, conservation efforts in domestic uses, groundwater recharging, rain water harvesting, afforestation, recycling and reuse are important to combat this problem.

Pathogenic pollution

- Water borne diseases are the most important water quality issues in India. This is mainly due to inadequate arrangements for transport and treatment of wastewaters.

Oxygen depletion

- Eutrophication [oxygen depletion due to algal blooms] is a common problem in most of the India lakes and rivers due to discharge of untreated sewage and industrial effluents.

Salinity

- There are number of cases where salinity is increasing in both surface water and groundwater.
- The increase in groundwater salinity is mainly due to increased irrigation activities or sea water intrusion in coastal areas.

Toxic pollution

- Due to discharge of toxic effluents from many industries and increased use of chemicals in agriculture and their subsequent contribution to the water bodies, many water bodies in the country are polluted due to presence of toxic substances.

Ecological health

- A large number of areas in our aquatic environment support rare species of aquatic and amphibious plants and animals and are, therefore, ecologically very sensitive. They need special protection.

Water Conservation and Management

- Primary source of water in India is south-west and north-east monsoons. Monsoon, however, is erratic and amount of rain fall is highly variable in different parts of our country. Hence, surface runoff needs be conserved.

EcoSan toilets

- Can you imagine the amount of water that one can save if one didn't have to flush the toilet? Well, this is already a reality. Ecological sanitation is a sustainable system for handling human excreta, using dry composting toilets.
- This is a practical, hygienic, efficient and cost-effective solution to human waste disposal.
- With this composting method, human excreta can be recycled into a resource (as natural fertilizer), which reduces the need for chemical fertilizers. There are working 'EcoSan' toilets in many areas of Kerala and Sri Lanka.

Bio-Toilets

- **Designed by -** Railways along with **DRDO**.

Why Bio Toilets in Rail?

- Direct discharge of human waste from the existing toilet system in trains causes corrosion of the tracks, costing crores to replace the rail tracks.
- The bio-toilets are fitted underneath the lavatories and the human waste discharged into them is acted upon by a particular kind of **bacteria** that converts it into non-corrosive **neutral water**.

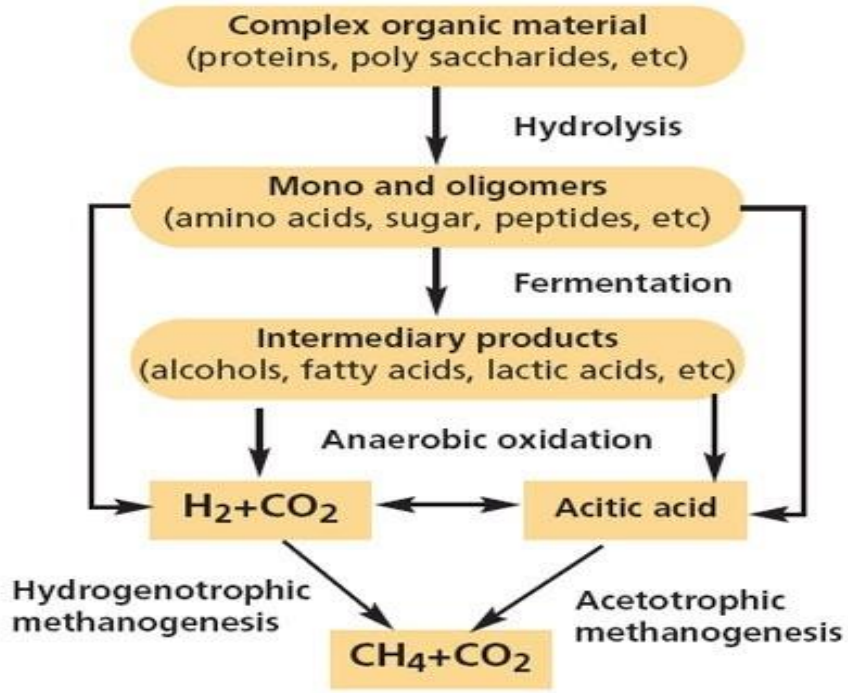
Terms associated with Bio-Toilets

- **Bio-digesters:** The term bio digester is used for the shells made up of steel for the **anaerobic** digestion of human waste.
- **Bio tank:** The term bio tank is used for the tanks made up of concrete for the anaerobic digestion of human waste.
- **Aerobic Bacteria:** Aerobic bacteria are those which flourish in the presence of free dissolved oxygen in the waste water and consume organic matter for their food, and thereby oxidizing it to stable end products.

HOW BIO-TOILETS WORK

Bio-toilets have a colony of anaerobic bacteria that converts human waste into water and small amounts of gases. The gases are released into the atmosphere and the water is discharged after chlorination on the tracks

Reaction



Source: Indian Railways

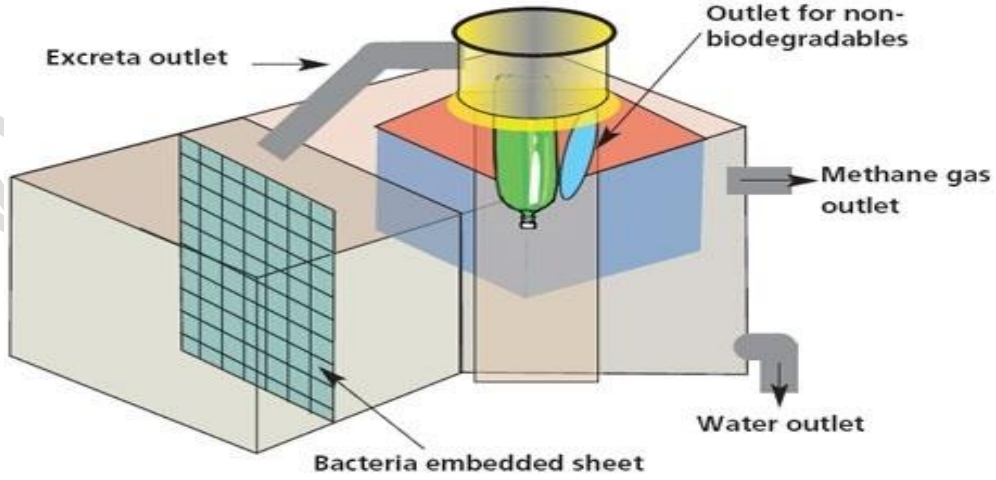
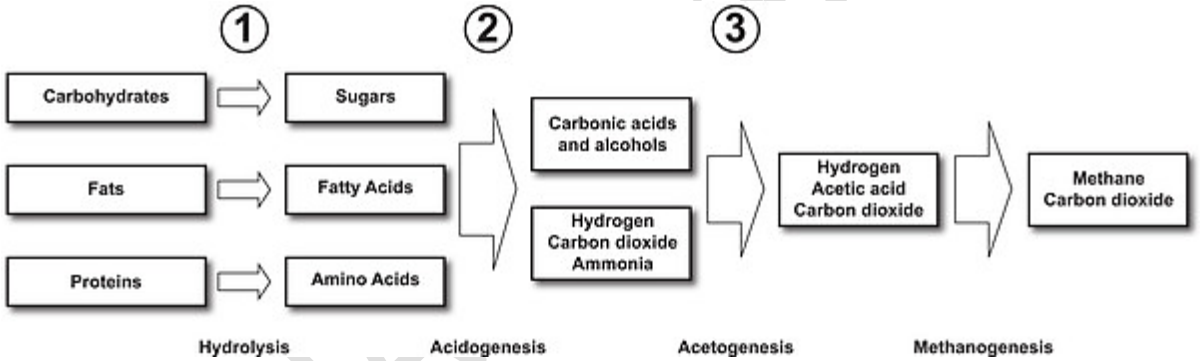


Illustration: Chaitanya Chandan

- **Anaerobic Bacteria:** Anaerobic bacteria flourish in the absence of free dissolved oxygen, and survive by utilizing the bounded molecular oxygen in compounds like nitrates (NO3) and sulphates (SO4) etc. thereby reducing them to stable end products along with evolution of foul smelling gases like **H2S (hydrogen sulphide), CH4 (methane)** etc.
- **Facultative Bacteria:** Facultative bacteria can operate either as aerobically or as anaerobically.
- **Anaerobic Microbial inoculums:** mixture of different types of bacteria (hydrolytic, Acidogenic, acetogenic and methanogenic groups) responsible for breakdown of complex polymers into simple sugars which are further broken down into low chain fatty acids and finally into **biogas**.

