Remedial Optimization: Transitioning from Physical LNAPL Removal to Enhanced Biological Degradation to Natural Depletion

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Background/Objectives. Diesel fuel released to the subsurface over a 30-year period resulted in an approximate 16-acre light non-aqueous phase liquid (LNAPL) body impacting shallow groundwater at a railyard. In 2008, the LNAPL thickness ranged from a few inches to approximately 1.5 feet, and the residual smear zone measured between 5 and 10 feet thick. The LNAPL-impacted shallow aquifer is comprised primarily of sands, gravels and occasional boulders, and is highly transmissive with groundwater flow rates ranging between 10 and 70 feet per day. The state regulatory agency requires the LNAPL be remediated to less than 0.01-foot thick. Initial remedial efforts consisted of operating a dual-level pumping system (DLPS) designed to depress groundwater and drive LNAPL towards extraction wells. A bioventing system was installed as a secondary remedial component to enhance remediation of the residual petroleum hydrocarbons in the smear zone. Reducing the petroleum mass in the smear zone minimizes the mass migrating and/or dissolving into groundwater, thereby reducing the time and effort to remediate groundwater.

Approach/Activities. The DLPS operated from 2008 through 2014, and removed approximately 4,500 gallons of LNAPL in the first 3 years of operation, after which the removal rate reduced significantly. The bioventing system operates as three separate, balanced, injection/extraction units across the LNAPL-impacted area. Performance monitoring includes collecting oxygen degradation and carbon dioxide production data on a semiannual basis. During the first five years of operation, oxygen degradation and carbon dioxide production rates indicated an estimated 40,000 to 55,000 gallons of petroleum hydrocarbons had been destroyed *in situ*. The difference in removal efficiencies between the DLPS (4,500 gallons in the first 3 years of operation) and bioventing systems, combined with the rapidly declining LNAPL removal rate from the DLPS provided the impetus for regulators to approve shutting down the DLPS and focus on petroleum hydrocarbon removal through bioventing.

Results/Lessons Learned. Results/Lessons Learned. Based on the superior removal efficiency of the bioventing system compared to the DLPS, it has replaced the DLPS as a primary LNAPL removal technique. Remedial actions have reduced the size of the LNAPL plume by over 90% and the residual petroleum hydrocarbon plume by 40% (currently estimated to be less than 12 acres in size). The bioventing system has successfully remediated the eastern extent of the LNAPL plume and smear zone to the point that LNAPL has been reduced to either a sheen or not present at all, oxygen concentrations in soil gas remain consistently above 10 percent, and carbon dioxide production rates remain low. As such, the eastern-most portion of the plume has transitioned to a natural degradation program. Bioventing continues to be effective across the western two-thirds of the plume and is resulting in remediation of the LNAPL and residual petroleum hydrocarbons in the smear zone. As LNAPL disappears from these areas, the bioventing system will be further optimized and its operational footprint reduced. Data clearly demonstrate bioventing is highly efficient and more suitable to the lithologic conditions than mechanical removal for this site. Bioventing also has a significantly smaller carbon footprint compared to dual-level pumping or high-vacuum extraction, and is U.S. Environmental Protection Agency Green Remediation compliant.