Dynamic LNAPL Distributions and the Conceptual Site Model: Using UV-Induced Fluorescence for Non-Destructive Testing

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Background/Objectives. The distribution of LNAPL in soils is a key factor in the light non-aqueous phase liquids (LNAPL) conceptual site model (CSM). This distribution is the result of interactions between the formation and multi-phase flow of the LNAPL and local groundwater. In turn, vertical LNAPL distributions affect LNAPL mobility, and LNAPL weathering and natural source-zone depletion processes. Monitoring wells have significant limitations in allowing understanding of these complex processes. For example, a drop in water table can generate decreasing or increasing LNAPL thickness in monitoring wells depending on whether the aquifer is confined or unconfined, respectively. Thus, observations at monitoring wells need to be understood in the context of the geology and the water saturation of the media in it.

In this project, the development of a UV-based tool to measure the vertical distribution of LNAPL in the soil column is presented. The concept is similar to fluorescence-based high-resolution site characterization tools (HRSC) such as laser-induced fluorescence (LIF), in which this tool uses ultra-violet light to generate and optically detect a fluorescence signal on the NAPL. In contrast to existing HRSC techniques, which are used only once on each location (as a destructive test), the new tool is deployed in a clear, UV transparent solid dry casing, enabling non-destructive repeated measurements on the same location. Thus, the data provided by the new tool are helpful in revealing the dynamics of LNAPL distributions in soils.

Approach/Activities. For the proposed method, a borehole is lined with a solid, UV-transparent casing. The solid casing is hydraulically isolated from the formation, avoiding concentration of LNAPL in the well annulus. UV-induced fluorescence measured through this monitoring port characterizes vertical LNAPL distributions in soil. The well casing is left in place after the initial high-density survey, providing a permanent port for repeated monitoring to enable characterization of the dynamics of LNAPL distribution in soils.

This presentation will include results from both sand-tank (laboratory) experiments and a small-scale field test in which the probe is deployed over an extended time (months). Laboratory scale experiments are used to validate the results of the probe measurements by comparing to stop-motion animations obtained with traditional UV-based digital photography on the external sand tank walls. An ongoing small field test will be used to identify medium-term effects due to NSZD reactions and changes in water table over a time scale over a period of nearly half a year.

Results/Lessons Learned. Current sand tank experiments reveal the strong dependence of LNAPL distributions on water saturations and the presence of air. In water-saturated soil (2-phase), LNAPL shows very limited mobility. The LNAPL shows increased mobility under unsaturated conditions (3-phase behavior). As a result, LNAPL distributions are determined by groundwater level history and lithology. Preliminary sand-tank laboratory experiments suggest that LNAPL distributions detected by the new probe are sensitive to the release of ebullition gases from natural source-zone depletion (NSZD) reactions. It is expected that this type of information collected from the small field scale test will be available by the time of the presentation.