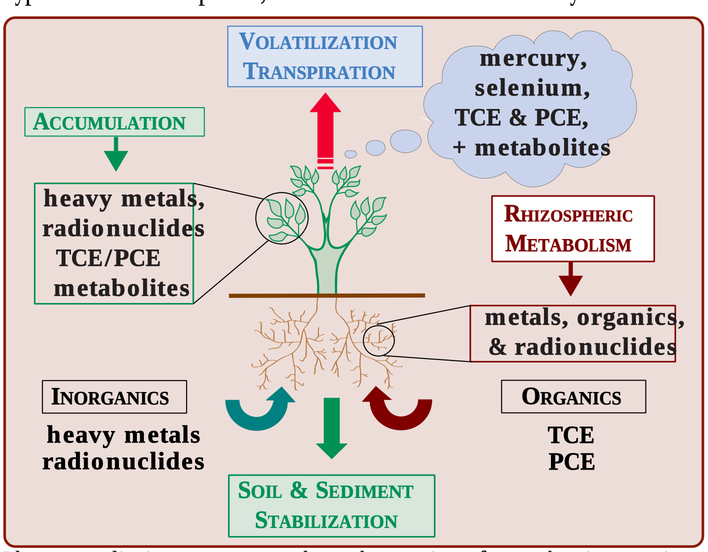
What is phytoremediation?

Soils frequently receive a wide range of contaminants from industrial activities, sewage sludge disposal, metal processing, and energy production, and in many cases remediation is both expensive and intrusive to the ecosystem. Phytoremediation is the use of plants and plant processes to remove, degrade, or render harmless hazardous materials present in the soil or groundwater. This emerging technology may offer a cost-effective, non-intrusive, and safe alternative to conventional soil cleanup techniques by using the ability of certain tree, shrub, and grass species to remove, degrade, or immobilize harmful chemicals from the soil.

The science of phytoremediation arose from the study of heavy metal tolerance in plants in the late 1980s. The discovery of hyperaccumulator plants, which contain levels of heavy metals that would be highly toxic to other plants, prompted the idea of using certain plant species to extract metals from the soil and, in the process, clean up soil for other less tolerant plants. Scientists also found that certain plants could degrade organic contaminants by absorbing them from the soil and metabolizing them into less harmful chemicals. In addition to plants, microorganisms that live in the rhizosphere (the actively growing root zone of the soil) play a major role in degrading organic chemicals, often using these chemicals as a carbon source in their metabolism. In many cases, even the physical presence of a plant can improve the condition of the soil, giving it structure and stability and altering hydrology by enhancing water retention and preventing erosion. There is no doubt that plants and the microbes associated with them can profoundly alter an ecosystem. Different types of phytoremediation have different potential results, such as accumulation of heavy metals in specific plant organs, voltilization from leaf surfaces, alteration of the form or availability of an organic chemical in the soil or within the plant, or actively excluding chemicals from plant tissues and keeping them out of the food chain. The result depends on site-specific research and this approach is not generally appropriate for grossly contaminated soils that are an immediate ecological health risk. The major challenge to using phytoremediation effectively remains gaining an understanding of these various plant–chemical interactions and learning how to apply them safely in remediation programs.



Phytoremediation can occur through a series of complex interactions between plants, microbes, and the soil, including accumulation, hyperaccumulation, exclusion, volatilization, and degradation. Plants also stabilize mobile contaminated sediments by forming dense root mats under the surface.

Phytoremediation can include aspects of three different processes:

