Source Characterization of a DNAPL Site Using Multiple Assessment Techniques

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Abstract: Multiple assessment techniques were used at a chlorinated solvent site in north-central Florida to define the horizontal and vertical extent of DNAPL in the subsurface. Two technological approaches were used for the source-area characterization: one used the membrane interface probe and direct push (GeoProbe®) and Rotasonic® core samples with an onsite laboratory conducting standard gas chromatograph analyses. The second approach used the Waterloo® piston cores with direct methanol preservation and extraction of soil samples collected from small, discrete intervals. Subsamples from the piston cores were evaluated in the field with the Sudan IV® dye to indicate the presence or absence of DNAPL. Additionally, soil samples were analyzed by an onsite mobile laboratory to compare purge and trap GC results with the methanol preservation/extraction Waterloo® analytical results. Additional physical and geotechnical data were collected concurrently with the assessment data to aid in evaluating the feasibility and/or the potential performance of several remedial options, including excavation, chemical oxidation, six-phase heating, three-phase heating, and dynamic underground stripping. The results of the MIP/GeoProbe® investigation yielded similar analytical results as the Waterloo® discreet core analyses, and were generally successful in delineating areas of high concentration contamination and potentially DNAPL. The direct push methods utilized in both approaches have the advantage of producing very little investigative waste, and can generally collect more and better cores per day than traditional drilling methods with split spoon sampling.

A source characterization study was conducted at a site to collect the specific physical, chemical, and geotechnical data that are necessary to select, design, and implement pilot tests of remedial technologies for dense non-aqueous phase liquid (DNAPL).

The Fairbanks Disposal Pit (FDP), a 10-acre sand and clay borrow pit operated by the Florida Department of Transportation (FDOT), is located in Fairbanks, Alachua County, Florida, a rural-residential area about seven miles northeast of Gainesville. In 1965, FDOT began using the FDP to dispose of waste and topsoil collected from roadsides, plus demolition and construction debris. Byproduct waste material consisting primarily of 1,1,1-trichloroethane (1,1,1-TCA), trichloroethene (TCE), benzene, xylene, and toluene was also disposed at the site in the 1970's and early 1980's. These source materials and contaminated soil were initially excavated in 1983 and later replaced completely with clean fill and a compacted soil cap. However, groundwater samples collected several years after the excavation contained persistent levels of chlorinated solvents, indicating the possible presence of DNAPL.

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An accurate horizontal and vertical delineation of DNAPL was needed to evaluate remedial options for the source area. An approach incorporating soil sampling and analysis, guided in part by the qualitative results gathered from a membrane interface probe (MIP) to infer the horizontal and vertical extent of free-phase product, was developed. In addition, soil samples were collected and analyzed for a variety of physical and geotechnical properties to assist with the evaluation of remedial options. The investigative methods and their respective uses are listed in the table below:

Investigative Method	Description	Purpose
Membrane Interface Probe	Fluorocarbon polymer membrane heated to 100°-120°, allowing VOCs to partition across the membrane; VOCs carried to surface for analysis. Produces a continuous log of VOC concentrations versus depth. A conductivity dipole and other sensors in the probe tip provide additional soil conductivity and penetration rate information.	Provides accurate depth to confining or semi-confining zones, and semi-quantitative VOC data (used to target specific depths to collect samples for laboratory analysis). Provides real-time identification of probable free-phase product areas.
GeoProbe® Core	Direct-push method that retrieves a continuous four-foot soil core. Limited to unconsolidated material, limited by borehole collapse during core extraction.	Provides a quantitative correlation for the MIP lithologic (conductivity) data and soil samples for laboratory analysis.
Waterloo® Piston Core	Five-foot continuous cores. Yields complete recovery with representative, undisturbed samples due to the vacuum created by extracting the piston as the core is advanced. Dual casings prevent borehole collapse and downward migration of contaminants.	Provides soil samples at very precise depth intervals, and facilitates lithologic descriptions that are complete and accurate.
Sudan IV® dye testing	Soil samples from the Waterloo® piston core are added to a mixture of Sudan IV® and water, and DNAPL presence/absence is shown by a color change.	Indicates the presence of DNAPL.
Rotasonic® Core	A rotating, vibrating 10 ft core barrel is advanced using water as a drilling fluid. The drilling produces a borehole with less smearing than other drilling techniques, and provides more continuous, less disturbed samples than split spoons. Dual casings prevent borehole collapse and downward migration of contaminants.	Facilitates fast, economical drilling to establish lithology and collect undisturbed soil samples.
Geotechnical Sampling	Split spoon – hollow sampler that retrieves relatively undisturbed samples Shelby tube – metal tube pushed into fine-grained sediment to retrieve undisturbed core	Split spoon samples used for grain size and lithologic analysis. Shelby tube samples used for grain-size analysis, permeability, bulk density, fractional organic carbon, Atterberg limits, penetrometer analysis, Torvane analysis, unconfined compression test.

The source-area characterization was conducted using two different approaches: one used MIP and direct push core samples with standard laboratory analyses; the other used the Waterloo® piston cores with methanol preservation of soil samples collected from small, discrete intervals.

The results from the MIP were used to target specific depth intervals that displayed high concentrations of volatilized organics for the collection of soil samples using both the GeoProbe® and Rotasonic® coring methods, with analytical support from an on-site laboratory. Soil data were then evaluated with respect to phase equilibrium partitioning algorithms to determine concentrations that would be indicative of free product at the study area (Feenstra, *et al*., 1991). The laboratory analytical results were, in turn, then used to calibrate the MIP data so that MIP data alone could be used to delineate probable free-phase product areas.

The Waterloo® sampling and analysis method provided precise sampling depth intervals (roughly 2 cm intervals) combined with sample preservation and analysis techniques designed to minimize the loss of volatiles from the soil sample. Subsamples from the piston cores were evaluated in the field with the Sudan IV® dye to indicate the presence or absence of DNAPL. Additionally, soil samples were collected at selected depth intervals and analyzed at an onsite mobile laboratory to compare results with the Waterloo® analytical results.

The results of the MIP/GeoProbe® investigation yielded similar analytical results as the Waterloo® investigation. Samples collected at similar depths from the same core contained target compounds in concentrations that were generally the same order of magnitude, with neither method showing a discernable trend of consistently detecting higher or lower concentrations than the other. Considering that these are soil data, which unlike water, are inherently heterogeneous, the results suggest that both methods accomplish the goal of delineation of the horizontal and vertical extent of DNAPL. The results of the Sudan IV dye tests were negative in all but two samples.

Concurrent with the source area characterization activities was the collection of physical and geotechnical data needed to support and implement remedial pilot studies. These data, listed in the table above, provide the information needed to evaluate the feasibility and/or potential performance of the following remedial options: excavation, chemical oxidation, six-phase heating, three-phase heating, and dynamic underground stripping.

The technologies employed in the source characterization of the FDP utilized relatively rapid techniques that produced the desired results for planning and implementing site remediation. Direct push methods (MIP, GeoProbe®, Waterloo®, and Rotasonic®) have the advantage of producing very little investigative waste, and can generally collect more and better cores per day than traditional methods such as split spoons. The MIP/GeoProbe® and Waterloo® investigations produced comparable results. The MIP/GeoProbe® techniques have a lower cost and more rapid analytical reporting than the Waterloo® techniques and also offer the advantage of real time data from the MIP. This in turns allows for rapid and complete assessment.

The authors gratefully acknowledge the helpful reviews by Terry Zinn and Porter-C. Knowles.

Reference

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