Use of Steam to Enhance VOC-TPH NAPL Mixture Dissolution at a Major Source Area through Volatilization, Recovery, and Biodegradation, Naval Air Station North Island

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Background/Objectives. Building 379 at Naval Air Station North Island has a footprint of 172,000 square feet and overlies a light non-aqueous phase liquid (LNAPL) plume comprised of jet fuel and Stoddard solvent mixed with trichloroethene (TCE) and 1,1,1-trichloroethane (1,1,1-TCA). Estimates of NAPL volumes range from tens to hundreds of thousands of gallons. Approximately 40 percent of the NAPL footprint incudes cVOCs. The depth to the top of LNAPL is approximately 23 feet below ground surface, and thickness exceeds 1 foot. Volatilization of cVOCs from the LNAPL has created a significant cVOC vapor plume underneath the building. NAPL temperatures are elevated proximal to the steam line (as high as 43 ^{o}C). Levels of cis-1,2-DCE in soil gas near the steam line are much higher than TCE; whereas TCE is much higher away from the steam line. Volatilization of cVOCs from the LNAPL has created a significant cVOC vapor plume underneath the building with initial VOC levels > 10,000,000 $\mu g/m^3$. A soil vapor extraction (SVE) system has been in operation with a dual screened well since May 2016, with recovery of >14,000 lbs of VOCs (allowing re-located female personnel to return to the building due to decreases in indoor air VOCs to acceptable levels. In 2017, the Navy installed three additional horizontal SVE wells and three steam injection wells (screened below NAPL) to enhance NAPL volatilization and biodegradation - specifically the cVOCs. In addition, two horizontal NAPL recovery wells were installed to recover mobilized NAPL (due to steam injection).

Approach/Activities. Analyses of the NAPL composition in 1998, 2015, and 2016 indicate that TCE concentrations have decreased and cis-1,2-dichlorothene (cDCE) concentrations have increased over time. Decreases in NAPL thickness were also observed. Temperature data for the NAPL collected in 2016 indicate temperatures over 30 ^{o}C at a number of locations. Significant levels of cDCE were detected in soil gas, both in sub-slab and at depth. Low levels of methane have also been detected in the vicinity of the NAPL. Laboratory microcosm tests using site aquifer material and NAPL, incubated without amendments for one year at room temperature, showed dechlorination of TCE to cDCE, with concentration of cDCE increasing in the NAPL. In 2016, at a number of locations, a black layer was observed between the NAPL and groundwater, which may also be indicative of biodegradation (at the NAPL-water interface). This will be coupled with measurement of carbon dioxide and methane (and oxygen) in vapor monitoring probes located above the NAPL plume.

Results/Lessons Learned. Biodegradation of cVOCs in NAPL is not commonly reported, possibly due to difficulty in measuring daughter products. However, given the right conditions (presence of electron donor and elevated temperatures), biodegradation is possible. Elevated temperatures are promoting biodegradation of TCE at the NAPL-water interface, with the petroleum hydrocarbons serving as a continuous source electron donor. Active injection of steam further increased temperatures within the NAPL plume, resulting in additional fortuitous biodegradation of cVOCs. Comparison of VOC levels in extracted vapor with and without steam injection show a significant increase in concentrations and monthly removal rates.