Report for 2002MO6B: Microbial Influences on Geophysical Signatures

There are no reported publications resulting from this project.

Report Follows:

Title: Microbial Influences on Geophysical Signatures: A Proxy for the Understanding and the Monitoring of
Natural Attenuation.
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Pollutants such as organic chemicals, heavy metals, and radionuclides remain a major problem of environmental concern by posing a threat to global groundwater resources. Currently, the number of hazardous waste sites in the US where ground water may be contaminated is estimated at 300,000-400,000 (Benkin et al., 2001). The remediation of such sites has become an area of high priority for many agencieswithin the US government (e.g., EPA, DOE, DOD, etc.). The EPA Office of Emergency and Remedial Response has compiled a National Priorities List (NPL) of seriously contaminated sites across the US (US EPA, 2001). Twenty-two NPL Sites are currently listed in Missouri. Current EPA regulations relating to NPL sites mandate a remedial investigation/feasibility study (RI/FS) with possible follow up remedial design, remedial action and operations and maintenance (O&M) procedures. The financial obligation of the State depends on ownership of the NPL. For publicly owned and publicly operated sites the State is responsible for at least 50% of the RI/FS, remedial design/action and first year O&M costs. For privately operated sites the State responsibility is 10% of remedial design/action and 10% of first year O&M costs. The EPA estimated average total cost per site is $1.3 m for RI/FS, $1.5 m for remedial design, $25 m for remedial action and $3.77 m for O&M procedures. The Missouri Department of Natural Resources Hazardous Waste Management Program (MDNR-HWMP) is responsible for preliminary assessments, site investigations, feasibility studies, remedial investigations and short/long term remedial action at contaminated sites in Missouri. In 1999 the MDNR-HWMP Hazardous waste remedial fund received $1.7 m, rising to $2.6 m in 2000 (Missouri State Government, 2001).

The high costs of engineered cleanup systems and their disappointing performance have spurred research in the development of more efficient, inexpensive and innovative methodologies to address the problem of contaminated soils. Over the past several years, natural attenuation (microbial mediated degradation) has become increasingly accepted as a remedial alternative for many contaminated soils, partly because of their relatively lower costs. However, the implementation of natural attenuation as a remedial strategy at a site often requires a demonstration that natural attenuation is occurring through several lines of evidence. One such line of evidence is the demonstration of the potential for intrinsic bioremediation. Because biodegradation is expected to cause predictive changes in groundwater chemistry, traditional methods for assessing an area for the potential of intrinsic bioremediation have relied heavily on extensive sampling and analyses of groundwater for intermediates of biological hydrocarbon metabolism, depletion of terminal electron acceptors, and assessment of microbial communities capable of metabolizing the hydrocarbons. Such investigations are very costly and increase the cost of remediation. Additionally, the above traditional techniques rely heavily on direct sampling methodologies for obtaining soil and water for site characterization.

Such direct sampling provides adequate data to interpret degradation activities at specific subsurface locations, but are flawed in several respects: 1) wells screened at a given depth can sample water (and any signals of bacterial activity) only at that specific point in space and time; 2) the determination of suitable sampling frequencies, sampling locations and subsurface interval for characterization is difficult and are arbitrary; 3) more frequent groundwater sampling and analyses translate to extremely high clean up costs; 4) it is difficult to use direct sampling techniques to span the entire spatial and temporal scales associated with biodegradation and provide in situ, real time monitoring of these and other dynamic subsurface environmental processes.

Biogeochemical processes occurring at contaminated sites are currently only partially understood because they occur within dynamic systems where the geochemical and hydrogeological conditions can change with time and location in the subsurface, and also because of the very sparse spatial and temporal sampling regiments often used to assess them. Non-invasive methods that adequately characterize and quantify the nature and fate of these contaminants ***are lacking.*** Thus, the need for research and development of more cost-effective methodologies that can serve as a surrogate for pore water and soils sampling and analysis to assess subsurface degradational processes and to monitor the cleanup of contaminated soils is critical. Such methodologies would have tremendous potential to reduce cleanup costs and reduce health risks to humans and the environment.

Geophysical methods have a tremendous potential for rapid, non-intrusive evaluation of spill sites, delineating the lateral and vertical extent of the impacted media. However, the potential changes in geoelectrical response to biogeochemical modifications of the subsurface impacted media resulting from microbial NAPL degradation have never been investigated. Although controlled spill and short-term laboratory experiments have provided valuable insights into the potential for geophysical detection of hydrocarbon contaminants these studies do not take into account the extent to which resident microbial communities modify NAPLs to different physical and chemical states, causing changes in the physical properties of the impacted media. The current project is therefore, **a first attempt** at investigating how biogeochemical processes associated with microbial LNAPL degradation affect geophysical properties of soils and groundwater at NAPL contaminated sites. Such information is critical for the interpretation of geophysical data from contaminated sites and is fundamental to the development of robust geophysical models that can describe these systems. Advances in the understanding of these relationships will provide the foundation necessary for the development of non-invasive geophysical techniques for studying coupled biogeochemical processes at contaminated sites. This work, while oriented toward LNAPL contaminant sites, will have significant implications for understanding any other classes of contaminant plumes (e.g., dense non-aqueous phase liquids (DNAPL), radio nuclides, and heavy metals) which exhibit electrical conductivity different from their surroundings, and which change electrical properties in space and time. Furthermore, we believe that the information derived from this study will foster the development of geophysical techniques as an **independent measure or proxy** for intrinsic biodegradation of contaminants in the subsurface, leading to cheaper clean up costs.

This study is considered the initial step in the development of an electrical method for in situ monitoring of NAPL biodegradation. Following the results of this study, down-borehole and field scale measurements are anticipated. This would incorporate both an element of instrumentation development as well as site characterization. The application of the method at NPL sites in Missouri is envisaged. We plan to use the preliminary results obtained in this study to aggressively seek funding for a much larger field-based study from the US Department of Energy and/or the US Environmental Protection Agency, as well as the National Science Foundation.

Student involvement

The primary student involvement is in the form of two full-time graduate (Masters and PhD) students dedicated to this project. Student responsibility includes data collection, analysis and interpretation. Student presentation of the results of the project at an international conference is expected. Both students will develop MS theses and PhD dissertation from this work. We will also recruit an undergraduate research student to participate in this project. Through these ***mentoring*** activities we expect to provide students with ***hands-on*** experience in the conduction of scientific research addressing both basic and applied science issues.

Status

The Water Center has given this project a six-month no-cost extension to finish collecting and submit further data.