Transition from Mechanical-Based Remedies to Natural Remedies: Molecular Biological Tools Demonstrate Petroleum MNA and NSZD in a Fractured Basalt Aquifer in Melbourne, Australia

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Background/Objectives. A hydrocarbon release in 2006 led to the use of several mechanical remedial efforts to address the presence of light nonaqueous phase-liquids (LNAPL) and dissolved-phase petroleum constituent fractions, with an end goal of achievement of cleanup to the extent practicable (CUTEP) in source areas. Continued remedial efforts now focus on residual (immobile) LNAPL and the dissolved-phase plume using in situ bioremediation supported with multiple lines of evidence (MLOE) for degradation.

Objectives are to transition site remedy to monitored natural attenuation (MNA) and natural source zone depletion (NSZD) using a weight of evidence approach including molecular biological tools (MBTs).

Approach/Activities. A tiered framework was developed for evaluating NSZD and MNA, including assessment (developing biogeochemical conceptual site model [CSM] and establishing baselines), design, and performance monitoring which integrated primary (petroleum hydrocarbons), secondary (geochemistry and redox parameters) and tertiary (MBTs) LOE. The latter included the novel deployment of Bio-Bags™ within the riser space of monitoring wells within the vadose zone for evaluation of fermentation and methanogenesis, as well as CENSUS® quantitative PCR (qPCR) for specific gene targets within the contaminant plume. The MBT assessment included deploying Bio-Traps® across the LNAPL/water interface within the fractured basalt bedrock matrix.

Results/Lessons Learned. A biogeochemical CSM was developed that paints a robust and dynamic model supporting both NSZD and evidence of MNA. Redox conditions show “text book” iron- and sulfate-reducing conditions proximal to the LNAPL plume, and manganese-reducing conditions along the distal and flank edges of the dissolved plume, indicating sulfate-reducing conditions near the petroleum core and manganese-reducing and nitrate-reducing conditions downgradient near the distal dissolved phase plume areas. The highest metabolic potential for petroleum degradation is exhibited and evidenced in the former release area, with good data correlations between dissolved methane and fermenters (R^2 = 72%) and methanogens (R^2 = 81%). Evidence of aerobic degradation are supported by Gaussian-like distribution of ring-hydroxylating toluene monooxygenase (RMO) down the long-axis of the contaminant plume.