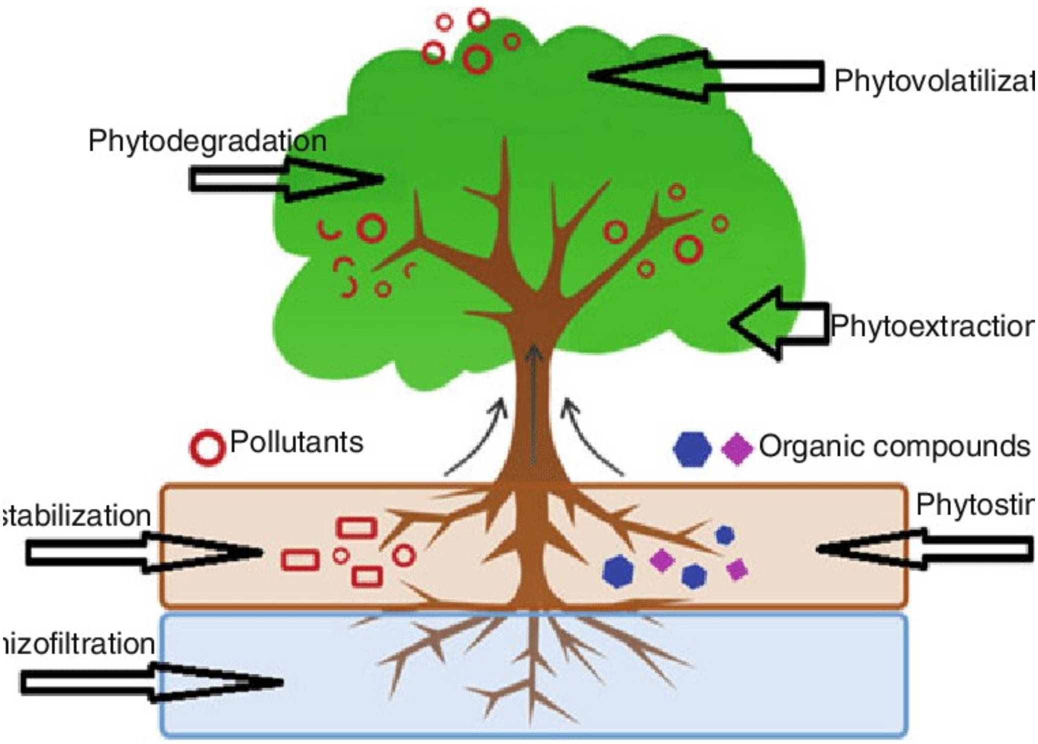
For B Sc Biotech 6 sem Env Biotech by Dr Santosh Thakur

Phytoremediatio

Phytoremediation from Ancient Greek meaning 'plant', and Latin *remedium*, meaning 'restoring balance') refers to the technologies that use living plants to clean up soil, air, and water contaminated with hazardous contaminants. It is defined as "the use of green plants and the associated microorganisms, along with proper soil amendments and agronomic techniques to either contain, remove or render toxic environmental contaminants harmless".

Phytoremediation is proposed as a cost-effective plant-based approach of remediation that takes advantage of the ability of plants to concentrate elements and compounds from the environment and to detoxify various compounds. The concentrating effect results from the ability of certain plants called hyperaccumulators to bioaccumulate chemicals. The remediation effect is quite different. Toxic heavy metals cannot be degraded, but organic pollutants can be and are generally the major targets for phytoremediation. Several field trials confirmed the feasibility of using plants for environmental cleanup.



Description

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. There are several different types of phytoremediation mechanisms. These are:

