High-Resolution Characterization of an Aged Toluene Source Zone and Plume in a Dolostone Aquifer

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Background/Objectives. Extensive research in fractured sedimentary rock at aged chlorinated solvent dense non-aqueous phase liquid (DNAPL) sites has shown the bulk of the contaminant mass is found in the dissolved or sorbed phases within the rock matrix due to diffusion processes. At these sites, it is necessary to quantify the mass distribution and identify biological and chemical processes within the rock matrix to understand source zone and plume evolution over time. These concepts are also very relevant to how light non-aqueous phase liquid (LNAPL) sites can be studied in fractured rock, and form the basis for a multidisciplinary research study of a mixed phase toluene plume in a shallow fractured Silurian dolostone bedrock aquifer in Guelph, Ontario. The discovery of a LNAPL plume in the late 1980s originating from leaking underground storage tanks and distribution lines at an urban industrial site led to multiple remediation efforts, the most recent in 2008 when phytoremediation was initiated in the source area consisting of hybrid poplar trees. The objectives of this study were to determine the contaminant mass and phase distributions in both the source zone and plume, and quantify advection/diffusion processes, ultimately leading to an improved assessment of the phytoremediation performance for attenuating the LNAPL source and plume extent.

Approach/Activities. This study focused on the hydrogeological evaluation of this site using a high-resolution approach to characterizing the transport and fate of contaminant mass, referred to as the discrete fracture-matrix (DFM) approach. These methods were utilized to understand and quantify process for this toluene LNAPL problem, including the collection of data at eleven boreholes advanced using both conventional drilling methods as well as portable drill coring technologies given access constraints within the phytoremediation area. Rock core volatile organic compound (VOC) samples were taken to inform rock matrix concentration profiles to evaluate the extent of diffusion into the rock matrix and to inform a conceptual model for flow and transport of LNAPLs in fractured rock. The hydrogeology of the site was informed by borehole geophysics, FLUTe transmissivity profiles, the application of active downhole temperature sensing (DTS), and installation of two different types of groundwater multi-level monitoring systems (MLSs), including a modified CMT MLS and a new G360 MLS developed for small-diameter coreholes that are also removable. Depth-discrete groundwater samples were analyzed for VOCs and hydrochemistry in conjunction with microbiological and CSIA tools to evaluate the role of phyto-induced hydraulic capture, toluene biodegradation in the aquifer and source mass depletion.

Results/Lessons Learned. The various high-resolution DFM tools applied provide an enhanced spatial and temporal understanding at multiple scales for the various physic-biochemical processes occurring at the site. Complementary datasets indicate a shallow water table plume strongly attenuated in lateral extent with low concentrations extending 20 m below water table due to both natural and anthopogenic influences in an urban flow system.