Anaerobic biodegradation system

- Anaerobic digestion is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen.



- The final waste are Methane and Carbon Dioxide.

Aerobic biodegradation Vs Anaerobic biodegradation

Aerobic biodegradation

- Forced aeration is essential which is energy intensive.
- Incomplete aeration (partial aerobic condition) leads to foul smell.
- Less effective pathogen inactivation.
- Cannot tolerate detergents
- Generate large amount of sludge.
- Repeated addition of bacteria/enzyme is required for the process.
- Maintenance & recurring cost is high.

Anaerobic biodegradation

- No aeration is required.
- Complete anaerobic conditions.

- More than 99% pathogen inactivation.
- Anaerobes can even degrade detergents/phenyl
- Sludge generation is very less.
- One-time bacterial inoculation is enough.
- Minimal maintenance and no recurring cost.

Contour farming

- Contour farming is an example of harvesting technique involving water and moisture control at a very simple level.
- It often consists of rows of rocks placed along the contour of steps. Runoff captured by these barriers also allows for retention of soil, thereby serving as erosion control measure on gentle slopes.
- This technique is especially suitable for areas having rainfall of considerable intensity, spread over large part i.e. in Himalayan area, north east states and Andaman and Nicobar Islands.
- In areas where rainfall is scanty and for a short duration, it is worth attempting these techniques, which will induce surface runoff, which can then be stored.

Ground water conservation

Artificial recharge

- Increasing the surface area for percolation, percolation tank constructions etc. are some artificial recharge methods.

Catchment Area Protection (CAP)

- It helps in withholding runoff water albeit temporarily by a check bund constructed across the streams in hilly terrains to delay the run off so that greater time is available for water to seep underground.
- Such methods are in use in north-east states, in hilly areas of tribal belts. This technique also helps in soil conservation. Afforestation in the catchment area is also adopted for water and soil conservation.

Inter-basin transfer of water

- Western and peninsular regions have comparatively low water resources/cultivable land ratio. Northern and eastern region which are drained by Ganga and Brahmaputra have substantial water resources.
- Hence, the scheme of diverting water from region with surplus water to water deficit region can be adopted.
- Ganga-Cauvery link would enable the transfer of vast quantities of Ganga basin flood

water running out to sea, to west and south west India.

- The transfer of the surplus Ganga water would make up for the periodical shortage in Son, Narmada, Godavari, Krishna and Cauvery.

Adoption of drip sprinkler irrigation

- Surface irrigation methods leads to water loss due to evaporation and percolation.
- Drip irrigation is an efficient method of irrigation in which a limited area near the plant is irrigated by dripping water. This method is particularly useful in row crop.
- Similarly sprinkler method is also suitable for such water scarce areas. About 80% water consumption can be reduced by this method, whereas the drip irrigation can reduce water consumption by 50 to 70 %.

Management of growing pattern of crops

- In water scarce areas, the crop selection should be based on efficiency of the crop to utilize the water. Some of the plants suitable for water scarce areas are:
    - plants with shorter growth period;
    - high yielding plants that require no
    - increase in water supply;
    - plants with deep and well trenched
    - roots and
    - plants which cannot tolerate surface
    - Irrigation.

Selection of crop varieties

- Crop performance and yield are the results of genotype expression as modulated by continuous interactions with the environment.
- Generally, the new varieties of crop do not require more water than the older ones. However, they require timely supply of water because their productivity is high.
- Frequent light irrigation is more conductive than heavy irrigation at large intervals for obtaining high yields.

Nutritional management

- Potassium plays a major role under stress conditions. It improves the tissue water potential by osmoregulation, ultimately increasing the water use efficiency.
- Experiments conducted at the Water Technology Centre, Coimbatore, indicated that foliar application of 0.5% potassium chloride can reduce the moisture stress in soyabean, sorghum and groundnut.

Role of anti-transpirants

- Application of anti-transpirants reduces transpiration maintaining thereby the tissue water potential. Plants then take up less water from soil.
- Anti-transpirants can prolong the irrigation intervals by slowing down soil water depletion. Application of Kaolin (3%) and lime wash (2%) was found to maintain the water balance of plant and resulted in normal yield of sorghum under moisture stress conditions.
- Certain growth regulators reduce the plants susceptibility to water stress. Application of **cycoel**, a growth retardant increases the ability to withstand drought.
- Cycoel application also reduces production of **gibberellic acid** which leads to closing of stomata. Transpiration loss of water gets reduced.

Reducing evapotranspiration

- Evapotranspiration losses can be reduced by reducing the evaporation from soil surface and transpiration from the plants, in arid zones, considerable amount of water is lost in evaporation from soil surface.
- This can be prevented by placing water tight moisture barriers or water tight mulches on the soil surface. Nonporous materials like papers, asphalt, plastic foils or metal foils can also be used for preventing evaporation losses.
- Transpiration losses can be reduced by reducing air movement over a crop by putting wind breaks and evolving such types of crops which possess xerophytic adaptations.

Recycling of water

- The wastewater from industrial or domestic sources can be used after proper treatment, for irrigation, recharging ground water, and even for industrial or municipal use. If agricultural lands are available close to cities, municipal waste water can be easily used for irrigation.

Reuse of wastewater

- Wastewater contains lots of nutrients. Its use for irrigation saves these nutrients. It improves the productivity of crops and soil fertility.
- Wastewater is a resource rather than a waste since it contains appreciable amount of nitrogen, phosphorus and potash.
- Stabilization ponds can be used for fish aquaculture. The effluent can also be used for cultivation of short-term and long term, ornamental, commercial and fodder crops.
- The potential applications of reusing of treated wastewater are in the following fields or areas:
    - Agricultural use through irrigation of crops as well as for improving river

amenity;
    - Industrial cooling especially in large industrial enterprises;
    - Reuse in municipal public areas such as watering lawns, parks, play grounds and trees;
    - Flushing toilets in hotels and residential districts;
    - Reuse of the treated wastewater for urban landscape purposes.
    - Treated waste water can also be used for groundwater recharging.

Grey water reuse

- Grey water is defined as untreated household wastewater, which has not come into contact with toilet waste. It can originate from the shower, bath, bathroom, washing basin, clothes washing machine and laundry trough. Grey water can be used in agriculture and many industries.

Reduce the loss of water due to evaporation

- The methods that reduce evaporation from water bodies are - installing wind breaks, reducing energy available for evaporation, constructing artificial aquifers, minimizing exposed surface through reservoir regulation, reducing ratio of area/volume of water bodies, locating reservoirs at higher altitudes and applying monomolecular firms.
- There are numerous methods to reduce losses due to evaporation and to improve soil moisture. Some of them are listed below:
- Mulching i.e. the application of organic or inorganic materials such as plant debris, compost, etc., slows down the surface run-off, improves soil moisture, reduces evaporation losses and improves soil fertility.
- Soil covered by crops, slow down run-off and minimizes evaporation losses; hence, fields should not be left bare for long periods of time.
- Ploughing helps to move the soil around. As a consequence it retains more water thereby reducing evaporation.
- Shelter belt of trees and bushes along the edge of agricultural fields slow down the wind speed and reduce evaporation and erosion.
- Planting of trees, grass, and bushes breaks the force of rain and helps rainwater penetrate the soil.
- Fog and dew contain substantial amounts of water that can be used directly by adapted plant species. Artificial surfaces such as netting surface traps or polythene sheets can be exposed to fog and dew; the resulting water can be used for crops.
- Contour farming is adopted in hilly areas and in lowland areas for paddy fields. Farmers recognize the efficiently of contour based systems for conserving soil and water.
- Salt-resistant varieties of crops have been also developed recently. Because these grow in saline areas, overall agricultural productivity is increased without making

additional demands on fresh water sources. Thus, this is a good water conservation strategy.

