Rapid DNAPL Source Zone Characterization with Dye-Enhanced Laser-Induced Fluorescence (DyeLIF)

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Background/Objectives. Dense non-aqueous phase liquid (DNAPL) source zones pose one of the biggest characterization challenges in the environmental industry. Conventional methods like monitoring wells are poorly suited to mapping DNAPL due to the highly heterogeneous distribution of DNAPL. Other high-resolution characterization tools, like the membrane interface probe, provide rapid screening-level assessments of dissolved phase mass, but do not directly detect DNAPL. Laser-induced fluorescence (LIF) is a successful, mature technology, with wide application for mapping non-aqueous phase liquids (NAPLs). However, LIF was limited to hydrocarbon LNAPL and tar-based DNAPLs only, until the recent development of the dye-enhanced laser-induced fluorescence (DyeLIF) tool. DyeLIF combines standard LIF technology with injection of a fluorescent, hydrophobic dye ahead of the LIF window to render non-fluorescent NAPLs such as chlorinated solvents fluorescent and measurable. The probe functions by injecting an aqueous delivery fluid containing the hydrophobic dye through a small injection port situated below the LIF window. As the probe is advanced through the subsurface, the injected dye contacts the soil and quickly partitions into any present DNAPL. A slightly modified TarGOST® is used to detect the dye-labeled chlorinated solvent DNAPL's fluorescence.

Approach/Activities. DyeLIF was used at a former chemical manufacturing plant to refine the distribution of DNAPL prior to any evaluation of potential remediation options. The DNAPL was thought to be located on top of an interbedded clay zone, and consisted of a mixture of chlorinated compounds such as 2-chloroethanol, dichloroethane, trichloropropane, and bis(2-chloroethoxy)methane. As the probe was advanced, fluorescence waveforms consistent with the site DNAPL were detected, along with other non-DNAPL sources of fluorescence (e.g., organic material). The differences between target and non-target fluorescence allowed real-time non-negative least squares analysis of the DyeLIF logs, which in turn allowed an adaptive investigation strategy. During the advancement of the probe, pressure associated with the injection of the dye was logged, and was used to interpret changes in relative permeability, similar to the commonly available direct-push injection logging tools on the market. By simultaneously interpreting both the relative permeability and the DyeLIF fluorescence log, it was possible to locate the DNAPL and the relative transport potential in the same boring.

Results/Lessons Learned. The DyeLIF data resulted in a significant change to the conceptual site model. DyeLIF borings demonstrated that the historical delineation of DNAPL, which was based on measurable presence in monitoring wells, did not represent the actual distribution of DNAPL. The DyeLIF results indicated the DNAPL was present in the complex interbedded soils underneath the site, which could be mapped using the pressure response on the DyeLIF tool. Three-dimensional interpretation of the hydrostratigraphy and DyeLIF results provided an unprecedented understanding of the extent and distribution of DNAPL within the subsurface. And, because DyeLIF provides real-time results, the investigation was able to delineate the extent of DNAPL in a single mobilization.