Phytoremediation of Soil and Groundwater

Argonne has long-term multidisciplinary experience in developing phytoremedial solutions to groundwater and soil contamination problems.

PROBLEM/OPPORTUNITY

A continuing environmental challenge is selecting a proper technology to achieve site remedial goals within a reasonable budget and environmental impact. One technology, which can be successful in a variety of site settings, is phytoremediation.

Phytoremediation is the use of plants to remediate groundwater or soil. The contaminants may range from metals and radionuclides to agrochemicals and hydrocarbons to waste solvents and nitroaromatics. These contaminants may be present in surficial soils or in deeper soils and groundwater. Phytotechnologies target the contaminants using various mechanisms, including

- plant uptake (followed by harvesting the plants to collect the concentrated contaminants),
- stabilization (the use of argonomic principles and plants to sequester contaminants in soils in a non-bioavailable form, thus reducing risk)
- removal (such as slow release of volatile organic compounds through leaves), and
- degradation (transformation of contaminants into less-toxic forms, either within the plant tissues or within the microbially active soil in contact with the roots).

For groundwater applications, intensive water-use trees (phreatophytes such as poplar and willow) may work in tandem with these approaches by providing hydraulic containment at a site.

Key issues in phytoremediation are:

- Assessing the suitability of phytoremediation for a site and determining the appropriate plant(s) for the given contaminants, concentrations, target depth, soil type, climate, and remediation schedule,
- Devising a proper scheme and procedures for monitoring the progress of the remediation,
- Designing the optimal system, and
- Predicting completion times.

APPROACH

Argonne has performed extensive research in this emerging field, including greenhouse studies, development of new laboratory analysis methods, testing of innovative planting methods, plant screening, modeling of expected influence of phreatophytes on groundwater flow, biomonitoring, and application of state-of-the-art groundwater samplers to assess root-contaminant interaction. Contaminant studies range from heavy metals and radionuclides, to salinity, to chlorinated organic solvents.

Argonne staff has been involved in testing endeavors at various federal sites since the early 1990s. Significant sites include Argonne National Laboratory (East and West), the Murdock, Nebraska USDA site, and Aberdeen Proving Ground.

At the Argonne East site, a full-scale plantation of 800 trees was installed and instrumented in 1999 under the Remedial Actions Project. Here, the

remedial design was comprised of robust hybrid willows in a volatile organic compound (VOC) source area and hybrid poplars in the downgradient groundwater plume. Because this plume flows beneath a surficial clay over 25 feet thick, the poplars were installed using the patented method of Applied Natural Sciences, Inc. to direct the trees' roots toward the deep, contaminated plume as their sole source of water. Monitoring and sampling of the site is on-going and includes groundwater, surface water, soil, tree tissues and transpirate, groundwater levels, and climatic data. This monitoring program has been conducted jointly by Argonne research divisions and Plant Facilities and Services, and the U.S. EPA Superfund Innovative Technology Evaluation (SITE) Program.

At Argonne West, research started with bench-scale studies on the phytoextraction of heavy metals and cesium-137 from surface soil. These bench studies were then followed by multi-year full-scale field trials that utilized innovative root harvesting techniques to maximize contaminant removal. Considerable reduction of contamination levels in the soil was obtained and final decisions on whether the target remediation has been reached are pending.

For the Murdock, Nebraska site, Argonne planted more than 2,000 trees to take up contaminated water and break down carbon tetrachloride. The plantation provides protection for a nearby creek by controlling the hydraulic gradient.

Argonne staff has been exploring innovations in monitoring techniques. At the Aberdeen site, a dialysis sampling device has been developed to study small-scale variations in groundwater VOC concentration within the root zone, and solid phase micro-extraction devices have been tested to sample evapotranspiration gases.

Argonne has always nurtured a strong industrial participation to their research and has recently been funded to further develop and test phytoremediation technologies for petroleum hydrocarbons in Russia, in collaboration with Russian research institutions and major U.S. oil companies.

RESULTS

The key benefit of a successful use of phytotechnology is remediation of target contaminants within an anticipated time frame. Because the technology has its roots in the 1990s, results of most initial pilot plantings and full-scale plantations such as Argonne-East's are only now coming into focus. Multidisciplinary approaches are used at the Argonne-East site to determine the system's performance: regulatory compliance monitoring of groundwater chemistry and elevation is integrated with modeling and biomonitoring of the vegetation to determine contaminant fate and transport. Plant tissue monitoring data are used experimentally to predict plant removal rates and model time to complete cleanup. At this site, trichloroethene (TCE), tetrachloroethene (PCE), carbon tetrachloride and breakdown products have been detected in plant tissues since the site's initial season. As the trees mature, monitoring data show improved water use and contaminant removal and a growing degree of hydraulic containment of the downgradient plume.

Intangible benefits of this green technology include high aesthetic value, public approval, and growing regulatory acceptance. In addition, this technology fits perfectly with ecological restoration and carbon sequestration principles and strategies.

FUTURE

The use of phytotechnologies in remedial efforts continues to grow, and Argonne's research and development will continue at the laboratory, pilot, and full plantation scales. Our expertise can provide site managers with proper decision-making regarding the use, design, monitoring and expected results of a phytoremedial application. On-going method developments in field monitoring, laboratory analysis and modeling of remedial designs remain active areas of research.

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