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Phytoremediation at Brownfields

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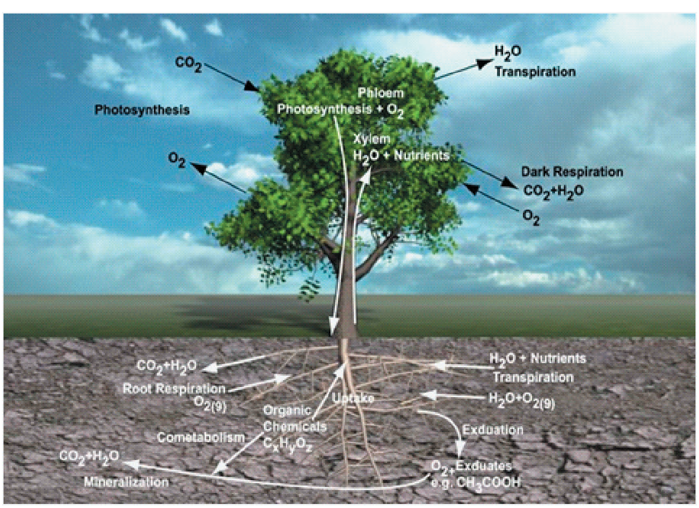
What is Phytoremediation?

Phytoremediation is the use of plants to reduce environmental risks due to contaminants in soil, sediment, surface water, and ground water. The plants may remove, transfer, stabilize, or destroy contaminants depending on the nature of the plants and contaminants. Phytoremediation includes all biological, chemical, and physical processes influenced by plants, including processes in the root zone (rhizosphere). Phytoremediation is usually an in situ or "in place" remediation process.

At brownfields, phytoremediation is most useful in addressing low to moderate environmental impacts by: 1) removing organics and salts in surface soils; 2) stabilizing metals, other contaminants, and soil; and 3) controlling and removing contaminants in surface and groundwater. The most important factors for successful use of phytoremediation are: anticipated land use, size, shape and redevelopment timing for a site; contaminant levels; cost; and natural conditions needed for plant growth.



How does Phytoremediation Work?

There are different mechanisms by which phytoremediation works. These mechanisms include phytoextraction, rhizosphere biodegradation, phytostabilization, and hydraulic control of ground water.

Phytoextraction is the use of plants to remove contaminants from soil, sediment, or water into the above-ground plant tissue. Subsequently, the contaminants may be concentrated and remain stored in the plant tissues. This is called *phytoaccumulation*. Some plants are very tolerant of certain contaminants. These hyperaccumulators can uptake more contaminant mass than "normal" plants. Examples of hyperaccumultaors are: barley, hydrangea, rapeseed, sunflower, tall fescue. For a list of hyperaccumultors for certain metals and radionuclides go to http://en.wikipedia.org/wiki/Phytoremediation. Note that specialized knowledge may be required to implement phytoaccumulation at a site.

Contaminants may also be released directly to the air along with water that is transpired or evaporated from the plant shoots and leaves. This process is called *phyto-transpiration* or *phytovolatilization*.

Organic contaminants such as pesticides, solvents and explosives, can be converted to harmless substances through either the plants' metabolism or via micro-organisms living in association with plant roots. This process is called *phytotransformation*.

Rhizosphere biodegradation is the process whereby contaminants break down in soil or ground water surrounding the plant roots. Plant roots produce chemicals and enzymes that promote the breakdown of chemicals and uptake of nutrients for the plant. These plant-produced chemicals also serve as nutrients for soil microbes that live near the roots of the plant.

Phytostabilization involves the reduction of the mobility of heavy metals and some organic contaminants in soil. Phytostabilization may be achieved by using plants that produce chemical compounds to immobilize contaminants at the root/soil interface. The mobility of contaminants can be reduced via three mechanisms: accumulation of contaminants by plant roots, adsorption onto roots, or precipitation within the root zone (rhizosphere). Adding soil amendments used to grow plants, such as organic matter, phosphates, lime, and biosolids decreases the solubility of metals in soil and minimizes leaching to groundwater. Adding soil amendments to make contaminants less bioavailable to plants may allow growth of vegetation where contaminant concentrations are otherwise too toxic to plants. This approach will usually not work in areas with high contaminant concentrations. Also, establishing vegetation on a site helps protect and hold the soil in place. This decreases wind-blown dust, minimizes soil erosion, and reduces contaminant leaching to groundwater and bioavailability to the food chain. A good example for phytostabilization is installation of vegetative cap to stabilize and contain mine tailings.

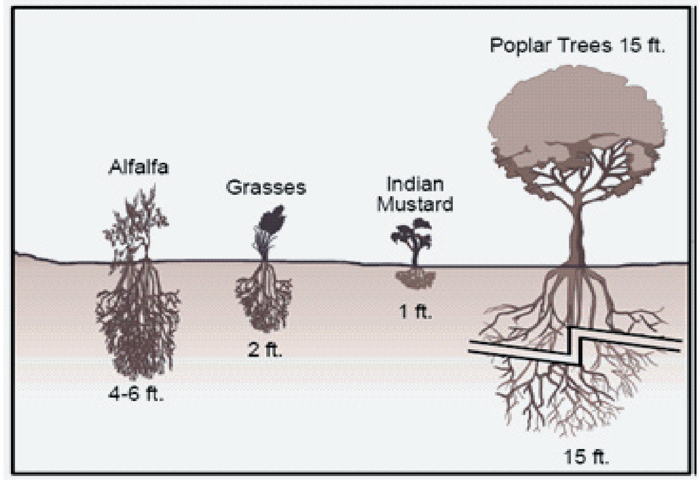
Hydraulic control of groundwater can be achieved by trees that transpire large quantities of water vapor. Hybrid poplar trees are especially successful at controlling shallow ground water plumes. Water uptake rates for these trees have been estimated at 2-10 gallons of water per day for each tree (UNEP). Plant roots must reach the water table to achieve hydraulic control.

