tech briefs

Westinghouse Savannah River Company

New method removes and stabilizes subsurface contaminants *in situ*

Phytoimmobilization

at a glance

- Costs a fraction of traditional methods
- Spans numerous plant growth cycles
- Removes multiple contaminants simultaneously
- Segregates waste by type
- Greatly reduces waste disposal
- U.S. Patent No. 6,560,920

for more information

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Scientists at Westinghouse Savannah River Company (WSRC) have developed a phytoimmobilization process to remediate shallow soil or ground water. The new method combines phytoextraction with contaminant stabilization in a specially amended top soil layer. Passive remediation continues over numerous plant growth cycles without the expense of removing and disposing of harvested above-ground biomass at the end of each growth cycle. Using multiple sequestering agents and various phytoextracting plants allows the simultaneous removal of multiple contaminants. This approach reduces the volume of waste for ultimate disposal and is more ecologically friendly to sensitive ecosystems.

Background

Traditional methods of remediating contaminated soil sites involve digging the soil up and removing it. Pump and treat methods are used for contaminated ground water. These methods result in the disposal of large volumes of waste. Cost of waste disposal can range from $3,700 per cubic meter for low level waste to $28,500 per cubic meter for transuranic waste.

Emergence of phytoremediation

Phytoremediation, a methodology that has emerged in the past decade, is the direct use of living plants for *in situ* risk reduction of contaminated soil, sludges, sediments, and ground water through contaminant removal, degradation, or containment. In *A Citizen's Guide to Phytoremediation*, the U.S. Environmental Protection Agency (EPA) describes phytoremediation as:

- An aesthetically pleasing, passive, solar-energy driven cleanup technique.
- Most useful at sites with shallow, low to moderate contamination.
- Useful for treating a wide variety of environmental contaminants.

Phytoextraction

Phytoextraction, one method used in phytoremediation, refers to a natural growth process in which subsurface minerals and ions are actively accumulated within plant tissues at concentrations greater than that accountable by simple concentration gradients. Certain species of plants (hyperaccumulators) show high affinity for select minerals or ions. The contaminants migrate from the roots into the above-ground parts of the plant. The plants are harvested and the contaminated plant material removed and disposed of as hazardous and/or radioactive waste.

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Phytoimmobilization

Frequent harvesting generates waste

In conventional phytoextraction, plants are grown and harvested in successive cycles. In the case of nonmetabolized contamination, such as heavy metal contaminants, this is a slow process that results in a large quantity of contaminated vegetation that must be disposed of.

In addition, this method of repeated planting, harvesting, removing, and disposing of contaminated vegetation offers little protection for and can be disruptive to sensitive ecosystems, such as wetlands.

New, simple, two-step process

Phytoimmobilization involves two steps. The first step is phytoextraction, which takes place mostly during the spring and summer. During this step, the plants extract contaminants from the subsurface into the roots and then translocate the contaminants to the aboveground biomass, or plant tissue. The second step is sequestration, which takes place mostly during the autumn and winter when annual plants senesce or deciduous trees drop their leaves. During this step, the contaminants leach from the fallen leaves into the specially amended top soil layer, or into a geomat (a mat in which a sequestering agent is sandwiched between two pieces of a geofabric), where they are immobilized.

Immobilization occurs when the leached contaminants come in contact with specially selected sequestering agents. The agents are designed to:

- Selectively retain the contaminants leached from the decaying plant parts,
- Immobilize the contaminants for a sufficient amount of time, and
- Not release undesirable constituents into the surrounding environment.

Versatile design

The sequestering agents can be mixed into the top soil layer or incorporated in one or more geomats. The advantage of the top soil mixing configuration is that no labor is required to make and remove the geomat. The advantage of the geomat configuration is that it can be easily removed for ultimate disposal.

The geomat may be in the form of long, continuous flexible rolls that are cut to size in the field. Geomats with a variety of sequestration agents for targeting different contaminants may be stacked at the same location to segregate different types of waste. For example, radioactive waste may be immobilized in one geomat and hazardous waste in another. This segregation enables the selection of an ultimate disposal method for each geomat that is appropriate for the type of waste segregated within the geomat. If it is acceptable to leave the segregated waste in place, the geomat can be capped by adding a barrier mat.

