WATER RESOURCES RESEARCH GRANT PROPOSAL

1. Title: Cost-Effective Monitoring Design for Intrinsic Bioremediation

2. Focus Categories: GW, WQL, MOD

3. Keywords: Groundwater quality, biodegradation, monitoring, groundwater modeling, decision model, optimization, risk management, economics, underground storage tanks, water quality monitoring, stochastic hydrology

4. Duration: September 1, 1998 to August 31, 2000

5. Federal Funds Requested: $45,652

6. Non-Federal Matching Funds: $91,435

7. Principal Investigators: Barbara S. Minsker and Albert J. Valocchi, University of Illinois

8. Congressional District: 15^{th}

9. Statement of Critical Regional or State Water Problems:

The release of petroleum hydrocarbons into the environment is a widespread problem throughout the United States, including the State of Illinois and the 13-state North Central region. One of the major sources of petroleum hydrocarbon contamination is leaking underground storage tanks (USTs). Refinery and pipeline sites, another significant source of petroleum hydrocarbon contamination, are much fewer in number than tank sites, though they typically have much greater volumes of released pollutants. The Environmental Protection Agency (EPA) predicts that USTs will comprise approximately 76 percent of all future sites to be remediated in the United States (*EPA*, 1996). Within the North Central region, a total of 83,524 USTs have confirmed releases (26 percent of the USTs with confirmed releases nationwide) and 115,566 cleanups have been initiated or completed at UST sites (29 percent of the cleanups initiated or completed nationwide) (*EPA*, 1996). EPA also estimated that the national cost to remediate USTs will be approximately $21 billion in 1996 dollars (*EPA*, 1996). State-specific figures on cost were not reported, but given the large fraction of leaking USTs that are located within the North Central region, a significant portion of this cost will presumably be borne by this region. Petroleum hydrocarbon contamination also exists at Superfund sites on the National Priorities List (NPL) and many facilities undergoing correction action (CA) under the Resource Conservation and Recovery Act (RCRA); the North Central region contains more than 350 NPL sites and 1,200 RCRA-CA sites (*EPA*, 1996). Remediation costs at these sites can be staggering; EPA (1996) reports an estimate of at least $10 million per NPL site. Hence, reducing the burden associated with remediating these sites is an issue of increasing concern at the national, regional, and state levels.

Nationwide, approximately 96 percent of UST sites and 53 percent of NPL sites contain some variety of petroleum products (*EPA*, 1996), whose regulated components biodegrade relatively easily (*National Research Council*, 1993). Biodegradation occurs when organic compounds are destroyed or transformed into other forms through microbial activity. In recent years, intrinsic bioremediation (also known as natural attenuation) has gained increasing attention as a viable approach for reducing the costs associated with remediation, particularly at sites with petroleum hydrocarbon contamination. The EPA reports that 47 percent of UST sites nationwide with groundwater contamination have implemented some form of intrinsic bioremediation (*EPA*, 1996). Bioremediation is one of the most commonly implemented innovative treatment technologies at NPL sites, and there is increasing interest in using intrinsic bioremediation following more active actions, such as source removal and soil vapor extraction (*EPA*, 1996). Although regional statistics are not available, our discussions with regulators at EPA regional offices in the North Central region have indicated that interest in intrinsic bioremediation is also quite high within this region. Intrinsic bioremediation can be defined as the coupling of on-site monitoring and regulation with natural biodegradation of contaminants through indigenous microbial activity. It has been shown in recent research that the regulated components within petroleum hydrocarbon releases can be naturally biodegraded into the innocuous byproducts of carbon dioxide and water (*Borden et al.*, 1997). The petroleum hydrocarbon contaminant acts as an electron donor and naturally occurring groundwater constituents such as oxygen, nitrate, sulfate, and methane act as electron acceptors in a respiratory process. The United States Air Force Center for Environmental Excellence has published a professional protocol which details a methodology for implementing intrinsic bioremediation at sites contaminated with petroleum hydrocarbons (*Wiedemeier et al.*, 1995). The methodology includes site characterization, modeling, and design of a long-term monitoring (LTM) plan. The LTM plan is the means by which the success or failure of intrinsic bioremediation is proven. The data gathered with LTM (primarily contaminant and electron acceptor concentrations) is used to ensure that the risk of exposure to downgradient populations remains at acceptably low levels, given the contaminant plume's relative location and rates of transport and biodegradation. The expense of sampling and analysis in LTM to ensure regulatory compliance over decades is a controlling factor in determining the cost-effectiveness of intrinsic bioremediation relative to shorter-term engineered remediation technologies. The goal of the proposed research is to develop a methodology for designing cost-effective LTM plans for intrinsic bioremediation which will explicitly address the uncertainties associated with groundwater fate and transport at real sites. The methodology will help regulators and the regulated community in the state and region to develop long-term monitoring plans which are both cost-effective and sufficiently protective of human health and the environment.

10. Statement of Results or Benefits:

The expected outcome of this work will be a valuable tool for designing long-term monitoring plans for intrinsic bioremediation. Although the protocol developed by *Wiedemeier et al.* (1995) clearly states the key role of the LTM network, no specific guidelines are provided for selection of the network. The protocol only states that the network should be designed in consultation with regulators. A recent EPA guidance document on intrinsic bioremediation (*EPA*, 1997) also has no specific guidelines for designing LTM plans. The research proposed here will develop a rigorous, scientifically-sound methodology for LTM design. The methodology will identify sampling networks that are cost-effective and that yield sufficient information to manage uncertainty in predicted contaminant concentrations at compliance wells. Once the methodology is developed, we expect considerable interest from industry and government in applying the methodology to some of the numerous sites in the state and region with petroleum hydrocarbon contamination. Future extensions of the methodology to incorporate more complexity are also planned, including applications to other contaminants such as chlorinated solvents. There is ongoing intensive research on natural biotransformation of halogenated organic compounds, and there is great interest at the state and federal level in using intrinsic bioremediation as part of the treatment train for these ubiquitous and hazardous pollutants.