Research Brief 180: Tools to Improve Success Rate of Bioremediation of Complex Chemical Mixtures

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Superfund Research Program
http://www.niehs.nih.gov/srp/

Background

In situ bioremediation holds great promise as a safe and cost-effective strategy for cleanup of contaminated sediments and groundwater. The design of bioremediation systems requires site-specific characterization of the types of microorganisms present, what their potential metabolic capabilities are, and to what extent degradative functions are being expressed. The interactions between microbial communities and hazardous wastes also need to be assessed because while microorganisms frequently control both the rate and extent of contaminant metabolism in the subsurface, contaminant mixtures and/or individual mixture components can affect the composition and activity of microbial communities indigenous to contaminated environments.

At many contaminated sites, suboptimal environmental conditions and a lack of sufficient microbial diversity and metabolic potential can explain why biodegradable pollutants fail to undergo biotransformation. Existing bottlenecks can often be addressed by **biostimulation** and **bioaugmentation**, i.e., the addition to the site of, respectively, nutrients and microorganisms. *In situ* microcosm array technology can provide answers on what treatment will work best at a given cleanup site.

Laboratory batch and column experiments provide some information about pollutant/microorganism interactions, but cannot reproduce field conditions such as ambient water chemistry, aquifer temperature and the composition of natural microbial communities. Small-scale pilot tests conducted in the field provide better data, but carry the risk of impacting expensive monitoring wells and irretrievably introducing chemical and biological agents into the groundwater. With funding from the SRP, Dr. Rolf Halden of the Biodesign Institute at Arizona State University is leading a research program to field test a novel diagnostic tool, the *in situ* microcosm array (ISMA), with the goal of improving the success rate of bioremediation at sites contaminated with complex chemical mixtures.

Advances

The ISMA is a miniaturized laboratory designed to capture, monitor, and enrich microorganisms in their natural habitat. The device, which can be deployed in a groundwater monitoring well, contains multiple flow-through column microcosms that are packed with site sediment and can be amended with chemical substrates and microorganisms to mimic biostimulation and bioaugmentation treatment approaches. As ambient groundwater is pumped through the device, resident microorganisms are allowed to interact with chemical and biological amendments. All water entering the device is stored in individual effluent containers to prevent release of substances into the monitoring well and to enable the calculation of mass balances and biotransformation rates. Upon retrieval of the device from the well, site-specific information becomes available on the effectiveness of each of the treatment strategies tested. Key advantages of this approach are that microcosms can be conducted *in situ* without the release of chemicals and foreign microorganisms into the deployment well. Dr. Halden's team of researchers conducts the *in situ* tests for periods of several weeks to allow sufficient time for microbial growth. Following retrieval of the tool from the well, microorganisms are extracted for enumeration and characterization. Proteomic analysis by matrix assisted laser desorption/ionization-time of flight mass spectrometry (MALDI-TOF MS) allows for the detection and identification of microorganisms and their pollutant-transforming catabolic enzymes expressed under *in situ* conditions.

Deployment of *in situ* microcosm array technology at a DOE Superfund site.

After successful laboratory experiments, the ISMA technology is now being tested at a Department of Energy Superfund site. The ongoing field tests are an important part of technology validation. This work is co-sponsored by the Environmental Security Technology Certification Program (ESTCP) of the Department of Defense.

Significance

DOE staff deploy *in situ* microcosm arrays under leadership of ASU doctoral student and SRP trainee Kristin McClellan, M.S.

More than 90% of environmental microorganisms cannot be cultured in the laboratory. Because the entire microbial community, not just the small fraction of culturable microorganisms, determines the fate of chemical contaminants, biodegradation studies are best conducted *in situ*. The innovative ISMA technology has been demonstrated to be capable of detecting and dissecting the complex interactions that occur between individual components of chemical mixtures and microorganisms.

In addition, use of microcosm arrays allows researchers to conduct a large number of *in situ* experiments simultaneously. Collected data are directly applicable to the hazardous waste site and can inform the selection of the most efficient and cost-effective bioremediation strategies.

Dr. Halden's technology (filed on behalf of the Johns Hopkins University) has been patented and additional patent applications are pending in the United States, Europe, and Asia. The ISMA technology already has led to the formation of a start-up company in Maryland. Encouraged by these successes, Dr. Halden's research group continues its independent development of groundwater remediation and monitoring technologies at Arizona State University's Biodesign Institute.

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To learn more about this research, please refer to the following sources

Halden, R. U.: Method and Apparatus for Environmental Monitoring and Bioprospecting. PCT WO 2004/081530 A2.

Halden, R. U.: Methods and Systems for Sampling, Screening and Diagnosis. PCT WO 2005/076887 A2.

Halden, R. U.: Parallel *In Situ* Screening of Remediation Strategies for Improved Decision Making, Remedial Design, and Cost Savings. Environmental Security Technology Certification Program (ESTCP). http://www.estcp.org/Technology/ER-0914-FS.cfm

SRP is seeking input from stakeholders as we develop a Strategic Plan. As a reader of the monthly Research Brief, we would appreciate your insight and opinions. Please visit http://tools.niehs.nih.gov/srp/about/register.cfm for information about the Strategic Planning process and to learn about the many ways you can participate in shaping the future direction of the program.

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