- Desalination technologies such as distillation, electro-dialysis and reverse osmosis are available.

Water Treatment for Domestic Use

- Substances that are removed during the process of drinking water treatment include suspended solids, bacteria, algae, viruses, fungi, and minerals such as iron and manganese.
- The processes involved in removing the contaminants include physical processes such as settling and filtration, chemical processes such as disinfection and coagulation and biological processes such as slow sand filtration.

Coagulation / Flocculation

- **Aluminium sulphate (alum)** is the most common coagulant used for water purification. Other chemicals, such as ferric sulphate or sodium aluminate, may also be used.
- During coagulation, liquid aluminium sulfate (alum) is added to untreated water.
- This causes the tiny particles of dirt in the water to stick together or coagulate.
- Next, groups of dirt particles stick together to form larger particles called flocs.
- Flocs are easier to remove by settling or filtration.

Sedimentation

- As the water and the floc particles progress through the treatment process, they move into sedimentation basins where the water moves slowly, causing the heavy floc particles to settle to the bottom.
- Floc which collects on the bottom of the basin is called sludge, and is piped to drying lagoons.
- In Direct Filtration, the sedimentation step is not included, and the floc is removed by filtration only.

Filtration

- Water flows through a filter designed to remove particles in the water. The filters are made of layers of sand and gravel, and in some cases, crushed anthracite.
- Filtration collects the suspended impurities in water and enhances the effectiveness of disinfection. The filters are routinely cleaned by backwashing.

Disinfection

- Water is disinfected before it enters the distribution system to ensure that any disease-causing bacteria, viruses, and parasites are destroyed.
- Chlorine is used because it is a very effective disinfectant, and residual concentrations can be maintained to guard against possible biological contamination in the water distribution system.
- The addition of chlorine or chlorine compounds to drinking water is called chlorination.
- Chlorine can combine with certain naturally occurring organic compounds in water to produce **chloroform** and other potentially harmful byproducts.
- The risk of this is very small, however, when chlorine is applied after coagulation, sedimentation, and filtration.
- Ozone gas may also be used for disinfection of drinking water. However, since ozone is unstable, it cannot be stored and must be produced on-site, making the process more expensive than chlorination.
- Ozone has the advantage of not causing taste or odour problems. It also leaves no residue in the disinfected water.
- The lack of an ozone residue, however, makes it difficult to monitor its continued effectiveness as water flows through the distribution system.

Sludge Drying

- Solids that are collected and settled out of the water by sedimentation and filtration are removed to drying lagoons.

Fluoridation

- Water fluoridation is the treatment of community water supplies for the purpose of adjusting the concentration of the free fluoride ion to the optimum level sufficient to reduce dental caries.
- Fluoride is generally present in all natural water. Its concentration up to certain level is not harmful. Beyond that level, the bones start disintegrating. This disease is called **fluorosis**.
- We have fluoride problem in many parts of our country. Bureau of Indian Standards prescribes 1.0 mg/l as desirable and 1.5 mg/l as maximum permissible limit for drinking water.
- Defluoridation at domestic level can be carried out by mixing water for treatment with adequate amount of aluminum sulphate (alum) solution, lime or sodium carbonate and bleaching powder depending upon its alkalinity (concentration of bicarbonates and carbonates in water) and fluoride contents.

pH Correction

- Lime is added to the filtered water to adjust the pH and stabilize the naturally soft water in order to minimise corrosion in the distribution system, and within customers' plumbing.
- ***Titbit: National Environmental Engineering Research Institute (NEERI) is at Nagpur.***

Removal of iron

- In many parts of our country we have problem of excess iron in drinking water especially in North-East regions. Iron causes bad taste and odour to the drinking water. Bureau of Indian Standards prescribes desirable limit for iron as 0.3 mg/l.
- A major part of iron is oxidized. Then the water is made to react with oxidizing media (lime stone). By aeration and further oxidation, the dissolved iron is converted to insoluble ferric hydroxide. The insoluble iron can thus be easily removed through filtration.

Removal of arsenic

- Arsenic is found in ground water in some parts of West Bengal. Arsenic is highly toxic in nature. It may cause a number of skin disorders or even cancer. Bureau of Indian Standards prescribes desirable limit for arsenic as 0.05 mg/l.
- Removal of arsenic is essential.
- Bleaching powder and alum are used for removal of arsenic.

Watershed Management

- Watershed is an area that contributes water to a stream or a water body through run-off or underground path.
- That is the region from which surface water draws into a river, a lake, wet land or other body of water is called its watershed or drainage basin.
- Watershed management is a technique for conservation of water and soil in a watershed.
- The presence of water in soil is essential for the growth of plants and vegetation. Forests and their associated soils and litter layers are excellent filters as well as sponges, and water that passes through this system is relatively pure.
- Various kinds of forest disturbances can speed up the movement of water from the system and in effect, reduce the filtering action.
- In mountainous terrain the forests play a prominent role in prevention of soil erosion.
- Erosion threat can be tackled by the maintenance of continual cover. Ideally, this is achieved by single stem harvesting; only one tree is felled at any one point, and the small gap so created is soon sealed by the outward growth of its neighbors.
- Despite the uncertain balance of water gain and loss, forests offer the most desirable

cover for water management strategies.

- In contrast to the rapid flows of short duration characteristics of sparsely vegetated land water yields are gradual, reliable and uniform in forests. Deforested land sheds water swiftly, causing sudden rises in the rivers below.
- Over a large river system, such as that of the Ganga and the Yamuna, forests are a definite advantage since they lessen the risk of floods. They also provide conditions more favourable to fishing and navigation than un-forested land.
- All natural streams contain varying amounts of dissolved and suspended matter, although streams contain varying amounts of dissolved and
- Suspended matter, although streams issuing from undisturbed watershed are ordinarily of high quality.
- Waters from forested areas are not only low in foreign substances, but they also are relatively high in oxygen and low in unwanted chemicals.
- The belief that forests increase rainfall has not been substantiated by scientific inquiry. Local effects can, however, prove substantial, particularly in semiarid regions where every millimeter of rain counts.
- The air above a forest, as contrasted with grassland, remains relatively cool and humid on hot days, so that showers are more frequent.
- Many areas in India used to get significant rainfall when they were forested are now facing severe draught due to denudation (example Rajasthan desert).

Individual and Community Role

- Building check dams on seasonal rivers.
- Micro-watershed management project.
- Constructing percolation tanks in every residential and industrial complex.
- Roof top rain water collection for drinking purposes. [2/3rd of water is wasted in RO – reverse osmosis filtration]

Government's efforts on water conservation

- National Water Policy 2002 strongly emphasizes conservation of water.
- Construction of large number of dams on various river systems.
- Interlinking of rivers (proposed).
- Promotion of bunds at village level.
- Promotion of rain water harvesting.
- Promotion of reuse and recycling of wastewater.
- Steps to protect water quality.
- Drought-proofing the future.
- Permanent conservation measures may include:
    - Subsidizing use of water-efficient faucets, toilets and showerheads

- Public education and voluntary use reduction.
- Billing practices that impose higher rates for higher amounts of water use
- Building codes that require water efficient fixtures or appliances
- Leak detection surveys and meter testing, repair and replacement
- Reduction in use and increase in recycling of industrial water

- Temporary cutbacks may include:
  - Reduction of system-wide operating pressure
  - Water use bans, restrictions, and rationing
  - Strengthening of local or municipal bodies could help addressing the issue of water shortage and its management in cities.