phytoextraction—uptake of contaminants

phytodegradation—breakdown or metabolism of contaminants

phytostabilization—reducing contaminant movement or availability

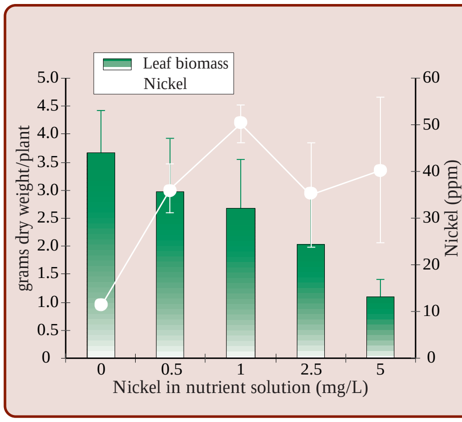
Phytoremediation research at SREL

At the Savannah River Ecology Laboratory (SREL), researchers are integrating the study of metal, organic, and radioactive contaminants, studying whole ecosystems contaminated with a wider and more realistic range of contaminants. Several research avenues are currently being explored, including **inorganic phytoremediation**, which screens plants in the presence of the most phytotoxic contaminant first, thereby excluding the most susceptible plants early in the program. The amount of contaminant that plants will phytoextract is predicted using hydroponic propagation techniques. **Organic phytoremediation** research investigates the ability of selected plants to absorb or degrade volatile organic chemicals such as trichloroethylene (TCE). Second-phase experiments monitor the performance of plants when grown with both heavy metals and TCE. **Bioaccumulation studies** target specific contamination problems, especially those arising from soil contaminated by mixtures of chemicals. In most cases, knowing exactly which contaminants are in the soil is not enough—chemical characterization at SREL provides information about the bioavailability of various contaminants before addressing the problem of remediation.

SREL research has shown that hybrid poplar trees have the ability to degrade organic contaminants such as TCE, but they react differently to soils contaminated with heavy metals. The general response of plants to metal contaminants such as nickel is a reduction in leaf biomass, indicating that the plant is experiencing a toxic response to contamination. Hybrid selection experiments at SREL have shown that certain poplar clones are able to survive in metal-contaminated soils and phytoextract metals into their leaves. The possibility of food chain transfer is reduced by choosing a plant that does not hyperaccumulate metals, thereby reducing the risk of bioaccumulation through herbivory.

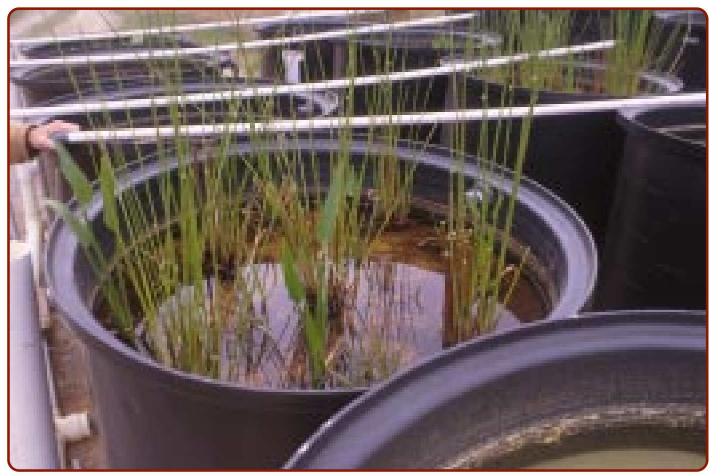
Plants are screened for their response to contaminants using hydroponic techniques. Here, hybrid poplar trees are selected for their ability to phytoextract nickel, cadmium, and zinc, common soil contaminants at the Savannah River Site and elsewhere.

An experiment to evaluate treatment wetland designs at a coal pile runoff basin on the Savannah River Site examines other aspects of phytoremediation. Native aquatic plant species may facilitate remediation of acidic, metal-contaminated, high sulfate runoff. These



Hybrid poplar cuttings grown for two weeks in a nutrient solution containing nickel show maximum uptake of Ni at a dose of 1 mg/L. In this case, the plant grows in a sublethal concentration of Ni while still removing nickel from the soil.

plants can aerate the wetland substrate and water column and potentially promote formation of insoluble metal oxides. Decomposing plants may provide organic matter to which metals readily bind. This research is also investigating the ability of native aquatic plants to assimilate metals directly and the fate of these metals when the plants die. For example, water lillies can take up and concentrate certain metals when exposed to high concentrations of that metal. Ultimately, phytoremediation may encompass both direct and indirect plant mediated processes in treatment wetlands.



An experimental treatment wetland in D-Area on the Savannah River Site tests the ability of native aquatic plants to remediate the acidic, metal-contaminated runoff from a coal pile.

The real phytoremediation ability of a collection of plant species living in a mixed-waste profile is currently unknown, and understanding the interaction of the processes involved may be the deciding factor in the success of a phytoremediation program. Phytoremediation research at SREL involves collaboration between biogeochemists, plant physiologists, analytical chemists, radiochemists, and wildlife specialists. Our aim is to work toward understanding contaminant availability and movement through the food chain and to develop a core technology for contaminant cleanup and ecosystem management which is cost-effective and safe.