



WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Limiting Factors in the Bioremediation of Soil and Groundwater Contaminated With Aromatic Hydrocarbons

Duration: From July 1, 1996 To June 30, 1997

Federal Funds \$20,200 Non-Federal Funds \$68,535

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Congressional District Fourth

Critical Water Problem Addressed:

Aromatic hydrocarbons are common pollutants found in soil and groundwater as a result of past and current industrial activity. For example, until the 1950s coal gasification was a common method of manufacturing combustible gas for use in municipal lighting and heating. Tanks used to collect heavy liquid condensates and other areas at manufactured gas plant (MGP) sites continue to be a source of pollutants to both ground and surface waters. Over contaminated MGP sites have been discovered in North Carolina, and there are an estimated 1,500 3,000 contaminated MGP sites across the U.S. Leaking tanks used to store gasoline and other petroleum products are also a major threat to groundwater. In North Carolina alone, over 2,000 contamination incidents from petroleum underground storage tanks (USTs) have been identified. Contamination of water supplies by aromatic hydrocarbons is therefore a significant problem at both regional and national level.

Polycyclic aromatic hydrocarbons (PAH) are among the contaminants of concern at MGP sites. Of the PAH, it is the high molecular weight compounds (those with four or more rings) that are normally of most concern with respect to potential health risks; seven of these compounds are regulated known carcinogens. PAH in general are characterized by very low solubility in water. Correspondingly, these compounds readily form non-aqueous phases in soil and sediment, and are also expected to bind tightly to soil constituents such as natural soil organic matter. Despite the limited water solubility of PAH, it has been shown that contact of water with PAH-contaminated sediment can lead to teratogenicity and toxicity of the water. Contaminated sediment in surface waters also represents a continuing source of contamination in the aquatic food chain. For USTs, the contaminants of concern are the monoaromatic hydrocarbons, principally benzene, toluene, and the xylenes (BTEX compounds). Benzene in particular is a known carcinogen, and is soluble in water concentrations far greater than the drinking water standard (1 micro gram/L). For BTEX compounds, the principal concern is their ready migration away from source areas.

Bioremediation has been considered as a method to clean up sites contaminated by aromatic hydrocarbons, including both in situ and above-ground applications. In fact, the N.C. Environmental Management Commission recently approved a temporary rule requiring owners and operators applying for reimbursement from the UST Trust Fund to submit corrective action plans based on "natural processes of degradation and attenuation of contaminants" ("intrinsic bioremediation"). There are, however, limitations associated with bioremediation despite its growing popularity and its potential as a low cost method of destroying contaminants. For PAH-contaminated soils, it is often found that the high molecular weight (HMW) compounds, including the carcinogenic PAH, are not removed completely after biological treatment. Since these are the compounds on which clean up standards are usually based, the extent of their biodegradation can determine the feasibility of bioremediation for given site. For BTEX compounds it has been found that intrinsic bioremediation can be used e dissolved hydrocarbon plumes, but the major factors controlling the rate and extent of biodegradation under anaerobic conditions (which are expected to prevail in a BTEX-contaminated plume) are not well known. In particular, the anaerobic biodegradation of benzene under ambient conditions is very poorly understood, and in many cases benzene is recalcitrant to in situ degradation. In the absence of an adequate mechanistic understanding of BTEX biodegradation, remediation plans which assume that intrinsic bioremediation will occur are primarily based on an unjustified leap of faith. Rates and extents of BTEX biodegradation under anaerobic conditions cannot yet be estimated accurately from laboratory data, even using the most sophisticated mathematical models.

Results and Benefits of Research:

Bioremediation of PAH-contaminated soil will be addressed through a project at the University of North Carolina at Chapel Hill (UNC), and anaerobic bioremediation of BTEX contamination will be addressed in two projects at North Carolina State University (NCSU). The work at UNC continues an ongoing project focusing on the use of an aboveground technology referred to as slurry-phase bioremediation. The aim of the project is to enhance the biodegradation of the carcinogenic PAH, through the combined use of surfactants (to improve the availability of these compounds to the indigenous microorganisms) and selective substrates (to sustain the growth of PAH degrading organisms after the readily available PAH substrates are depleted). The two projects at NCSU will further our understanding of the biodegradation and fate of benzene under anaerobic conditions, and on the effect of protozoan grazing on rates of BTEX biodegradation in sediments under anaerobic conditions.

Work on PAH biodegradation will develop strategies to optimize HMW PAH biodegradation in field situations by treating contaminated soil from an MGP site in bench-scale slurry-phase bioreactors. The site is owned by Duke Power Company and located in Greenville, South Carolina. If we are able to demonstrate the removal of carcinogenic PAH to lower levels than are achieved with current bioremediation techniques, then we expect that bioremediation will be considered seriously for remediation of many of the MGP sites in the Southeast. The methods proposed to stimulate PAH biodegradation are based on fundamental principles and general concepts

that can be extended to a wide range of bioremediation situations. The methods will be tested in bioreactors treating actual contaminated soil, and results from this work can be scaled up directly to pilot or field scale. Strategies developed during this project also can be applied to in situ bioremediation situations. If successful, therefore, the range of PAH contaminated sites for which bioremediation will be feasible can be increased.

Work on anaerobic biodegradation of benzene will extend preliminary observations that benzene was anaerobically biodegraded in sediment from a petroleum-contaminated aquifer located in North Carolina. Benzene biodegradation in the preliminary study was observed only after an extensive lag period of greater than 150 days. Follow up work will examine (1) whether benzene is mineralized (converted to CO₂ and water) or only partially degraded; and (2) factors governing the extensive lag period in anaerobic sediment. Results from this research will improve our understanding of how and when benzene biodegrades in the subsurface. This information essential for reliable interpretation of monitoring data from field studies and to predict the rate and extent of intrinsic bioremediation in petroleum-contaminated aquifers.

One of the principal factors governing in situ rates of biodegradation is the size of the indigenous microbial community. Protozoa are known to graze on bacteria, thereby having a major impact on the microbial community, but the extent to which protozoan grazing influences subsurface populations responsible for BTEX degradation is unknown. Work on protozoan grazing will be conducted with samples from the petroleum-contaminated aquifer and will determine (1) the relative importance of protozoan grazing in determining rates of biodegradation; and (2) whether bacterial and protozoan populations vary over time in laboratory microcosms. Findings from this work will establish whether commonly-used, small-scale laboratory microcosms can predict intrinsic bioremediation rates reliably. It also will permit the development of models to describe large-scale intrinsic bioremediation.