Source Zone Characterization Approaches Including Contaminant Mass Flux

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Source Zone Characterization

Characterization of contaminant source zones that include non-aqueous phase liquids (NAPL) continues to pose a significant challenge for site investigations. The presence of dense NAPL (DNAPL) greatly increases the difficulty due to the complex distribution produced by media heterogeneities. After a DNAPL release has approached a state of mechanical equilibrium, the resulting distribution is often very complex involving narrow vertical fingering and thin laterally continuous layers that can be less than one centimeter thick. Currently, the only means of quantifying DNAPL distributions at such small scales is through high-resolution soil coring. An example of this is the Sages Dry Cleaner site in Jacksonville Florida (Jawitz et al., 2000). Perchloroethylene (PCE) concentrations in soil cores from the Sages site show thin layers of high saturation DNAPL that were often present in only one sample during core sampling conducted using one inch vertical intervals (Figure).

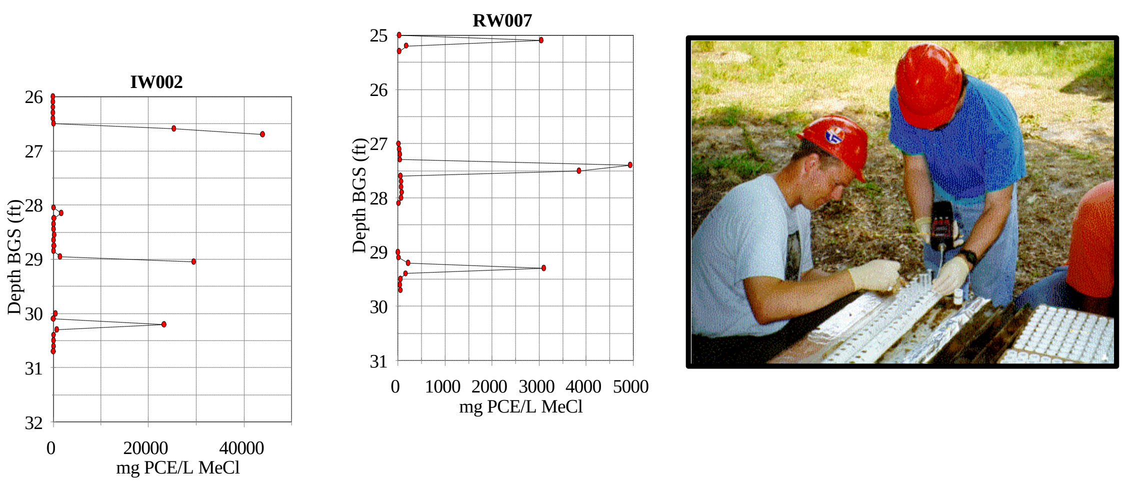

Figure: High-resolution core sampling at Sages.

An alternative to high-resolution core sampling is full core extraction analysis. In this approach, the entire core collected in a samppling tube is extracted in a solvent such as methanol. By extracting the entire core, thin layers of DNAPL are not missed and a mass balance for the entire core will be complete. While some detailed infromation regarding the NAPL distribution is lost, alalytical costs are greatly reduced as is the potential to miss significant NAPL contaminated zones.

Thin layers of DNAPL can be difficult to detect for techniques that average information over larger volumes of the aquifer. Many non-invasive geophysical techniques such as ground penetrating radar, seismic reflection, and electrical resistance tomography have difficulty sensing small volumes of NAPL sparsely distributed such as the Sages data. These techniques still have great value in characterizing aquifer properties that influence NAPL behavior and may be useful in locating large NAPL pools.

A technique that has increased as a tool for locating NAPL is direct push probes. A number of probes/sensors can be deployed on cone penetrometer or direct push rigs. These often involve information gathered through a widow on the side of the probe to transmit optical information. Laser Induced Fluorescence (LIF) is an example of an optical signal that is read continuously as the probe is advanced. If the system responds to the presence of NAPL it can be used to locate zones of high NAPL saturation. Methods such as this have great potential for detecting small NAPL layer but may have difficulty quantifying the mass present. Direct push probes have great potential for mapping out the extent of the NAPL source zone and providing an estimate of the mass present. Other examples of direct push probes include resistivity, visual imaging, and the membrane interface probe (MIP).

Another technology currently employed for delineating the vertical NAPL distribution is the Ribbon NAPL Sampler. This method typically involves a material, such as hydrophobic dyes, that become visible when contacted with NAPL. These are deployed in a borehole to contact the formation. After retrieval, zoned of high NAPL saturation can be determined visually. This method has great potential for delineating the extent of a source zone but may provide limited information of the mass present.

An integral approach to characterizing NAPL source zones can be conducted using chemical tracers (Jin et al. 1995). Tracers that partition into NAPL are pumped through he source zone and transport relative to a non-reactive tracer is used to quantify the volume of NAPL present. Tracer methods are excellent for obtaining an estimate of the mass (or volume) of NAPL present in a source zone. Errors associated with tracer test can be relatively low when conducted properly. Comparable error estimates using core samples may require an unacceptably high number of cores.

Flux Based Site Characterization

Given the great difficulty and cost associated with quantifying the amount and distribution associate with NAPL source zones, an alternative approach is proposed. The primarily environmental concern associated with many source zones is the delivery of mass to a much larger dissolved contaminant plume. This mass delivery can be quantified by the mass flux leaving the source zone. Here we define mass flux as the mass per unit area per time. The magnitude of the mass flux is a measure of the source zone strength. The total mass discharge, obtained my integrating the mass flux across the entire source zone may also be considered a measure of source zone strength. Only recently have new methods been proposed to measure mass flux.

In the past, quantification of mass flux involved establishing a dense network of multilevel samplers and measuring contaminant concentrations in groundwater across a transect. This information was converted to flux by estimating local velocities through knowledge of the hydrologic conductivity field or tracer tests. While this method is sound, it requires significant effort. Two new methods have been recently proposed for measuring mass flux from contaminant source zones. The first is an integral pump test in which water is pumped from a transect of wells downgradient of a NAPL source zone (Bockelmann et al., 2001). Contaminant concentrations are monitored in the effluent and the signature over time is used to estimate the natural gradient mass load (or flux) leaving the source zone. The second method is a borehole technique in which a granular sorbent is place in a well and contaminant mass flux and groundwater velocity are measured (Hatfield et al., 2002). Tracers are equilibrated in the sorbent prior to installation in the borehole. These tracers are leached out according the partitioning properties and the velocity of groundwater flow. The loss of tracer is used to quantify the local groundwater velocity. The mass of contaminant sorbed is used to quantify contaminant mass flux.

The mass flux leaving a source zone is an alternative approach to source zone characterization. This information can be used to assess risk or characterize remedial performance by measuring mass flux before and after remedial efforts. Finally, linking contaminant mass flux from source zones to the assimilation capacity of an aquifer will allow appropriate end points to be established in terms of mass flux.

References

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