Soil Pollution

- Soil pollution is defined as the 'addition of substances to the soil, which adversely affect physical, chemical and biological properties of soil and reduces its productivity.
- It is build-up of persistent toxic compounds, chemicals, salts, radioactive materials, or disease causing agents in soil which have adverse effects on plant growth, human and animal health.

Causes and Sources of Soil Pollution

Plastic bags

- They accumulate in soil and prevent germination of seeds. They stay in soil for centuries without decomposing (non-biodegradable).
- Burning of plastic in garbage dumps release highly toxic and poisonous gases like **carbon monoxide, carbon dioxide, phosgene, dioxins** and other poisonous **chlorinated compounds**.
- Toxic solid residue left after burning remains in soil. The harmful gas enters soils through chemical cycles.

Industrial sources

- They include **fly ash, metallic residues, mercury, lead, copper, zinc, cadmium, cynides, thiocynates, chromates, acids, alkalies, organic substances, nuclear wastes** etc.
- Large number of industrial chemicals soil and are known to create many health hazards including cancer.

Pesticides

- Pesticides are chemicals that include insecticides, fungicides, algicides, rodenticides, weedicides sprayed in order to improve productivity of agriculture, forestry and horticulture.
- **Chlorohydrocarbons (CHCs) like DDT, endosulfan, heptachlor** accumulate in soil and cause biomagnification. Some of these pesticides like DDT and endosulfan are banned by most of the countries.

Fertilizers and manures

- Excessive use of chemical fertilizers **reduces the population of soil borne organisms** and the crumb structure of the soil, productivity of the soil and increases salt content of the soil.

Discarded materials

- It includes concrete, asphalt, rungs, leather, cans, plastics, glass, discarded food, paper and carcasses.

Radioactive wastes

- Radioactive elements from mining and nuclear power plants, find their way into water and then into the soil.

Other pollutants

- Many air pollutants (acid rain) and water pollutants ultimately become part of the soil and the soil also receives some toxic chemicals during weathering of certain rocks.

Effects of soil pollution

Agriculture

- Reduced soil fertility due to increase in alkalinity, salinity or pH.
- Reduced crop yield due to reduced fertility.
- Reduced nitrogen fixation due to the reduced number of nitrogen fixers.
- Increased erosion due to loss of forests and other vegetation.
- Run off due to deforestation cause loss of soil and nutrients.
- Deposition of silt in tanks and reservoirs due to soil erosion.

Health

- Health effects are similar to effects of water pollution.

Environment

- Ecological imbalance.
- Foul smell and release of gases.
- Waste management problems.

Control measures

- More or less same as for water pollution
- Indiscriminate disposal of solid waste should be avoided.
- To control soil pollution, it is essential to stop the use of plastic bags and instead use bags of degradable materials like paper and cloth.
- Sewage should be treated properly before using as fertilizer and as landfills.
- The organic matter from domestic, agricultural and other waste should be segregated and subjected to vermicomposting which generates useful manure as a byproduct.
- The industrial wastes prior to disposal should be properly treated for removing hazardous materials.
- Biomedical waste should be separately collected and incinerated in proper incinerators.
- Use of bio pesticides, bio fertilizers. Organic farming.
- Four R's: Refuse, Reduce, Reuse, and Recycle.
- Afforestation and Reforestation.
- Solid waste treatment.
- Reduction of waste from construction areas.

Noise Pollution

- Noise by definition is “sound without value” or “any noise that is unwanted by the recipient”.
- Noise level is measured in terms of decibels (dB). An increase of about 10 dB is approximately double the increase in loudness.
- W.H.O. (World Health Organization) has prescribed optimum noise level as 45 dB by day and 35 dB by night. Anything above 80 dB is hazardous.

Effects of noise pollution

- Noise pollution leads to irritation, increased blood pressure, loss of temper, mental depression and annoyance, decrease in work efficiency, loss of hearing which may be first temporary but can become permanent in the noise stress continues.

Prevention and control of noise pollution

- Road traffic noise can be reduced by better designing and proper maintenance of vehicles.
- Noise abatement measures include creating noise mounds, noise attenuation walls and well maintained roads and smooth surfacing of roads.
- Retrofitting of locomotives, continuously welded rail track, use of electric locomotives or deployment of quieter rolling stock will reduce noises emanating from trains.
- Air traffic noise can be reduced by appropriate insulation and introduction of noise regulations for takeoff and landing of aircrafts at the airport.
- Industrial noises can be reduced by sound proofing equipment like generators and areas producing lot of noise.
- Power tools, very loud music and land movers, public functions using loudspeakers, etc. should not be permitted at night. Use of horns, alarms, refrigeration units, etc. is to be restricted. Use of fire crackers which are noisy and cause air pollution should be restricted.
- A **green belt of trees** is an efficient noise absorber.

Ambient Noise Level Monitoring

- Noise Pollution (Control and Regulation) Rules, 2000 define ambient noise levels for various areas as follows:

Category of Area/ Zone	Limits in dB(A) Leq	
	Day Time	Night Time
	6 a.m. to 10 p.m.	10 p.m to 6 a.m
A. Industrial Area	75	70
B. Commercial Area	65	55
C. Residential Area	55	45
D. Silence Zone	50	40

- **Silence Zone** is an area comprising not less than 100 metres around hospitals, educational institutions, courts, religious places or any other area declared as such by a competent authority.

THINK!

- What was the recent controversy regarding 'Silence Zone'?
- What was the recent amendment done by Central Government regarding noise pollution rule?

The Indian Constitution of 1950 did not have any provisions directly dealing with environmental pollution. But the 42nd Amendment of Constitution passed in 1996 inserted article 48-A and Article 51-A to protect and improve the environment as has been discussed in Chapter II.

Radioactive Pollution

Sources

Artificial Sources of Radioactive pollution

- Accidents in nuclear power plants and nuclear waste.
- Nuclear weapon testing and explosion (Nuclear fallout). The fall Out contains radioactive substances such as **strontium-90, cesium-137, iodine-131**, etc.
- Uranium mining and mining of other radioactive material like **thorium** etc. Uranium contamination is well observed in India.
- Radiation therapy and direct exposures to radiation for diagnostic purposes (e.g. X-rays), chemotherapy etc.
- The slow nuclear radiations can emanate from a variety of sources viz. nuclear reactors, laboratories, hospitals, and direct exposures to X-rays etc.

Natural Sources

- They include cosmic rays from space and terrestrial radiations from radio-nuclides present in earth's crust such as **radium-224, uranium-238, thorium-232, potassium-40, carbon-14**, etc.
- Some species of animals and plants preferentially accumulate specific radioactive, materials. For example, oysters deposit 65Zn, fish accumulate 55Fe, marine animals selectively deposit 90Sr.

