PHYTOREMEDIATION

Phytoremediation is a bioremediation process that employs varieties of plants to eliminate, transfer, maintain, extract or degrade contaminants in the soil and groundwater.

Classification of phytoremediation on the basis of mechanisms:

There are different types of phytoremediation mechanisms that are used to eliminate or degrade contaminants from soil and water discussed as follows:

1. Rhizosphere biodegradation:

- In this process, the plant secrets natural substances from its roots and these are nutrients needed for growth of micro-organisms in the soil.
- The micro- organisms grow speedily and stimulate biological degradation of contaminants present in soil.

2. Phytostabilisation:

- The process in which certain plant species are used to immobilise the contaminants in the soil and groundwater is termed as phytostabilisation.
- In this process, chemical compounds secreted by the plant immobilise contaminants, rather than degrade them.
- This takes place through absorption and accumulation in plant tissues, adsorption onto roots, or precipitation within the root zone prohibiting their migration in soil, as well as their transportation by erosion and deforestation.

3. Phytoaccumulation (phytoextraction):

- The process of uptake/absorption and translocation of contaminants by plant roots into the plant shoots, that can be harvested and metabolised to gain energy and also for recycling the metal from the ash is termed as phytoextraction.
- In this process, rhizosphere part of the plant roots function to absorb the contaminants along with other nutrients and water.
- The contaminant is not detoxified but stored in the part of plant such as shoots and leaves. This method is mostly employed for wastes consisting of metals.
- Plant species selected for their ability to take up large quantities of lead (Pb) are seen to uptake water-soluble metals.
- The plants aerial shoots store the metals, which are harvested and either smelted for potential metal recovery or are disposed of as a hazardous waste.
- Generally bioavailable metals for plant uptake include cadmium, nickel, zinc, arsenic, selenium, and copper.
- Moderately bioavailable metals are cobalt, manganese, and iron. Lead, chromium, and uranium are not very bioavailable.
- Chelating agent can play a vital role to get metal bioavailable, for instance, lead can be made much more bioavailable by the addition of chelating agents to soils.
- Likewise, the availability of uranium and radio-cesium 137 can be improved by use of citric acid and ammonium nitrate, as chelating agents.

4. Rhizofiltration (Hydroponic systems for treating water streams):

- The process in which adsorption or precipitation of contaminants occurs onto plant roots or absorption and sequestration in the roots is known as rhizofiltration.

- Contaminants that are found in solution form encloses the root zone by formation of wetland for cleaning up contaminated wastewater.
- Rhizofiltration is almost identical to phyto-accumulation, but the plants used for this purpose are grown in greenhouses with their roots in water not in soil.
- This system can be implied for *ex situ* groundwater treatment.
- Groundwater is drawed to the surface to irrigate these plants and at that time period these plants arrest contaminants in different part of plants.
- Typically hydroponic systems utilise an artificial soil medium, such as sand mixed with perlite or vermiculite.
- As the roots become soaked with contaminants, they are harvested and disposed of.

5. Phytovolatilization:

- In this process plants uptake water containing organic contaminants and free the contaminants into the air through their leaves as volatile components.
- The uptake and elimination of a contaminant by a plant, with release of the contaminant or a modified form of the contaminant to the atmosphere from the plant during transpiration is termed as phytovolatilization.
- It takes place when growing trees and other plants uptake water along with the contaminants present in water.
- These contaminants pass through the plants to the leaves and vapour out into the atmosphere at comparatively low concentrations.
- Plants also play a major role in physically stabilising the soil with the help of their root system.

- This also aids for preventing erosion, protecting the soil surface, and decreasing the impact of rain.
- At the same time, plant roots delivers nutrients that help to enhance the growth of microbes to convert it to a rich microbial community in the rhizosphere.
- The complex interactions between soil type, plant species, and root zone location affects the presence of bacterial community and its composition in the rhizosphere region.
- Due to availability of nutrients nearby this rhizosphere part of soil and also due to a symbiotic relationship between soil micro-organisms and plants, the population of micro- organisms is generally higher in the rhizosphere compare to the root-free soil.
- Due to this symbiotic relationship, bioremediation processes can be accelerated.
- Plant roots also plays role as surfaces provider for absorption or precipitation of metal contaminants. In this remediation process the root zone acts as focus of interest.
- The root absorbs the contaminants to be eventually stored or metabolised by the plant.
- The plant enzymes released from the roots degrade contaminants in the soil which is also an important phytoremediation mechanism.
- Many contaminants prefer route in which passive uptake takes place, via., micropores in the root cell wall and finally into the root, where degradation occurs.

6. Phytodegradation:

- In this process, specific plant species is used for a particular contaminant on the basis of the degradation capability of plant species.
- In this process, plants actually metabolise and deteriorate contaminants within plant tissues.

7. Hydraulic control:

- In hydraulic control process, trees are used as they have potential to carry water from depth surface as compared to plants.
- They indirectly amend by controlling groundwater movement.
- When roots of trees reach down towards the water table, they behave as natural pumps and forms a dense root mass that uptakes large quantities of water. For example, A poplar tree, pulls out 30 to 35 gallons of water per day from ground, and a cottonwood can uptake up to 340 gallons per day.

Application of phytoremediation:

- Phytoremediation is applied for the elimination/treatment of metals, radionuclides, pesticides, explosives, fuels, Volatile Organic Compounds (VOCs) and Semi Volatile Organic Compounds (SVOCs).
- Researchers are also working to find out how phytoremediation plays role to remediate perchlorate, a contaminant that has been shown to be consistent in surface and groundwater systems.
- It may be used to clean up contaminants present in soil and groundwater.

- For radioactive substances, chelating agents are sometimes used to make the contaminants accessible to plant uptake.

Limitations and concerns of phytoremediation :

- Even after biodegradation the toxicity and bioavailability of products, is not always known.
- The degraded by-products may be organized in groundwater or bio-accumulated in animals or other aquatic life.
- The determination of the fate of various compounds released during degradation of contaminants in the plant metabolic cycle is required to make sure that plant parts/droppings and products do not provide toxicity or harmful chemicals into the food chain.
- It is also required to understand if contaminants that gets collected in the leaves and wood of trees are released when the leaves fall in the autumn or when firewood or mulch from the trees is used.
- The high contamination of metals in harvested plants can be a problem during its disposal.
- One of the limiting factor for the remediation of the contaminants is the location of contaminants inside soil.
- The plant's capacity to reach the depth determines the treatment zone. It is limited to shallow soils, streams, and groundwater.
- If the plant root is unable to reach up to that depth where contaminants are present in water then pumping the water out of the ground and using it to irrigate

plantations of trees may be the alternative to treat contaminated groundwater in such case.

- Generally, the application of phytoremediation is limited to sites where contaminants concentration is low and contamination in shallow soils, streams, and groundwater.
- However, researchers are working to find that the use of trees (rather than smaller plants) permits them to treat deeper contamination as tree roots have capability to reach up to more depth into the ground.
- The outcome of phytoremediation may be seasonal, relying on location and climatic conditions of the area where the plant are to be grown.
- These climatic factors will also affect its effectiveness.
- The outcome of remediation also depends upon the selection of plant species from plant community.
- Bioremediation using plants is tedious process as the establishment of the plants may require several seasons of irrigation.
- It is prime to examine extra mobilisation of contaminants in the soil and groundwater during bioremediation if possible.
- The other limitation to this process is the high concentration of contaminant as plants may die in high concentration of contaminants.
- Phytoremediation is not useful for strongly absorbed contaminants such as polychlorinated biphenyls (PCBs).
- Phytoremediation also needs a wide range of land for remediation.