1. *Rhizosphere biodegradation.* In this process, the plant releases natural substances through its roots, supplying nutrients to microorganisms in the soil. The microorganisms enhance biological degradation.
2. *Phyto-stabilization.* In this process, chemical compounds produced by the plant immobilize contaminants, rather than degrade them.
3. *Phyto-accumulation (also called phyto-extraction).* In this process, plant roots sorb the contaminants along with other nutrients and water. The contaminant mass is not destroyed but ends up in the plant shoots and leaves. This method is used primarily for wastes containing metals. At one demonstration site, water-soluble metals are taken up by plant species selected for their ability to take up large quantities of lead (Pb). The metals are stored in the plantÍs aerial shoots, which are harvested and either smelted for potential metal recycling/recovery or are disposed of as a hazardous waste. As a general rule, readily 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. Lead can be made much more bioavailable by the addition of chelating agents to soils. Similarly, the availability of uranium and radio-cesium 137 can be enhanced using citric acid and ammonium nitrate, respectively.
4. *Hydroponic Systems for Treating Water Streams (Rhizofiltration).* Rhizofiltration is similar to phyto-accumulation, but the plants used for cleanup are raised in greenhouses with their roots in water. This system can be used for *ex-situ* groundwater treatment. That is, groundwater is pumped to the surface to irrigate these plants. Typically hydroponic systems utilize an artificial soil medium, such as sand mixed with perlite or vermiculite.

As the roots become saturated with contaminants, they are harvested and disposed of.

5. *Phyto-volatilization.* In this process, plants take up water containing organic contaminants and release the contaminants into the air through their leaves.
6. *Phyto-degradation.* In this process, plants actually metabolize and destroy contaminants within plant tissues.
7. *Hydraulic Control.* In this process, trees indirectly remediate by controlling groundwater movement. Trees act as natural pumps when their roots reach down towards the water table and establish a dense root mass that takes up large quantities of water. A poplar tree, for example, pulls out of the ground 30 gallons of water per day, and a cottonwood can absorb up to 350 gallons per day.

Application

Phytoremediation is used for the remediation of metals, radionuclides, pesticides, explosives, fuels, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). Research is underway to understand the role of phytoremediation to remediate perchlorate, a contaminant that has been shown to be persistent in surface and groundwater systems. It may be used to cleanup contaminants found in soil and groundwater. For radioactive substances, chelating agents are sometimes used to make the contaminants amenable to plant uptake.

Phytoremediation may be applied to polluted soil or static water environment. Examples where phytoremediation has been used successfully include the restoration of abandoned metal mine workings, and sites where polychlorinated biphenyls have been dumped during manufacture and mitigation of ongoing coal mine discharges reducing the impact of contaminants in soils, water, or air. Contaminants such as metals, pesticides, solvents, explosives, and crude oil and its derivatives, have been mitigated in phytoremediation projects worldwide. Many plants such as mustard plants, alpine pennycress, hemp, and pigweed have proven to be successful at hyperaccumulating contaminants at toxic waste sites.

Not all plants are able to accumulate heavy metals or organics pollutants due to differences in the physiology of the plant. Even cultivars within the same species have varying abilities to accumulate pollutants. This technology has been increasingly investigated and has been employed at sites with soils contaminated with lead, uranium, and arsenic. While it has the advantage that environmental concerns may be treated in situ, one major disadvantage of phytoremediation is that it requires a long-term commitment, as the process is dependent on a plant's ability to grow and thrive in an environment that is not ideal for normal plant growth.

Summary of phytoremediation techniques

Table 3
Summary of the different techniques of phytoremediation.

Technique	Description
Phytoextraction	Accumulation of pollutants in harvestable biomass i.e., shoots
Phytofiltration	Sequestration of pollutants from contaminated waters by plants
Phytostabilization	Limiting the mobility and bioavailability of pollutants in soil by plant roots
Phytovolatilization	Conversion of pollutants to volatile form and their subsequent release to the atmosphere
Phytodegradation	Degradation of organic xenobiotics by plant enzymes within plant tissues
Rhizodegradation	Degradation of organic xenobiotics in the rhizosphere by rhizospheric microorganisms
Phytodesalination	Removal of excess salts from saline soils by halophytes

Advantages and limitations

- **Advantages**:
  - in principle, plants that engage in phytoremediation of toxic elements could be harvested, thus removing these elements from the polluted site.
  - the cost of the phytoremediation is lower than that of traditional processes both *in situ* and *ex situ*
  - the plants can be easily monitored
  - the possibility of the recovery and re-use of valuable metals (by companies specializing in "phyto mining")
  - it is potentially the least harmful method because it uses naturally occurring organisms and preserves the environment in a more natural state.
  - it preserves the topsoil, maintaining the fertility of the soil
  - Increase soil health, yield, and plant phytochemicals
  - the use of plants also reduces erosion and metal leaching in the soil[6]