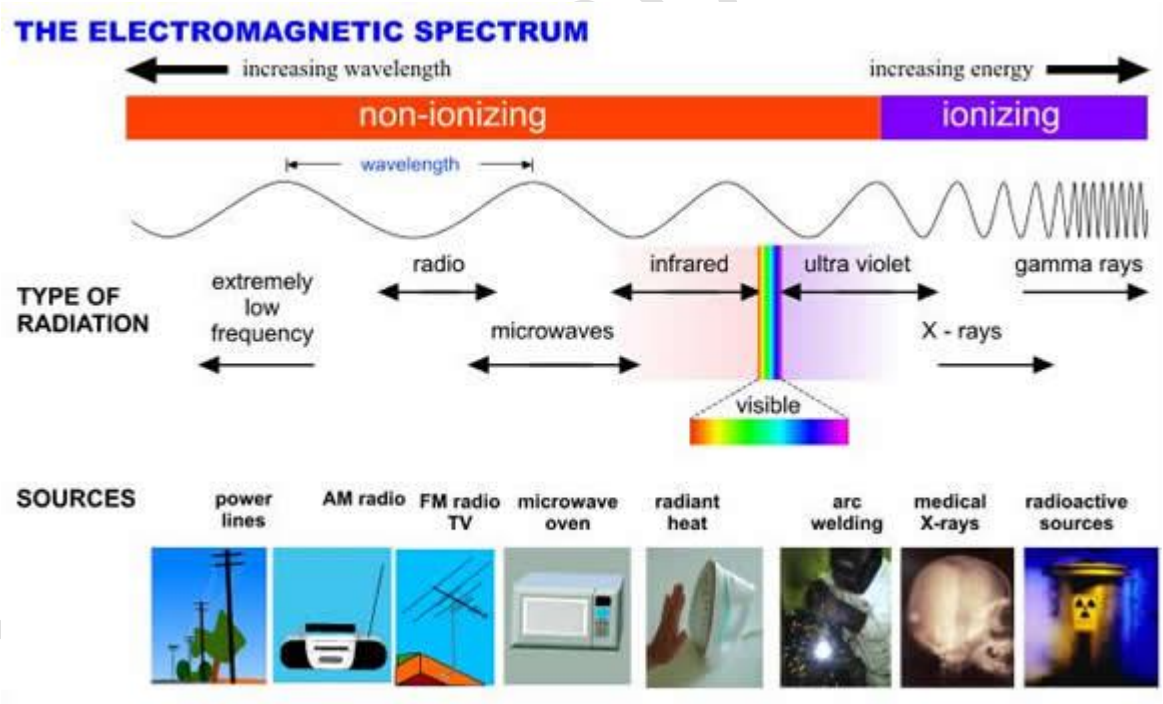
Effects of Radioactive pollution

- The use of nuclear energy has two very serious inherent problems.
    - accidental leakage, as occurred in the **Three Mile Island, Chernobyl** and **Fukushi**ma incidents
    - Safe disposal of radioactive wastes. It has been recommended that storage of nuclear waste, after sufficient pre-treatment, should be done in suitably shielded containers buried within the rocks, about 500 m deep below the earth's surface. However, this method of disposal is meeting stiff opposition

from the public.

- The quick devastating and immediate effects of nuclear radiations are well known as witnessed following Hiroshima and Nagasaki in Japan during World War II.
- Continued small dose exposure to nuclear radiation can cause **childhood leukemia, miscarriage, underweight babies, infant deaths, increased susceptibility to AIDS and other immune disorders and increased criminalities**.
- Underground bomb testing releases radiations in very small doses of radicals that pollute water and soil.
- This radioactive water is taken by plants through roots. The radioactivity enters food chain when such plants are eaten by animals and humans. Such radioactivity has been detected even in the milk.
- Radiation, that is given off by nuclear waste is extremely damaging to biological organisms, because it causes mutations to occur at a very high rate.
- At high doses, nuclear radiation is lethal but at lower doses, it creates various disorders, the most frequent of all being cancer.

Ionizing and Non-Ionizing Radiation



- Radioactivity is a phenomenon of spontaneous emission of **proton (alpha-particles)**, **electrons (betaparticles)** and **gamma rays (short wave electromagnetic waves)** due to **disintegration of atomic nuclei** of some elements. These cause radioactive pollution.
- Radiations can be categorized into two groups namely the non-ionizing radiations and the ionizing radiations.

Non-ionizing radiations

- Non-ionizing radiations are constituted by the electromagnetic waves at the **longer wavelength** of the spectrum ranging from near **infra-red rays to radio waves** [include **higher wavelength ultraviolet rays, microwaves** etc.].
- These waves have energies enough to excite the atoms and molecules of the medium through which they pass, causing them to vibrate faster but **not strong enough to ionize them**.
- In a microwave oven the radiation causes water molecules in the cooking medium to vibrate faster and thus raising its temperature.
- They may damage eyes which may be caused by **reflections from coastal sand**, snow (**snow blindness**) directly looking towards sun during eclipse.
- They injure the cells of skin and blood capillaries producing blisters and reddening called sunburns.

Ionizing radiations

- Ionizing radiations cause **ionization** (one or more electrons are pealed out from the outer shells of an atom) of atoms and molecules of the medium through which they pass.
- Ionization is the process by which an atom or a molecule acquires a negative or positive charge by gaining or losing electrons to form ions, often in conjunction with other chemical changes.
- Electromagnetic radiations such as **short wavelength ultra violet radiations** (**UV), X-rays** and **gamma rays** and energetic particles produced in nuclear processes, electrically charged particles like **alpha and beta particles** produced in radioactive decay and **neutrons** produced in nuclear fission, are highly damaging to living organisms.
- Electrically charged particles produced in the nuclear processes can have sufficient energy to knock electrons out of the atoms or molecules of the medium, thereby producing ions.
- The ions produced in water molecules, for example, can induce reactions that can **break bonds** in proteins and other important molecules.
- An example of this would be when a gamma ray passes through a cell, the water molecules near the DNA might be ionized and the ions might react with the DNA causing it to break.
- They can also cause chemical changes by breaking the chemical bonds, which can damage living tissues.
- Short range effects include burns, impaired metabolism, dead tissues and death of the organisms.
- Long range effects are **mutations** increased incidence of **tumors and cancer**, shortening of life-span and developmental changes.

Non-ionising radiations affect only those components which absorb them and have low penetrability.

Ionising radiations have high penetration power and cause breakage of macro molecules.

Biological Damage Due to Ionizing Radiations

- The biological damage resulting from ionizing radiations is generally termed as **radiation damage**.
- Large amounts of radiation can kill cells that can dramatically affect the exposed organism as well as possibly its offspring.
- Affected cells can mutate and result in cancer. A large enough dose of radiation can kill the organism.
- Radiation damage can be divided into two types: (a) **somatic damage** (also called **radiation sickness**) and (b) **genetic damage**.
- Somatic damage refers to damage to cells that are not associated with reproduction.
- Effects of somatic radiation damage include reddening of the skin, loss of hair, ulceration, **fibrosis of the lungs**, the formation of holes in tissue, a **reduction of white blood cells**, and the induction of **cataract in the eyes**. This damage can also result in cancer and death.
- Genetic damage refers to damage to cells associated with reproduction. This damage can subsequently cause genetic damage from **gene mutation** resulting in abnormalities. Genetic damages are passed on to next generation.

Radiation dose

- The biological damage caused by the radiation is determined by the intensity of radiation and duration of the exposure.
- It depends on the amount of energy deposited by the radiation in the biological system.
- For example, alpha particles (protons) do much more damage per unit energy deposited than do beta particles (electrons).
- A traditional unit of human-equivalent dose is the **rem**, which stands for radiation equivalent in man.
- At low doses, such as what we receive every day from background radiation (<1 m rem), the cells repair the damage rapidly.
- At higher doses (up to 100 rem), the cells might not be able to repair the damage, and the cells may either be changed permanently or die.
- Cells changed permanently may go on to produce abnormal cells when they divide and may become cancerous.
- At even higher doses, the cells cannot be replaced fast enough and tissues fail to function. An example of this would be "**radiation sickness**." This is a condition that results after high doses is given to the whole body (>100 rem).

Damage due to radiation particles

- Alpha particles can be blocked by a piece of paper and human skin.
- Beta particles can penetrate through skin, while can be blocked by some pieces of glass and metal.
- Gamma rays can penetrate easily to human skin and damage cells on its way through, reaching far, and can only be blocked by a very thick, strong, massive piece of concrete.

