DNAPL Surface Chemistry: Its Impact on DNAPL Distribution in the Vadose Zone and its Manipulation to Enhance Remediation

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Research Objectives

The remediation of DNAPLs in subsurface environments is often limited by the heterogeneous distribution of the organic fluid. The fraction of DNAPL that is in the high conductivity regions of the subsurface can often be recovered relatively easily, although DNAPL in lower conductivity regions is much more difficult to extract, either through direct pumping or remediation measures based on interface mass transfer. The distribution of DNAPL within the vadose zone is affected by a complex interplay of heterogeneities in the porous matrix and the interfacial properties defining the interactions among all fluid and solid phases. These complex interactions are needed to understand the current distribution of DNAPL in the subsurface and to plan effective remedial strategies. Results of this effort could potentially be used to increase the accessibility and, therefore, the recovery of DNAPL during vapor extraction or other vadose zone remediation efforts.

The primary hypothesis of this work is that surface-active chemicals and/or microorganisms present in the unsaturated zone can significantly alter the interfacial phenomena governing the migration of DNAPLs, thereby affecting the accessibility of a DNAPL during remediation efforts. The surface-active materials are present in complex NAPL mixtures and are produced through microbial metabolic processes. The overall goal of this proposed research is to understand the role of and changes in interfacial phenomena on the accessibility of DNAPL in the vadose zone.

Research Progress and Implications

A multi-task approach involving experimental measurements at both laboratory and field scales has been designed to meet the objectives of this research. Materials for this research have been chosen to be applicable to vadose zone contamination problems at the Savannah River site (SRS). Initial stages of the research are focusing on well-characterized materials with a shift to site-specific media as the processes are understood. This research offers a unique opportunity to develop our fundamental understanding of the fate of DNAPLs in the vadose zone through both laboratory scale testing and evaluation of field samples collected at SRS. The fieldwork provides a detailed assessment of the distribution of DNAPL in the subsurface as a function of microbial populations, mineral characterization, and heterogeneous grain size distribution. Concurrent laboratory testing provides an understanding of the fundamental mechanisms governing these distributions.

With research activities beginning September 15, 1999, only preliminary progress has been made by March 1, 2000. Most significantly, fieldwork for the first year has been planned and completed. In addition, progress has been made on the design and construction of laboratory apparatus for multiphase flow experiments.

Two soil borings at each of two sites at SRS have been drilled and sampled. These sites were chosen based on differences in the NAPL composition, aqueous geochemistry, and geological strata. At one site, spent solvent (PCE/TCE) was co-disposed with water with a wide range of pH values.

NAPL at this site is generally found in lower permeability zones in the unsaturated zone with a pool suspected in the saturated zone above a green clay unit. NAPL at the second site was not co-disposed with acidic or basic waters. Contamination at this site is found in a clay unit at much shallower depths. Split spoon samples were collected from each of these borings over the depths that were expected to be most contaminated. Samples are presently being analyzed for total bacteriological counts (Acridine Orange Direct Counts), total organic contamination (gas chromatography headspace analysis), grain size and mineralogy distributions, and identification of TCE as well as PCE degrading microorganisms. Soil samples were collected under both aerobic and anaerobic sampling conditions. Preliminary analysis supports the expectation that microbial counts are closely correlated with NAPL contamination levels.

The laboratory component of this research has been limited primarily to method development and verification at this point in time. Analytical methods to support the field sampling have been taught and tested for quality control. Prototypes for the micromodels, which will be used for multiphase flow experiments, have been fabricated and are currently being improved to ensure the observed multiphase flow is not dominated by experimental artifacts.

Planned Activities

A three-pronged approach is planned for the next year of this project. These concurrent activities include:

1. Continued analysis and interpretation of field results.
2. Identification of conditions that lead to alteration of interfacial properties and, therefore, capillary flow. This includes consideration of variable NAPL composition, aqueous geochemistry (pH), microbial strains, microbial growth conditions. Adhesion and interfacial tension will be used as preliminary screening properties.
3. Begin analysis of the implications of altered interfacial properties on multiphase flow behavior in micromodels and capillary pressure-relative permeability columns.

Information Access

None available yet.