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Development of a New and Innovative Environmental Tracer for Characterization of Hazardous Waste Sites

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Biological Tracer for Waste Site Characterization

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A natural, biological tracer has proven able to assist characterization activities in support of remediating hazardous waste sites. It is a safe alternative to conventional techniques using radioactive and other tracers.

Introduction

Remediating hazardous waste sites requires detailed site characterization. In groundwater remediation, characterizing the flow paths and velocity is a major objective. Various tracers have been used for measuring groundwater velocity and transport of contaminants, colloidal particles, and bacteria and nutrients.

The conventional techniques use dissolved solutes, dyes, and gases to estimate subsurface transport pathways. These tracers can provide information on transport and diffusion into the matrix, but their estimates for groundwater flow through fractured regions are very conservative. Also, they do not have the same transport characteristics as bacteria and suspended colloid tracers, both of which must be characterized for effective in-place remediation. Bioremediation requires understanding bacterial transport and nutrient distribution throughout the acquifer; knowledge of contaminants sorbed to mobile colloidal particles is just as essential.

Concept Description

A biological tracer developed by Oak Ridge National Laboratory (ORNL) has potential application for numerous sites for meeting sitewide needs to characterize waste-flow pathways. This product has been used domestically and internationally in other industries; thus, much of the environmental and toxicological testing has been done.

For its testing, ORNL used the commercially available Snomax® product,[a] which is the ice nucleating active (INA) bacterium *Pseudomonas syringae* that is processed (killed and mixed with an inert ingredient). In addition to the dead Snomax® product, ORNL has also investigated using numerous other strains of INA bacteria (both viable and killed) in addition to or in place of the Snomax® product. Viable bacteria may be particularly useful for characterizing in-situ bioremediation sites when the potential transport of live bacteria may be significantly different from that of inorganic tracers and dead bacteria.

ORNL's general method in characterizing waste sites introduces the INA material into the test system (e.g., the stream, groundwater, and drilling fluids) to determine the INA tracer's movement and distribution. The INA's presence or absence can be determined by measuring the freezing point and comparing it with the freezing point of the background water(s).

The INA tracer has numerous unique features that work in combination to

[a] Produced by Snomax Technologies, Rochester, NY, who sell the bacterium as a nucleator for making artificial snow.

provide additional information regarding the subsurface environment. The material is natural and will eventually biodegrade. The active component in the Snomax® product is a microbe, and thus will transport in a manner that is more similar to microbial transport. The tracer is stable within a pH range of 2.3 to 11.0 and does not require expensive and highly technical equipment. The presence of typical groundwater contaminants (e.g., toluene, trichloroethylene, xylenes, and carbon tetrachloride at 10 ppm) does not interfere with the assay.

Key Experimental Results

In the first field testing, the INA tracer was injected along with microsphere beads, several viable strains of bacteria, and two virus strains into a fractured matrix. The INA tracer showed that a portion of the groundwater was moving more than 2 orders of magnitude faster than previously determined with the conservative tracers (rhodamine dye and noble gases). Furthermore, this information was obtained within 3 minutes of collecting the samples. Data from viable bacteria and viruses required 3 to 5 days for sample processing.

The INA tracer was also demonstrated as part of a multi-point hydrofracturing injection into a clay matrix. The demonstration was performed at a clean test site to determine if chemicals and/or bacteria could be distributed into this matrix for remediation at a contaminated site. The INA tracer was introduced along with bromide and forced into the subsurface using a high-pressure injection method. Soil cores were collected and the concentration of the INA tracer and bromide were assayed. Results showed little detection of the bromide above background levels. However, the INA tracer was detected throughout the 10-foot injection region and occasionally to 12 feet below land surface. The INA concentration was 3 orders of magnitude above the detection limits.

Using the INA bacteria as a drilling tracer, ORNL performed additional field tests in conjunction with a project examining the heterogeneities of subsurface bacteria. Soil cores were collected and microsphere beads--along with the INA tracer--were used to identify core integrity. The results identified which portions of the soil core may have been contaminated with drilling fluids and thus could adversely affect the data collected for microbial analysis. The INA tracer corresponded directly with the microsphere beads; however, it was much more sensitive.

Economics and Market Potential

The cost for the INA tracer is minimal. The commercial Snomax® biological tracer is used at 270 gm/100,000 gallons (for snow making) and retails at $810.00/case (ten 270-gm pouches). The amount used in the groundwater transport testing has varied, depending on the potential dilution in the aquifer. However, the analysis of the groundwater samples (or soil samples) is somewhat labor-intensive and results in a maximum analysis of 50 to 75 samples per day, depending on the sensitivity needed.

The advantages of using a tracer that provides immediate results have significantly outweighed the costs of sample analysis. For example, the results obtained with the INA tracer have been used to select and restrict the number of samples for other more labor-intensive tracer assays, such as those for bacterial and virus transport. The increased sensitivity has also provided information that is well below the detection limits of other tracers such as bromide and microsphere beads. Furthermore, the INA assay can be performed onsite, which has enabled ORNL to schedule its use at a radioactive groundwater plume study where samples cannot be transported offsite. The real-time picture obtained also allows for immediate field adjustments.

Potential markets include numerous industries and agencies that need to perform site characterization studies involving fluid dynamics in surface waters (stream) and groundwaters (shallow or deep aquifers). The ORNL tracer also has potential for use in drilling fluids when aseptic technique is vital to sample integrity.

Future Development Needs

Currently, a cost-effective, automated system is being developed for analyzing large numbers of contaminated samples. Recent site characterization tests have required analyses of 2,000 to 5,000 groundwater samples, a number currently not possible using the manual method.

A prototype of the analysis instrument, comparable in size to a portable computer, has been designed and tested. The system is based on an optical detection scan, which has resulted in a 3-order-of-magnitude increase in the signal during the ice nucleation event. Field testing is planned for 1995.

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