Half-Life - Period of Radioactivity

- Each radioactive material has a constant decay rate. Half-life is the time needed for half of its atoms to decay.
- Half-life of a radio nuclide refers to its period of radioactivity. The half-life may vary from a fraction of a second to thousands of years.
- The radio nuclides with **long half-time** are the chief source of environmental radioactive pollution.

Accidents at nuclear power plants

- Nuclear fission in the reactor core produces lot of heat which if not controlled can lead to a meltdown of fuel rods in the reactor core.
- If a meltdown happens by accident, it will release large quantities of highly dangerous radioactive materials in the environment with disastrous consequences to the humans, animals and plants.
- To prevent this type of accidents and reactor blow up, the reactors are designed to have a number of safety features. Inspire of these safety measures three disasters in the nuclear power plants are noteworthy – **Three Mile Island' in Middletown (U.S.A.) in 1979, Chernobyl (U.S.S.R.) in 1986 and Fukushima Daiichi nuclear disaster in 2011**.
- In the first two cases a series of mishaps and errors resulted in over heating of the reactor core and lot of radiation was released into the environment.
- The leakage from Three Mile Island reactor was apparently low and no one was injured immediately. However, in case of Chernobyl the leakage was very heavy causing death of some workers and radiation spread over large areas scattered all over Europe.
- The latest one – Fukushima Daiichi nuclear accident was triggered by an earthquake.
- Other important nuclear power plant disasters include Chalk river, Canada, Windscale Plutonium Production Center, U.K and Monju, Japan.
- Accidents with nuclear submarines and nuclear warships is a possibility.

Safe Disposal of Nuclear Wastes

- Radioactive wastes are of two types
    - low level radioactive wastes (LLW) which include civilian applications of radionuclides in medicine, research and industry, materials from decommissioned reactors, protection clothing worn by persons working with radioactive materials or working in nuclear establishments.
    - High level radioactive wastes (HLW) results from spent nuclear fuel rods and obsolete nuclear weapons.

Some proposed methods of disposing nuclear waste are:

- Bury it deep underground in insulated containers. This is a strategy being pursued in United States.
- Shoot it into the space or into the sun. The cost would be very high and a launch accident should be disastrous.
- Bury it under the ice sheet of Antarctica or Greenland ice cap. The ice could be destabilized by heat from the waste. The method has been prohibited by international law.
- Dump it into deep oceans by keeping the waste into glass and steel cases. But the containers might leak and contaminate the ocean.
- Change it into harmless or less harmful isotopes. Currently no method is known to do that and the method would be too costly.
- Presently waste fuel rods are being stored in special storage ponds at reactor sites or sent to reprocessing plants. Even though reprocessing is more expensive but some countries use reprocessing as an alternative to waste storage.

Preventive/Control Measures

- Prevention is the best control measure as there is no cure available for radiation damage.
- All safety measures should be strictly enforced. UN should have more powers to perform safety checks in various nuclear establishments across the world.
- Worldwide monitoring of radiation leakage should be a priority.
- Proper technologies should be developed to prevent contamination of water and soil by radioactive waste and radioactive materials.
- More avenues for safe disposal of radioactive must be worked out.
- Regular monitoring through frequent sampling and quantitative analysis in domestic nuclear establishments.
- Appropriate steps should be taken to protect from occupational exposure.
- Gradually decreasing the share of nuclear power is a necessity.

- World must unite to ban production and use of nuclear weapons.

Impact of Radiation from Mobile Phone Towers

- The radiation that comes from mobile tower radiation is non-ionizing radiation.

Health Impacts

- Every antenna on cell phone tower radiates Electro-Magnetic Radiation (EMR).
- One cell phone tower is being used by a number of operators, more the number of antennas more is the power intensity in the nearby area.
- The power level near towers is higher and reduces as we move away.
- EMR may cause cellular and psychological changes in human beings due to thermal effects that are generated due to absorption of microwave radiation.
- The exposure can lead to genetic defects, effects on reproduction and development, Central Nervous System behavior etc.
- EMR can also cause non thermal effects which are caused by radio frequency fields at levels too low to produce significant heating and are due to movement of calcium and other ions across cell membranes.
- Such exposure is known to be responsible for fatigue, nausea, irritability, headaches, loss of appetite and other psychological disorders.
- The current exposure safety standards are purely based on the thermal effects considering few evidences from exposure to non-thermal effects.

Impact on birds

- The surface area of bird is relatively larger than their body weight in comparison to human body so they absorb more radiation.
- Also the fluid content in the body of the bird is less due to small body weight so it gets heated up very fast.
- Magnetic field from the towers disturbs birds' navigation skills hence when birds are exposed to EMR they disorient and begin to fly in all directions.
- A large number of birds die each year from collisions with telecommunication masts.

What are the responsibilities of Stakeholders?

MoEF

- The MoEF has to notify the impacts of communication towers on wildlife and human health to the concerned agencies for regulating the norms for notification of standards for safe limit of EMR.

State/Local Bodies:

- Regular monitoring and auditing in urban localities/educational/hospital/industrial/ residential/recreational premises including the Protected Areas and ecologically sensitive areas.
- Carry out an 'Ecological Impact Assessment' before giving permission for construction of towers in wildlife and ecologically important areas.

State Environment and Forest Department

- State Environment and Forest Department are entrusted with the task of providing regular awareness among the people about the norms on cell phone towers and dangers of EMR from them.

Department of Telecommunications

- Avoid overlapping of high radiation fields. New towers should not be permitted within a radius of one kilometer of the existing tower.
- The location and frequencies of cell phone towers and other towers emitting EMR should be made available in the public domain GIS mapping of all the cell phone towers to be maintained to monitor the population of bird and bees in and around the wildlife protected area and the mobile towers.
- Need to refine the Indian standard on safe limits of exposure to EMR, keeping in view the available literature on impacts on various life forms.
- To undertake Precautionary approaches to minimize the exposure levels and adopt stricter norms perennial, that live longer than agricultural crops.
- Any study conducted on impact of EMF radiation on wildlife needs to be shared to facilitate appropriate policy formulations.

Solid Wastes

- Solid wastes or municipal solid wastes generally comprise paper, food wastes, plastics, glass, metals, rubber, leather, textile, etc.
- Open-burning reduces the volume of the wastes, although it is generally not burnt to completion and open dumps often serve as the breeding ground for rats and flies.
- Sanitary landfills were adopted as the substitute for open-burning dumps. In a sanitary landfill, wastes are dumped in a depression or trench after compaction, and covered with dirt every day.
- Landfills are also not really much of a solution since the amount of garbage generation especially in the metros has increased so much that these sites are getting filled too.
- Also there is danger of seepage of chemicals, etc. from these landfills polluting the underground water resources.

Effects of Plastic Waste

- Conventional plastics, right from their manufacture to their disposal are a major problem to the environment.
- The land gets littered by plastic bag garbage and becomes ugly and unhygienic.
- Conventional plastics have been associated with **reproductive problems** in both humans and wildlife.
- **Dioxin** (highly carcinogenic and toxic) byproduct of the manufacturing process is one of the chemicals believed to be passed on through **breast milk** to the nursing infant.
- Burning of plastics, especially **PVC** releases dioxin and also **furan** into the atmosphere.
- *Dioxins are environmental pollutants. They belong to the so-called "dirty dozen" - a group of dangerous chemicals known as **persistent organic pollutants** (POPs).*
- *The name "dioxins" is often used for the family of structurally and chemically related **polychlorinated dibenzo para dioxins (PCDDs)** and **polychlorinated dibenzofurans (PCDFs)**.*
- Plastic bags can also contaminate foodstuffs due to leaching of toxic dyes and transfer of pathogens.
- Careless disposal of plastic bags chokes drains, blocks the porosity of the soil and causes problems for groundwater recharge.
- Plastic disturbs the soil microbe activity. The terrestrial and aquatic animals misunderstand plastic garbage as food items, swallow them and die.
- Plastic bags deteriorates soil fertility as it forms part of manure and remains in the soil for years.
- Designing eco-friendly, biodegradable plastics are the need of the hour.

