HAZARDOUS SUBSTANCE RESEARCH CENTER • SOUTH & SOUTHWEST •

Research Brief #14

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Aquatic Plant Lagoon Systems for Explosives Remediation

Introduction

Phytoremediation, the use of aquatic plants to assimilate and detoxify hazardous substances, is one of the promising cleanup methods for TNT-contaminated sites under consideration by the HSRC/ South & Southwest, Environmental Protection Agency, and the Department of Defense. At the Georgia Institute of Technology, researchers in the School of Civil and Environmental Engineering and the Georgia Tech Research Institute have conducted research that confirms the strong potential of phytoremediation to clean up TNT-contaminated sites.

Based on extensive laboratory batch studies, the Georgia Tech research team identified numerous aquatic plants that effectively remediate TNT, and advanced understanding of key chemical and physical processes of phytoremediation. This work is detailed in *Research Brief #13*, with associated information in *Research Brief #11* and *Research Brief #12*.

Concurrent with the laboratory studies, researchers constructed a field scale experimental lagoon on the Georgia Tech campus to compare the laboratory results with a large-scale field environment system.

Field Studies

The pilot-scale plant lagoon system was designed, constructed, and operated to simulate field conditions which would occur during remediation of TNT-contaminated soil. The pilot-scale tests focused on the investigation of appropriate parameters to allow development of an expanded field study.

System Design

Five cylindrical internal cells (each 175 gallons) were placed inside a larger pilot-scale system designed to support surface and submerged aquatic vegetation. These cells contained aquatic plants: *Elodea* and *Hydrilla spp.*; *Myrophyllum aquaticum* (parrot feather); a mixed marsh of *Pontederia cordata* (blue broad leaf pickerel rush), *Eleocharis tuberosa* (Chinese water chestnut), *Marsilea drummondii* (green four-leaf water clover), and *Iris pseudacorus* (yellow iris); *Nelumbo nucifera* (lotus), and *Nymphea ordorata* (water lily), respectively. Additionally, seven separate control cells were placed inside the pilot-scale system. All systems contained sediments which would naturally be associated with the aquatic systems. Mild aeration was used to enhance the overall cell hydraulic mixing and to more uniformly distribute the influent wastewater.

Researchers used a continuous flow process to feed soluble TNT at low concentrations (10 mg/L) at a hydraulic retention time of ten days. Grab and composite samples of effluent TNT and by-products, pH, alkalinity, and nutrient levels were measured, with temperature, rainfall and sunlight intensity monitored electronically.

A subsurface waterflow system dampened temperature fluctuations in the environment, mimicking effects of a natural soil system. Plant cells were exposed to ambient conditions throughout a seasonal growth cycle that included summer, fall, and winter environmental conditions typical of the southeastern United States.

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Summary of the Problem

Researchers at Georgia Institute of Technology, Louisiana State University, and Rice University are investigating the effectiveness of aquatic plants as a means of cleaning soils contaminated with trinitrotoluene (TNT). An explosive compound used in munitions, TNT is found in soil at many ammunition plants and military bases in the United States. The ability of aquatic-plant enzymes to reduce and assimilate TNT and convert it into nonhazardous plant mass has been investigated in bench-scale and pilot-scale studies with aquatic plants and natural organic matter in soils and sediments. Researchers have developed and investigated a working hypothesis in which TNT is initially transformed to aminated intermediates which are then conjugated and assimilated into plant mass.

Rice University is conducting fundamental studies of plant transformations and pathways. Georgia Tech is studying whole-plant biochemical processes, as well as the physicochemical processes that affect the fate of biochemical intermediates produced by the remediative plant/soil system. Georgia Tech researchers also conducted pilot-scale studies aimed at placing (and testing) the plant remediation system in the field. Louisiana State University characterized the transport of TNT in contaminated soils from soil to water, and are developing models of TNT transport for use in investigating an enhanced-flow TNT-treatment system.

The three-university project on phytoremediation of TNT was managed by HSRC/S&SW Co-Director F.M. Saunders at Georgia Tech. This fact sheet focuses on Georgia Tech's pilot field study phase of the project.

Results and Discussion

Results indicate that the TNT removal in plant cells matched laboratory batch-study predictions. Removal percentages relative to TNT loading for all species ranged from 85.4 percent to 99.7percent. The lagoon with *M. aquaticum* provided the highest mean TNT removal percentage at 96.7percent; the mean TNT removal for all species composite samples taken was 93.5 percent. A statistical analysis based upon a 95 percent confidence interval indicated no significant difference between species studied. As TNT was removed, however, amino dinitrotoluene (ADNT) was generated at levels comparable to TNT effluent concentrations, again in agreement with kinetic predictions.

Plant cell pH is a function of influent pH, photosynthesis, and respiratory activity. For all lagoons, plant cell pH ranged from 5.5 to 7.9 pH units, and was within expected normal physiological ranges for aquatic vegetation.

No additional nutrients were added to the influent feed or to the water column with the exception of nutrients provided by the sediments. Throughout the study, no detectable levels of total phosphate were found in the samples taken from *M. aquaticum,* or *Elodea*. Nitrate levels ranged from non-detect to 5.7 mg/L for all species, and ammonia levels ranged from non-detect to 32 mg/L for all species.

The integrated laboratory and field studies assessing the effectiveness of aquatic plants for remediation of low-concentration, high-volume TNT-contaminated waters have allowed researchers to accelerate real-world testing of an innovative remediation technology. Developing and incorporating additional effluent treatment processes, such as algae-based systems and longer hydraulic retention times may be dictated for removal of ammonia nitrogen species and ADNT generation resulting from these plant lagoons systems. Research continues in this area.

Simulated field studies of submerged aquatic plants for remediating TNT (left) enables researchers to move phytoremediation technology from flask to field (below).

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