A Comparison of Field Techniques for Confirming Dense Non-aqueous Phase Liquids (DNAPLs)

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Abstract: A field study was recently performed comparing several approaches to DNAPL characterization at a site where indirect, as well as limited direct evidence of DNAPL exists. The techniques evaluated included: a three-dimensional (3-D) high resolution seismic survey, field screening of soil cores with a flame ionization detector (FID)/organic vapor analyzer (OVA), hydrophobic dye (Sudan IV)-impregnated reactive Flexible Liner Underground Technologies (Flute™) liner material used in combination with Rotasonic drill cores, centrifuged soil with Sudan IV dye, ultraviolet light (UV) fluorescence, a Geoprobe® Membrane Interface Probe (MIP™), and phase equilibrium partitioning evaluations based on laboratory analysis of soil samples. Several of the techniques evaluated provided positive identification of DNAPL in the subsurface. The continuous screening of cores with an OVA/FID provided reliable information regarding the presence of heavily impacted soils, helping to focus confirmation sampling activities. The Flute™ liner reactive strips provided direct confirmation of pure phase DNAPL at the site, and provided information regarding the thickness and general character of the product in the subsurface (i.e., ganglia, pools, etc.). However, residual quantities of DNAPL may have been missed with this technique. The MIP™ provided rapid delineation of heavily-impacted soils and allowed for accurate selection of optimal soil sample locations and depths. Phase partitioning evaluation of soil analytical data in combination with the MIP™ records provided reliable delineation of the DNAPL area and proved to be the most effective technique for rapid evaluation of DNAPL areas. Other techniques evaluated in this study (e.g., UV fluorescence, soil sample centrifugation, hydrophobic dye addition to soil samples) were not beneficial at this study site.

A 3-D high resolution seismic survey was performed as the initial phase of this investigation. The primary objectives of the survey were to create a 3-D image of subsurface structures and stratigraphy beneath the study area, from the near surface to a depth of more than 100 ft bls; to delineate potential trapping structures for DNAPL ganglia and pools; and to delineate potential shallow migration pathways from the likely DNAPL (release) locations to the trapping structures. A secondary objective of the survey was to evaluate seismic data within a confirmed DNAPL area to determine if signal attenuation was evident. The seismic survey was successful in identifying small-scale structural features in the subsurface and fracture systems within unconsolidated strata. However, little if any correlation between confirmed DNAPL and structural features was apparent at this study site.

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Sonic drilling techniques were used to obtain continuous cores at all sample locations (except at select MIP™ locations). For each core interval of interest, a 3-inch wide strip of reactive flexible liner material was placed within the plastic core bags prior to core extrusion. The flexible liner material was constructed of hydrophobic Tyvek™ material and was impregnated with similarly hydrophobic (Sudan IV) dye. The flexible liner is designed to turn bright red in areas where hydrophobic, immiscible organic solvents come into contact with the impregnated material. DNAPL was confirmed using the Flute™ liner in several locations throughout the study area. However, minor discoloration of the liner material associated with routine handling and contact with the plastic core bags, as well as the less dramatic reaction associated with Freon 113 (compared to TCE) made interpreting select intervals difficult. Therefore, contact of small ganglia of residual DNAPL with Flute™ liner material could easily be missed. During this study, the Flute™ liner was stained at all locations where DNAPL was confirmed. While minor amounts of DNAPL could be missed by this investigation technique, it provided a simple and effective means of confirming substantial quantities of DNAPL.

OVA readings were collected at two-foot intervals by cutting a roughly three-inch long slice in the core bags, opening a void space within the core, and inserting the tip of an OVA/FID into the void space to obtain a reading. Field screening for organic vapors along the length of cores provided an excellent method of focusing sample collection on impacted areas; however, results of OVA/FID readings were not always consistent with laboratory or Flute™ liner material observations. In general, OVA/FID readings exceeding about 3,000 parts per million (ppm) were associated with areas where staining of reactive Flute™ liner material or where Freon 113 was detected above a concentration of 84 milligrams per kilogram (mg/kg).

Based on the OVA readings and observations of Flute™ liner reactions, aliquots of soil were collected from select portions of the cores for additional analyses using a hydrophobic dye shake test and centrifugation method described by Cohen and Mercer (1993). Adding hydrophobic dye to soil sample solutions was not effective in identifying DNAPL presence during this study and this technique was omitted after confirmed DNAPL samples provided negative results.

Ultraviolet (UV) Fluorescence refers to the spontaneous emission of visible light resulting from a concomitant movement of electrons to higher and lower energy states when excited by UV radiation (Cohen and Mercer 1993). While many organic contaminants fluoresce to varying degrees (e.g., aromatic or polyaromatic hydrocarbons and PCBs), saturated aliphatic hydrocarbons generally do not fluoresce unless mixed with fluorescent impurities. UV Fluorescence of organic contaminants was not effective in identifying DNAPL presence during this study and this technique was omitted after confirmed DNAPL samples provided negative results.

The MIP™ is a direct push technology (DPT)-based sampling method developed by Geoprobe® Systems (Christy 1996). The MIP™ system consists of a thin film fluorocarbon polymer membrane mounted on a stainless steel drive point. The drive point is advanced using direct push (Geoprobe®) technology. The membrane is heated to approximately 100° to 120° C and a clean carrier gas (nitrogen, helium, or purified air) is circulated across the internal surface of the membrane. Volatile organic compounds (VOCs) that partition across the membrane are subsequently measured by a conventional detector system (e.g., GC/MS, PID, FID, ECD) at the

ground surface. A continuous log of VOC detections versus depth is generated. Soil conductivity and penetration rate information are also provided by use of a conductivity dipole and other sensors, providing real-time lithology-based data for interpretation. For this study, the MIP™ provided rapid delineation of heavily-impacted soils and allowed for accurate selection of optimal soil sample locations. Additionally, a characteristic MIP signature was established that was considered indicative of DNAPL.

Soil samples were collected from core intervals with elevated OVA readings and/or Flute liner discoloration and were submitted to a field laboratory for GC/MS analysis of VOCs. Field laboratory analyses of soil samples provided specific identification of the contaminants present as well as analyte quantification. The soil analytical results were also used to assess the likely presence of DNAPL. Feenstra et al. (1991) and Pankow and Cherry (1996) present a method for assessing the potential presence of DNAPL using analytical data and principles of phase equilibrium partitioning. Using site specific data for f_{oc}, soil bulk density, and porosity; and published data for the solubility of Freon 113, DNAPL would be expected to exist at a total concentration greater than 84 mg/kg. These data were then used in combination with other screening method results to delineate DNAPL areas.

Based on the results of this study, we conclude that the most effective strategy for identifying and delineating likely DNAPL areas in the subsurface includes initial evaluation of existing groundwater quality data to estimate the 1% solubility isopleth boundary for the contaminant(s) in question. The presence of DNAPL can then be confirmed and delineated using a combination of the MIP™ system and laboratory analysis of soil samples. Performing a MIP™ survey allows selection of core sample locations and intervals. Subsequent laboratory analysis of core samples using phase equilibrium partitioning algorithms allows for estimation of the specific analyte concentrations in soil that would be indicative of DNAPL at a given study area. Extrapolation of laboratory data to other MIP™ records allows for delineation of the DNAPL area(s).

References

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