Remedy for Plastic Waste

- **Polyblend** is a fine powder of recycled and modified plastic waste. This mixture is mixed with the **bitumen** that is used to lay roads.
- Blends of Polyblend and bitumen, when used to lay roads, enhanced the bitumen's water repellant properties, and helped to increase road life by a factor of three.

Industrial solid waste

- Thermal power plants producing coal ash/fly ash;
- The integrated iron and steel mills producing blast furnace slag;
- Non-ferrous industries like aluminium, copper and zinc producing **red mud** and tailings;
- Sugar industries generating **press mud**;
- Pulp and paper industries producing **lime mud**;
- Fertilizer and allied industries producing **gypsum**;

Recoverable Matter

- Pulp and paper: Ligno-sulphate,
- sodium salts.
- Textile: Caustic soda.
- Distillery: Potassium salts, yeast Fertilizer (phosphatic) Calcium sulphate, fluoride.
- Coke oven: Ammonia, ammonium sulphate, tar, naphthalene, phenol.

Concept of Cleaner Technologies

- One way to emulate nature is to recycle and reuse the chemicals used in industries instead of dumping them into the environment.
- Industries may interact in such a way that they establish a "resource exchange" programme in which waste of one industry or manufacturer is utilized as raw material by another-industry- similar to food web in nature.
- Use of CNG by automobiles instead of petrol, as an automobile fuel, is an example of cleaner technology which has reduced pollution of the environment.
- Instead of throw away economy which creates huge amount of waste, the manufacturers can make more money if their product is redesigned so that it uses minimum amount of raw materials lasts longer, easy to maintain, repair, remanufacture, reuse or recycle.

Hazardous Waste

- Any substance that is present in the environment or released into the environment causing substantial damage to public health and welfare of the environment is called hazardous substance.
- Any hazardous substance could exhibit any one or more of the following characteristics: **toxicity, ignitability, corrosivity or reactivity** (explosive). Thus, any waste that contains hazardous or very hazardous substance is called hazardous waste.
- Hazardous wastes can originate from various sources such as: house-hold, local areas, urban, industry, agriculture, construction activity, hospitals and laboratories, power plants and other sources.
- The hazardous waste when disposed of release a number of environmentally unfriendly substance(s).
- Hospitals generate hazardous wastes that contain disinfectants and other harmful chemicals, and also pathogenic micro-organisms. Such wastes also require careful treatment and disposal. The use of **incinerators** (destroy, especially waste material, by burning) is crucial to disposal of hospital waste.

Stockholm Convention on Persistent Organic Pollutants

- Stockholm Convention is an international environmental treaty
- Came into effective in 2004
- Aims to eliminate or restrict the
- Production and use of persistent organic pollutants (POPs).
- POPs are defined as "chemical substances that persist in the environment, bio-accumulate through the food web, and pose a risk of causing adverse effects to human health and the environment".

Important Listed substances

- **Aldrin:** Used as a local ectoparasiticide and insecticide
- **Heptachlor:** Used as a termiticide (including in the structure of houses and underground), for organic treatment and in underground cable boxes
- **Hexachlorobenzene:** Used as a chemical intermediate and a solvent for pesticides
- **Endrin:** Endrin has been used primarily as an agricultural insecticide on tobacco, apple trees, cotton, sugar cane, rice, cereal, and grains.
- **Polychlorinated biphenyl:** PCB's commercial utility was based largely ontheir chemical stability, including low flammability, and physical properties, including electrical insulating properties. They are highly toxic.
- **DDT:** DDT is the best-known of several chlorine-containing pesticides used in the 1940s and 1950s.

Basel Convention

- Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and Their Disposal.
- International treaty that was designed to reduce the movements of hazardous waste between nations.
- Main goal is to prevent transfer of hazardous waste from developed to less developed countries (LDCs).
- It **does not** address the movement of **radioactive waste**.
- 182 states and the European Union are parties to the Convention
- Location → Basel, Switzerland

Rotterdam Convention

- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.
- Multilateral treaty to promote shared responsibilities in relation to importation of hazardous chemicals.
- The convention promotes open exchange of information and calls on exporters of hazardous chemicals to use proper labeling, safe handling, and inform purchasers of any known restrictions or bans.
- Signatory nations can decide whether to allow or ban the importation of chemicals listed in the treaty.

Electronic Waste: E – WASTE

- The discarded and end-of-life electronic products ranging from computers, equipment, home appliances, audio and video products and all of their peripherals are popularly known as Electronic waste (E-waste).
- E-waste is not hazardous if it is stocked in safe storage or recycled by scientific methods or transported from one place to the other in parts or in totality in the formal sector. The e-waste can, however, be considered hazardous if recycled by primitive methods.

E — Waste in India

- India generates about 18.5 lakh metric tonnes (MT) of electronic waste every year, with Mumbai and Delhi-NCR accounting for the biggest chunk. The figure is likely to reach up to 30 lakh MT per year by 2018.
- Bangalore, Chennai, Kolkata, Ahmadabad, Hyderabad, Pune, Surat and Nagpur are other important cities generating substantial amount of e-waste.

- Among the eight largest e-waste generating states, **Maharashtra** ranks first followed by **Tamil Nadu** (2nd), **Andhra Pradesh** (3rd), Uttar Pradesh (4th), Delhi (5th), Gujarat (6th), Karnataka (7th) and West Bengal (8th).
- Over half of the e-wastes generated in the developed world are exported to developing countries, mainly to China, India and Pakistan, where metals like copper, iron, silicon, nickel and gold are recovered during recycling process.
- Unlike developed countries, which have specifically built facilities for recycling of e-wastes, recycling in developing countries often involves manual participation thus exposing workers to toxic substances present in e-wastes.

Heavy Metal Toxicity and Methods of Their Prevention

- Toxic metals are dispersed in the environment through metal smelting industrial emissions, burning of organic wastes, automobiles and coal based power generation.
- Heavy metals can be carried to places far away from their source of origin by winds when they are emitted in gaseous form or in form of fine particulates.
- Rain ultimately washes the air having metallic pollutants and brings them to the land and to water bodies.
- Heavy metals may endanger public health after being incorporated in food chain.
- Heavy metals cannot be destroyed by biological degradation.
- Incidence of heavy metal accumulation in fish, oysters, mussels, sediments and other components of aquatic ecosystems have been reported from all over the world.
- The heavy metals often encountered in the environment include lead, mercury, arsenic, chromium. These are known to cause toxic effects in living organisms.

Lead

- Lead enters the atmosphere from automobile exhaust. **Tetraethyl lead (TEL)** was added to petrol as an **antiknock agent** for smooth running of automobile engines.
- TEL has now been replaced by other anti-knock compounds to prevent emission of lead by automobiles. Lead in petrol is being phased out by introduction of lead free petrol.
- Many industrial processes use lead and it is often released as a pollutant. Battery scrap also contains lead. It can get mixed up with water and food and create cumulative poisoning.
- Lead can cause irreversible behavioral disturbances, neurological damage and other developmental problems in young children and babies. It is a carcinogen of the lungs and kidneys.

Mercury

- In Japan, mass mercury poisoning (**Minamata disease**) was observed in 1960s, caused by eating fish from Minamata Bay which were contaminated with **methyl mercury**.

