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Evaluate a Remedial Alternative to Long-Term LNAPL Management at a Former Refinery Site

David B. Gent (David.B.Gent@usace.army.mil), Anthony M. Friona (ERDC, Vicksburg, MS. USA)
James Wang (Geosyntec Consultants, Columbia, MD, USA)
Gavin Grant, Suzanne O'Hara (Savron, Guelph, ON, Canada)
Martin T. Kuhn, M. Pam Horner, Brian Bouwhuis, (Army Corps Engineers, Detroit, MI, USA)
Sara Pearson, John Pawloski (MDEQ, Lansing, MI, USA)

Background/Objectives. The approximately 100-acre former Zephyr Refinery Site in Muskegon, Michigan was a petroleum refinery facility that produced gasoline, naphthas, light heating oils, and industrial oil fuels until 1968. Many reported petroleum product spills over the history of site resulted in a LNAPL plume of approximately 50 acres and a groundwater plume of approximately ½ -mile long and 1/3-mile wide. Free product has been manually recovered from recovery and monitoring wells, while a site-wide groundwater recovery and treatment system is operated to control the migration of contaminants towards nearby wetland and surface water bodies. A Laser Induced Fluorescence (LIF) investigation conducted in 2012 estimated that over 1.5 million gallons equivalent of contaminants still existed in site soil. This presentation discusses the evaluation of an in-situ smoldering technology (STAR), including treatability tests and field pilot tests, as a remedial alternative to address the LNAPL. One important objective was to assess the efficacy of in-situ smoldering process for treating site soils contaminated with light fractions of petroleum hydrocarbons.

Approach/Activities. A laboratory treatability study was first conducted on site-specific soils impacted with gasoline range organic (GRO) and diesel range organic (DRO) compounds. The treatability tests demonstrated good smoldering of the DRO compounds, but GRO compounds in the soils were too volatile to sustain smoldering without the addition of a fuel surrogate, such as emulsified vegetable oil (EVO). Subsequently, an enhanced STAR (with surrogate fuel) pilot test and a standard STAR pilot test were conducted in separate areas where soil contained different levels of GRO, DRO, and oil range organics (ORO). For each pilot test, an ignition well and the associated thermocouples and vapor extraction points were installed in each target treatment area. The treatment depth intervals were generally between 26 and 32 ft bgs, which was below the water table. For the enhanced STAR pilot test, a total of 3,900 gallons of EVO solution (12.5% to 25% oil v/v) was injected to the subsurface within the target treatment area. During each of the 10-day pilot tests, combustion gases were monitored in real-time throughout the test, while vapor samples were also collected periodically for laboratory analyses. Pre- and post-test soil samples were collected to assess treatment efficiency.

Results/Lessons Learned. The treatability tests demonstrated that smoldering combustion could be effective in treating site soils containing various levels of GRO and DRO. Successful injection and combustion of EVO in the enhanced STAR pilot test allowed a robust smoldering reaction, resulting in the treatment of an approximately 4 to 6 ft thick interval below the water table with a radius of influence (ROI) of 10 ft. A total of more than 1,500 kg of LNAPL mass was removed from the subsurface during the 10-day pilot test. With the standard STAR test, an estimated 236 kg of LNAPL was removed in 10 days. In each test, self-sustaining smoldering combustion was observed based on vapor emissions and subsurface temperature monitoring with and estimated combustion front propagation velocity of 1.3 ft per day. The results of pilot tests allowed the development of a conceptual approach to applying in-situ smoldering combustion as a remedial alternative at this site.