Control, treatment, and removal of surface runoff using vegetative buffer strips and bioretention cells is becoming very common in brownfields redevelopment.

What Type of Contaminants are Suitable for Phytoremediation?

Tests have shown that plants have the potential to enhance remediation of the following types of contaminants (EPA, 2001):

- •Petroleum hydrocarbons
- •Polycyclic aromatic hydrocarbons (PAH)
- •Polychlorinated biphenyls (PCB)
- •Trichloroethene (TCE) and other chlorinated solvents
- •Ammunition wastes and explosives
- •Heavy metals
- •Pesticides
- •Radionuclides
- •Nutrient wastes (such as phosphates and nitrates)



Source: EPA. 2000. *Introduction to Phytoremediation* (EPA/600/R-99/107). National Risk Management Research Laboratory. February.

Research is ongoing and other types of contaminants may be treated with phytoremediation. It is important to look specifically at the site conditions (soil nutrients, soil acidity, climate, growing season, etc.), type of contaminants, and cleanup goals before deciding if and how to use phytoremediation as a remedy.

What Type of Sites are Suitable for Phytoremediation?

Phytoremediation may be used for a wide variety of sites, if the circumstances are right (see below). Types of sites where phytoremediation may be applied include pipeline sites, fuel storage tank farms, and gas stations; industrial and municipal landfills; agricultural fields; wood treating sites; dry cleaning sites; military installations; army ammunition plants; sewage treatment plants; and mining sites.

What are the Limitations of Phytoremediation?

Phytoremediation is a useful remediation technology, but it also has technical limitations. Limitations are related to the types and levels of contaminants, soil properties, acceptable exposure risks, and other site-specific considerations. Some limitations are listed below.

Cost. Although installation and operating costs may be low, monitoring costs could be higher than for other methods, especially if the cleanup rates are slow. Harvesting and proper disposal of plant materials containing contaminants may be costly.

Depth of contamination. Plants can be used to clean up shallow soil or groundwater, but cannot remediate deep aquifers. Trees and certain grass types have longer roots and can clean up deeper contamination than plants, typically 10-20 feet (EPA, 2001), but cannot remediate deeper without special measures. For example, case studies have shown that engineered deep rooting is feasible to at least 40 feet (Negri,2004).

Land Use, Size, Shape, and Redevelopment Timing. Phytoremediation is typically not a fast remedy; it can take many growing seasons to clean up a site. The area over which vegetation is planted must be compatible with land use requirements for the redevelopment schedule. Sufficient area must be available to install the plantings and maintain them.

Toxicity. Plants that absorb toxic materials may contaminate the food chain. Sites where plants with high levels of contaminants may be consumed by animals or humans are not good candidates for phytoremediation.

Transfer of contaminants. Accumulation of contaminants or transpiration of contaminants by plants can transform a pollution problem into a plant waste disposal or an air pollution problem.

Leaching. Phytoremediation may not completely prevent the leaching of contaminants into groundwater.

Type of contaminants. Phytostabilization may be most feasible for metals.

Natural soil and climate conditions. Soil type, annual precipitation, length of growing season, soil drainage and depth to groundwater, are all important considerations.

Research is ongoing and other types of contaminants may be treated with phytoremediation. It is important to look specifically at the site conditions (soil nutrients, soil acidity, climate, growing season, etc.), type of contaminants, and cleanup goals before deciding if and how to use phytoremediation as a remedy.

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Glossary of Terms

Absorption • The process of absorbing or assimilating substances into plant cells or across the plant tissues

Adsorption • Accumulation of substances on the surface of plant roots

Alkalizing agents • Chemicals used to raise the pH of soils (make the soils less acidic)

Biosolids • Nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility

Bioretention • Cells landscaping features adapted to provide on-site stormwater treatment

Buffer Strips • Strips of grass or other close-growing vegetation that separate a waterway (ditch, stream, creek) from an intensive land use area (subdivision, agricultural land)

Engineered Deep Rooting • This technique is mostly used for trees. The rooting depth is in creased by planting trees in depressions or by providing water directly to the desired rooting depth.

Hydraulic control • Controlling groundwater flow by pumping of the ground water. A stand of deep-rooted trees can act as a biological pump.

In situ • In place

Leaching • Removal of materials by dissolving them away from solids

Phytoremediation • The use of plants to remediate soils, sludges, sediments and water contaminated with organic and inorganic chemicals. “Phyto” means plant.

Rhizosphere • Soil zone surrounding and directly influenced by plant roots

Transpiration • Releasing water vapor (and other compounds) through plant tissue. The transpired vapor may or may not contain contaminants, depending on the site conditions and type of contamination.

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