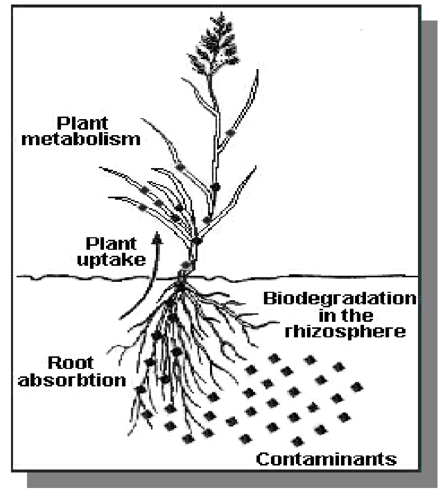
Perchlorate Treatment Technology
Fact Sheet

Phytoremediation

What is Phytoremediation?

Phytoremediation is a treatment technology that uses natural plant processes and microorganisms associated with the root system to remove, contain, or degrade environmental contaminants in soil, sediment, and water. There are several processes associated with phytoremediation. Depending on the contaminant to be treated and site-specific conditions, these processes may work together, with the entire plant acting as a single system to remove the contaminant, or they may work individually with certain processes having a greater influence on contaminant removal. These processes include:



Biodegradation through Phytoremediation

Rhizodegradation – This process occurs in the soil surrounding plant roots. Natural substances released by plant roots serve as substrates for the microorganisms present in the rhizosphere and speed up contaminant degradation. Perchlorate-reducing bacteria can grow on a variety of substrates (*e.g.*, organic acids, ethanol, simple sugars, amino acids, and possibly hydrogen

Phytostabilization – Plants may absorb and extract large quantities of toxic substances (*e.g.*, metals in soils). By so doing, they prevent the substance from entering into groundwater or other media. The plant immobilizes the contaminants into biologically unavailable forms rather than degrade them.

Phytoaccumulation – Roots take up contaminants, typically metals, along with other nutrients and water. The contaminant mass is not destroyed but ends up in the plant shoots and leaves that can be harvested for disposal.

Rhizofiltration – This process is similar to phytoaccumulation but only applies to liquid waste streams. Plants are grown without soil and transported to contaminated sites. As the roots become saturated with contaminants, they are harvested and disposed of.

Phytovolatilization – Plants take up water containing organic contaminants and release the contaminants into the atmosphere through their leaves.

Phytodegradation – Using naturally occurring plant enzymes, contaminants are degraded within the plant tissues.

Hydraulic Influence – In this process, trees aid remediation by influencing groundwater movement. Trees act as natural pumps when their roots reach downwards to the water table and establish a dense root mass that takes up large quantities of water (*e.g.*, mature cottonwoods can absorb 350 gallons per day).

Where Has Phytoremediation Been Used to Treat Perchlorate?

A significant amount of laboratory research has been conducted into applying phytoremediation to perchlorate-contaminated soils and groundwater. Current research focuses on gaining a better understanding of the effects of phytoremediation, and on identifying both plant species and rhizosphere bacteria capable of remediating groundwater contaminated with perchlorate and other contaminants.

Laboratory studies have confirmed that perchlorate can be degraded through phytoremediation

Until recently, only certain bacteria had been shown to perform the stepwise reduction of perchlorate to chloride. However, several recent studies have shown that plants are also capable of taking up, and at least partially reducing, perchlorate. Research funded by the Air Force Aeronautic Systems Center (ASC) Engineering Directorate and conducted by the University of Georgia, and funded by the US Army Operations Support Command and conducted by the University of Iowa, confirm the ability of phytoremediation to remove perchlorate from contaminated water and soils. Experimental results suggest that the two most important phytoremediation processes for perchlorate involve the uptake and subsequent phytodegradation of the chemical in branches and leaves, and rhizode-

gradation. University of Georgia researchers have identified select woody plants (*e.g.*, willow and Eastern Cottonwood) that are capable of significantly reducing concentrations of perchlorate within weeks. Related experiments have also demonstrated some plant species can degrade other contaminants, such as trichloroethylene (TCE), simultaneously with perchlorate.

Other research conducted by the University of Iowa has confirmed initial findings on the ability of poplar trees to uptake and transform perchlorate-contaminated soil and water. Further studies are required to ensure that the poplar trees are able to achieve complete detoxification of perchlorate (not simply transfer perchlorate from soil or water to plant tissues), and to more fully assess the role of competing ions such as nitrates on perchlorate reduction in the field.

Cost Effectiveness

Because many phytoremediation technologies are still in the field demonstration stage, and their application to perchlorate has not yet advanced to field demonstrations, defensible data on cost and performance need to be developed. However, the application of phytoremediation to treat one acre of lead-contaminated soil to a depth of 50 cm has been estimated to cost $60,000 to $100,000, whereas excavating and landfilling the same soil volume has been estimated to cost $400,000 to $1,700,000. The technology is likely to be a technically and economically viable remediation alternative when properly designed and managed, and is likely to be more cost effective than constructing and maintaining mechanical systems, or excavating, treating, and disposing of contaminated soils. Because there is no air stripping or water discharge, the need for air pollution discharge permits or water discharge (*i.e.*, NPDES) permits are eliminated. There may also be cost avoidance realized if there are no hazardous waste disposal costs or future liability issues associated with off-site disposal.

Site Facts

Status: Laboratory and bench scale experiments

Contaminated Media: Soil and groundwater

Treatment Technology: Phytoremediation

Objective: Establish and validate fate pathways of phytoremediation; identify plant species and rhizosphere bacteria capable of remediating groundwater contaminated with perchlorate and chlorinated co-contaminants.

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Advantages

- Passive, minimal environmental disturbance, aesthetically pleasing, and "permanent”
- Cleanup of soils using this technology can prevent further groundwater contamination
- Applicable to many contaminants in addition to perchlorate
- Potential low cost (although validated cost and performance data are generally still lacking)
- Reduced generation of secondary wastes requiring subsequent treatment and/or disposal

Disadvantages

- Lack of data – While research is ongoing, overall processing rates, endpoints, and cost data are lacking
- Depth limits – Contaminants in soil or groundwater must be within reach of the proposed plant
- Unfamiliarity – Regulators may be unfamiliar with certain types of phytoremediation and its capabilities
- Some phytoremediation activities may be slower than competing remedial technologies
- Potential cross media transfer contamination (*e.g.*, soil and/or water to plant tissues)
- Long lengths of time required (usually several growing seasons); not a short-term clean up option, and sometimes slower than alternative technologies