- Largest source of mercury pollution is through aquatic animals such as fish which accumulate mercury as methyl mercury.
- Mercury kills cells in the body and damages organs which come in contact with mercury and thus impairs their functioning.
- Inhalation of mercury vapours is more dangerous than its ingestion.
- Chronic exposure causes lesions in the mouth and skin and neurological problems.
- Typical symptoms of mercury poisoning are irritability, excitability, loss of memory, insomnia, tremor and gingivitis.
- Exposure to mercury can be prevented by taking care that mercury is not released in the environment as well as by replacing mercury by other materials.
- Mercury thermometers used earlier are getting replaced by mercury free thermometer.

Arsenic

- Arsenic is associated with **copper, iron and silver ores**.
- Arsenic is also emitted from **fossil fuel burning**.
- Liquid effluents from **fertilizer plants** also contain arsenic.
- Ground water contamination with arsenic is very common in areas where it is present.
- Chronic arsenic poisoning causes melanosis and keratosis (dark spots on the upper chest, back and arms are known as melanosis. The next stage is keratosis in which palms become hard) and leads to loss of appetite, weight, diarrhoea, gastrointestinal disturbances and skin cancer.
- Surface waters are generally free from arsenic pollution and should be preferred for drinking and cooking.
- Alternatively the tube well/ hand pump water should be purified to remove arsenic before consumption. Techniques for removing arsenic from water are available.

Cadmium

- Mining especially of **zinc** and metallurgical operations, electroplating industries, etc. release cadmium in the environment.
- It may enter the human body by inhalation or from aquatic sources including fish, etc.
- It may cause hypertension, liver cirrhosis, brittle bones, kidney damage and lung cancer.
- **Itai-itai** disease first reported from Japan in 1965 was attributed to cadmium contamination in water and rice caused by discharge of effluents from a zinc smelter into a river.

Other Heavy Metals

- Metals such as **zinc, chromium, antimony** and **tin** enter food from cheap cooking utensils.
- Preserved foods stored in tin cans also cause contamination by tin.
- Zinc is a skin irritant and affects pulmonary system.
- Problems of heavy metal toxicity can be prevented by avoiding the use of utensils made from materials containing these heavy metals or use of drinking water and consuming fish having these heavy metals.

Occupational Health Hazards

Black lung disease

- In coal mining areas coal dust is the main air pollutant. The deposits of coal dust makes miners lungs look black instead of a healthy pink and hence the name black lung disease.
- Black lung disease is the common name for **pneumoconiosis (CWP) or anthracosis**, a lung disease of older workers in the coal industry, caused by inhalation over many years, of small amounts of coal dust.
- The particles of fine coal dust accumulate in lungs. Eventually this build-up causes thickening and scarring making the lungs less efficient in supplying oxygen to the blood.
- In some cases a progressive massive fibrosis develops, in which damage continues in the upper parts of the lungs even after exposure to dust has ended.
- X-rays can detect black lung disease before it causes any symptoms.

Noise

- Workers in mining, manufacturing and construction industries are exposed to high levels of noise which is a very important stress factor.
- Sound levels higher than 80 to 90 dB for more than eight hours are harmful to human ear. Some of the adverse effects of sound are –

Psychological

- Noise leads to emotional disturbances such as annoyance, disturbed sleep, lack of concentration and reduced efficiency.

Auditory effects

- Auditory fatigue – Occurs when noise level is in the range of 85 to 90 dB e.g. noise of a food blender.

- Deafness or impaired hearing – It may be temporary or permanent. Temporary hearing loss occurs on continuous exposure to noise as in case of telephone operators.
- Repeated or continuous exposure to noise more than 90 dB may result in permanent loss of hearing.

Non-auditory effects

- Interference with speech and communication.
- Annoyance: Most people are annoyed by noise and some may become neurotic. Neurotic people lose their temper quickly and become irritable.
- Efficiency: High level of noise at the work place reduces working efficiency. Quiet environment helps in increasing efficiency.
- General change in the body: Exposure to noise increases blood pressure, pulse rate, breathing and sweating or headache.

Chemicals and Biological Agents

- Workers in many industries are exposed to chemicals which are hazardous and may be even carcinogenic such as in textiles, cement and construction industries.
- Substances such as **benzene, chromium, nitrosamines** and **asbestos** may cause cancers of lung, bladder, skin, mesothelium, liver, etc.
- Occupational asthma is caused due to exposure to organic dusts, microorganisms, bacteria, fungi and moulds and several chemicals.
- **Silicosis** first reported from Kolar gold mines in 1947 is a common disease among miners, pottery and ceramic industry workers.
- **Pneumoconiosis** and **byssinosis** are common among mica and textile industry workers respectively.

Treatment and disposal of solid waste

Open dumps

- Open dumps refer to uncovered areas that are used to dump solid waste of all kinds.
- The waste is untreated, uncovered, and not segregated. It is the breeding ground for flies, rats, and other insects that spread disease.
- The rainwater runoff from these dumps contaminates nearby land and water thereby spreading disease. Treatment by open dumps is to be phased out.

Landfills

- It is a pit that is dug in the ground. The garbage is dumped and the pit is covered with soil everyday thus preventing the breeding of flies and rats.

- After the landfill is full, the area is covered with a thick layer of mud and the site can thereafter be developed as a parking lot or a park.
- Problems - All types of waste are dumped in landfills and when water seeps through them it gets contaminated and in turn pollutes the surrounding area. This contamination of groundwater and soil through landfills is known as leaching.

Sanitary landfills

- Sanitary landfill is more hygienic and built in a methodical manner to solve the problem of leaching.
- These are lined with materials that are impermeable such as plastics and clay, and are also built over impermeable soil. Constructing sanitary landfills is very costly.

Incineration plants

- The process of burning waste in large furnaces at high temperature is known as incineration.
- In these plants the recyclable material is segregated and the rest of the material is burnt and ash is produced.
- Burning garbage is not a clean process as it produces tonnes of toxic ash and pollutes the air and water.
- A large amount of the waste that is burnt here can be recovered and recycled. In fact, at present, incineration is kept as the last resort and is used mainly for treating the infectious waste.

Pyrolysis

- It is a process of combustion in **absence of oxygen** or the material burnt under controlled atmosphere of oxygen. It is an alternative to incineration.
- The gas and liquid thus obtained can be used as fuels.
- Pyrolysis of carbonaceous wastes like firewood, coconut, palm waste, corn combs, cashew shell, rice husk paddy straw and saw dust, yields **charcoal** along with products like **tar, methyl alcohol, acetic acid, acetone** and **fuel gas**.

Composting

- Composting is a biological process in which micro-organisms, mainly fungi and bacteria, decompose degradable organic waste into humus like substance in the presence of oxygen.
- This finished product, which looks like soil, is high in carbon and nitrogen and is an excellent medium for growing plants.
- It increases the soil's ability to hold water and makes the soil easier to cultivate. It helps

the soil retain more plant nutrients.

- It recycles the nutrients and returns them back to soil as nutrients.
- Apart from being clean, cheap, and safe, composting can significantly reduce the amount of disposable garbage.

Vermiculture

- It is also known as earthworm farming. In this method, Earth worms are added to the compost. These worms break the waste and the added excreta of the worms make the compost very rich in nutrients.
- Four R's – Reduce, Reuse, Recycle and Recover.

Waste Minimization Circles (WMC)

- WMC helps Small and Medium Industrial Clusters in waste minimization in their industrial plants.
- This is assisted by the **World Bank** with the Ministry of Environment and Forests acting as the nodal ministry.
- The project is being implemented with the assistance of **National Productivity Council (NPC), New Delhi**.
- The initiative also aims to realize the objectives of the Policy Statement for Abatement of Pollution (1992), which states that the government should educate citizens about environmental risks, the economic and health dangers of resource degradation and the real economic cost of natural resources.
- The policy also recognizes that citizens and non-governmental organizations play a role in environmental monitoring, therefore, enabling them to supplement the regulatory system and recognizing their expertise where such exists and where their commitments and vigilance would be cost effective.