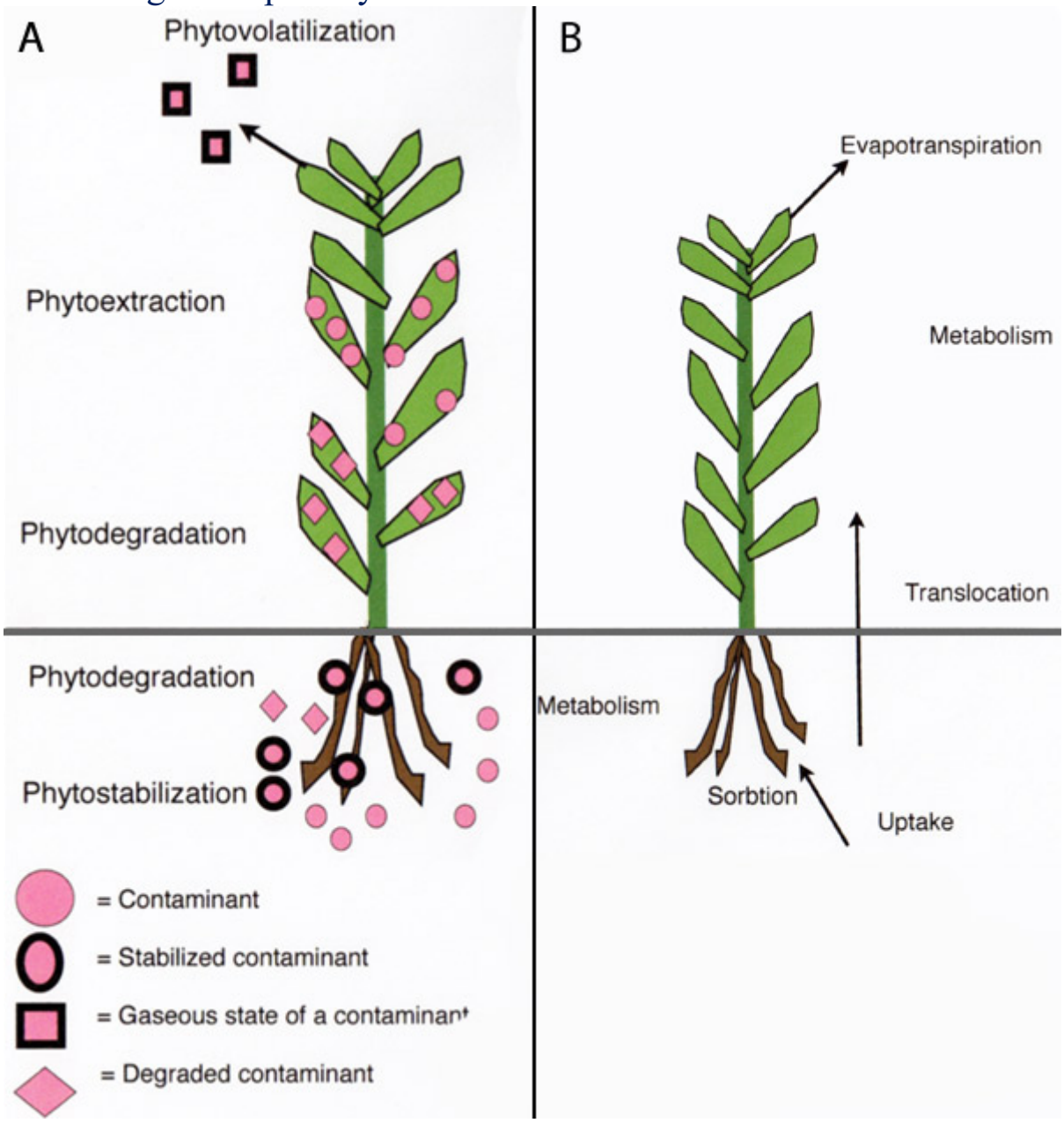
Phytoremediation

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.



The plants most used and studied are poplar trees. The U.S. Air Force has used poplar trees to contain trichloroethylene (TCE) in groundwater. In Iowa, EPA demonstrated that poplar trees acted as natural pumps to keep toxic herbicides, pesticides, and fertilizers out of the streams and groundwater. The US

Army Corps of Engineers has experimented with wetland plants to destroy explosive compounds in the soil and groundwater. Submersed and floating-leafed species (coontail and pondweed, and arrowhead, respectively) decreased trinitrotoluene (TNT) to 5% of original concentration. Submersed plants were able to decrease Royal Demolition Explosive (RDX) levels by 40%, and when microbial degradation was added, RDX decreased by 80%. Sunflowers, using rhizofiltration, were used successfully to remove radioactive contaminants from pond water in a test at Chernobyl, Ukraine.

Limitations and Concerns

The toxicity and bioavailability of biodegradation products is not always known.

Degradation by-products may be mobilized in groundwater or bio-accumulated in animals. Additional research is needed to determine the fate of various compounds in the plant metabolic cycle to ensure that plant droppings and products do not contribute toxic or harmful chemicals into the food chain.

Scientists need to establish whether contaminants that collect 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.

Disposal of harvested plants can be a problem if they contain high levels of heavy metals.

The depth of the contaminants limits treatment. The treatment zone is determined by plant root depth. In most cases, it is limited to shallow soils, streams, and groundwater. Pumping the water out of the ground and using it to irrigate plantations of trees may treat contaminated groundwater that is too deep to be reached by plant roots. Where practical, deep tilling, to bring heavy metals that may have moved downward in the soil closer to the roots, may be necessary.

Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams, and groundwater. However, researchers are finding that the use of trees (rather than smaller plants) allows them to treat deeper contamination because tree roots penetrate more deeply into the ground.

The success of phytoremediation may be seasonal, depending on location. Other climatic factors will also influence its effectiveness.

The success of remediation depends in establishing a selected plant community. Introducing new plant species can have widespread ecological ramifications. It should be studied beforehand and monitored. Additionally, the establishment of the plants may require several seasons of irrigation. It is important to consider extra mobilization of contaminants in the soil and groundwater during this start-up period.

If contaminant concentrations are too high, plants may die.

Some phytoremediation transfers contamination across media, (e.g., from soil to air).

Phytoremediation is not effective for strongly sorbed contaminants such as polychlorinated biphenyls (PCBs).

Phytoremediation requires a large surface area of land for remediation.

Applicability

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.

Technology Development Status

Phytoremediation is a broad technology type that has been successfully demonstrated for some contaminants and is experimental for others.