PHYTOREMEDIATION RESEARCH ON TNT DEGRADATION

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INTRODUCTION AND BACKGROUND

Phytoremediation is a remediation technology in which plants are used to treat contaminated soil, groundwater or wastewater. Plants can be used the following ways to assist in remediation;

- By enhanced bacterial and fungal activity in the root zone (Anderson et al., 1993; Cunningham et al., 1995; Schwab et al., 1995).
- By accumulating the contaminant in the stems of the plants which can be harvested (Dushenkov et al. 1995; Nanda Kumar et al., 1995; Moffat, 1995; Kelley and Guerin 1995; Cornish et al., 1995; Wang et al., 1995),
- As an organic "pump" to control groundwater migration (Gatliff, 1994; Licht, 1995),
- By destruction by plant enzymes and other plant proteins (Dec and Bollag, 1994, Terry, 1995, Strand et al., 1995, Carreira and Wolfe, 1997, Medina, et al., 1997).

Plants and microorganisms often have symbiotic relationships, making the root zone, or rhizosphere, a very active area of microbiological activity. Plants can help moderate the environment in the root zone, providing ideal conditions for bacteria and fungi to degrade organic pollutants.

Certain plants hyperaccumulate metals, radionuclides or organic compounds. These plants can be placed in areas of contamination where they remove the contaminant. Afterwards, the plants can be harvested and the contaminant can be disposed, destroyed or recovered.

Many plants require large amounts of water in their daily lives. For example, willow trees may use up to 5,000 gallons per day (Gatliff, 1994). These plants can be used to inexpensively "pump" groundwater in certain, shallow aquifer conditions.

Some plants contain enzymes that can destroy contaminants. Of particular interest are;

- dehalogenase: for destroying chlorinated compounds.
- peroxidase: for destroying phenolic compounds.
- nitroreductase: for destroying explosives and other nitrated compounds.
- nitrilase: for destroying cyanated aromatic compounds.
- phosphatase: for destroying organophosphates.

Phytoremediation is attracting much attention as a low cost treatment alternative. However, phytoremediation has several limitations that must be considered. *In situ* phytoremediation is limited to shallow soils or aquifers. Phytotreatment is likely to be slower than excavation, incineration, adsorption or chemical treatments. Phytoremediation is new and, therefore, regulatory agencies are not yet familiar with it. There are possibilities of increased contaminant migration with improperly designed phytotreatment. Although there are some effective, full-scale phytoremediation projects underway, phytoremediation is still largely in the experimental stage. Winter may slow or stop phytoremediation. Competition with native plants may eliminate the plant chosen for phytoremediation. Phytoremediation designs must be aware of the use of nuisance plants to avoid their propagation.

Overall, phytoremediation is a promising new technology. In some forms, it is already available and proven. New applications are being tested and developed. Phytoremediation, like bioremediation, is relatively slow. Its main advantage is cost savings.

TREATMENT OF EXPLOSIVES

Many military bases and explosives manufacturing facilities are contaminated with munitions. The most prevalent munitions' contaminant is trinitrotoluene (TNT). Other commonly found contaminants include RDX, HMX, Picric Acid, Trinitrobenzene (TNB), and Tertyl.

Numerous studies have documented that plants can uptake and transform TNT from both soil and water (Palazzo and Leggett, 1986; Folsom et al. 1988; Cataldo et al., 1989; Young, 1995; Mueller et al., 1995; Schnoor et al., 1995; Medina and McCutcheon, 1996; Carreira and Wolfe, 1997, Medina et al. 1997). The rates of transformation compare favorably to those of published microbial studies and there appears to be no lag phase (McCutcheon et al., 1995). Previous work conducted by USEPA/NERL isolated a nitroreductase enzyme in plants (Carriera and Wolfe, 1997). This enzyme is capable of sequentially reducing TNT to triaminotoluene (TAT). TAT is an unstable molecule that autooxidizes in aerobic conditions. However, many plants also contain the laccase enzyme, which catalyzes the breakup of the TAT structure. This mechanism is a promising technology for treating TNT contaminated groundwater.

Plant screening studies were conducted for the treatment of TNT contaminated groundwater (Medina, et al., 1997). Parrot Feather (Myriophyllum aquaticum) has been chosen as the plant to concentrate experiments on. Removal rates were found to increase with increasing plant density. Temperature variation studies indicated that as temperature increased, the removal rates of increased until the high temperatures became lethal to the plan.

Some preliminary modeling was conducted for the treatment of TNT and its breakdown products (Medina and McCutcheon, 1996). The models assumed idealized plug-flow, first order kinetics and non-reversible, sequential reactions. Bench-scale, continuous flow through reactor studies were also conducted. High removal percentages were achieved on influent concentrations of 4.7 ppm and 12.1 ppm with a 5-day residence time (Medina et al., 1997).

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