The end use of the remediated site, the need to separate contaminants by waste type, and the risk associated with leaving the sequestered contaminants in place are considerations in selecting the appropriate configuration.

Mix and match

Appropriate plant biota can be chosen to target specific soil contaminants for use with an appropriate sequestration agent. The ability to grow multiple species of phytoextractors within a single contaminated region allows a more aggressive and diverse treatment protocol. Mixing various sequestering agents in the top soil or stacking geomats containing different agents enables the simultaneous treatment of multiple contaminants.

Lower cost, less disruption

With this new method, at the end of each growing cycle, the plants senesce or shed leaves naturally or may be harvested. In all cases, the plant matter is left to decay *in situ*. Avoiding the cyclical removal and disposal of plant matter reduces the cost of waste disposal associated with conventional phytoextraction.

Cost of waste disposal is further reduced by concentrating the contaminants in the sequestering agents.

This method also is less disruptive to sensitive ecosystems, such as wetlands.

Customized to meet your needs

Designed for site-specific conditions, the amended top soil layer or geomat(s) may contain specially selected sequestering agents as well as fillers, extenders, or binders. Some of the sequestering agents that may be included are ion exchange resins, zeolite (natural and synthetic), clays, modified clays, cements, reducing agents, reactive blast furnace slag, reagent chemicals, sodium titanate, phosphate-containing minerals, sulphur-containing minerals, amorphous silica, amorphous alumina, calcium hydroxide, kiln dust, and surface active refractories.

Examples of sequestering agents selected for specific contaminants include: (1) phosphate, apatite, and zero valent iron for uranium removal; (2) illite for cesium; (3) cation exchange resin for heavy metals like cadmium, copper, and chromium; and (4) zero valent iron for chromium (VI) reduction.

Where appropriate, microorganisms designed to metabolize certain organic contaminants may be added to the top soil layer or geomat, making it possible to both immobilize and subsequently degrade contaminants.

Nonreactive agents that may be included as fillers, extenders, or binders are sands, fly ashes, synthetic fibers, kiln dust, and crushed lightweight aggregates. Permeability of the amended layer can be controlled through various combinations of reactive and/or filler materials. For example, depending on the amount of clay and other compactable material included in the soil amendment, the amended layer can be compressed to control the amount of water percolation or movement into the subsoil.

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Phytoimmobilization

Proof-of-principle studies

A series of proof-of-principle studies was conducted to evaluate the potential effectiveness of phytoimmobilization at an outfall delta on the Savannah River Site in Aiken, SC. Leaf litter at the site was found to have measurable concentrations of actinium, cobalt, chromium, mercury, lead, radium, thorium, and uranium.

Plant species studied included the netted-chain fern and several trees including tupelo, water oak, bald cypress, loblolly pine, red maple, sweetgum, and American sycamore. Sequestering agents tested included metallic iron, apatite, hydroxylapatite, zeolite, iron oxide waste, gypsum, and pyrite.

These lab and field studies showed that the indigenous plant species were able to extract high concentrations of a wide variety of contaminants and selected sequestering agents were able to very efficiently immobilize these contaminants.

Calculations based on these studies showed that all the contaminants except thorium could be remediated to a soil screening level of $10e^{-5}$ within ten years using phytoimmobilization.

Partnering opportunity

U.S. Patent No. 6,560,920 has been issued for this new method. WSRC invites interested companies with proven capabilities in this area of expertise to enter a licensing agreement with WSRC for the purpose of using phytoimmobilization in commercial applications.

Technology transfer

WSRC is the managing contractor of the Savannah River Site for the U.S.Department of Energy. WSRC scientists and engineers develop technologies designed to improve environmental quality, support international nonproliferation, dispose of legacy wastes, and provide clean energy sources.

WSRC is responsible for transferring technologies to the private sector so that these technologies may have the collateral benefit of enhancing U.S. economic competitiveness.

technology transfer