

Thermal Remediation of Creosote Impacted Sand: Treatability Testing during Heating and Post-Heating Dissolution

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Background/Objectives. In situ thermal remediation (ISTR) technologies, including electrical resistance heating (ERH) and thermal conductive heating (TCH), have been implemented at former manufactured gas plant (MGP) sites impacted by coal tar and creosote. However, much of the published ISTR research has been focused on volatile organic compounds (VOCs) and volatile non-aqueous phase liquids (NAPLs) rather than on semi-volatile organic compounds (SVOCs) and polycyclic aromatic hydrocarbon (PAH) NAPL mixtures. Formal research is needed to better understand fundamental mechanisms, develop optimization strategies, and establish ISTR performance expectations at MGP and creosote sites. For example, volatile NAPL removal occurs by volatilization during NAPL-water co-boiling at temperatures less than the boiling point of water. However, most components of semi-volatile (e.g., PAH) NAPL have higher boiling points than VOCs and co-boiling occurs essentially at the boiling point of water. Research is needed to understand the relationships between heating duration, heating temperature, NAPL mass removal and NAPL component composition.

Approach/Activities. A series of laboratory treatability tests was conducted using sand mixed with water and different initial saturations (10%, 30% or 60%) of fresh creosote. Each heating test was conducted in a 1 L stainless steel cylinder heated to a maximum temperature of 130-320 °C using a laboratory convection oven. Maximum temperatures were maintained for 10 days. Throughout each heating test, vapor produced in the cylinders was vented, condensed and collected. Condensate (LNAPL, DNAPL and water) volume was measured to determine changes in fluid saturation in the cylinders. Replicate cylinders heated simultaneously in the same oven were sacrificed to measure changes in PAH soil concentrations during heating. Following the heating tests, a series of dissolution tests was conducted using heated sand that was cooled and re-packed into separate cylinders (5 cm-long one-dimensional columns) designed for water flow through the sand. Room temperature (22 °C) water was pumped through the columns at an average pore-water velocity of 25 cm/day. Effluent from the columns containing sand treated at 130-320 °C was sampled for analysis of priority PAHs, and compared to results from water flushing of unheated sand at the same NAPL saturation.

Results/Lessons Learned. Many of the results of the heating tests were consistent with expectations based on ISTR industry experience in treating semi-volatile NAPLs: no co-boiling occurred below the water boiling temperature, substantial VOC removal occurred during co-boiling, creosote NAPL removal by volatilization was incomplete, both LNAPL and DNAPL condensate were produced, naphthalene precipitation occurred during condensation, and congealing of the sand was observed at an elevated treatment temperature. In addition, NAPL removal was observed to occur in two distinct stages: during co-boiling (100 °C) and at greater than 290 °C. Extending the heating time in tests at 130 °C and 205 °C did not increase NAPL removal or further decrease PAH soil concentrations, which demonstrates that a higher maximum temperature is more important for removal than a longer heating duration and that treatability testing can help in the selection of target temperatures. The results of the dissolution tests showed mixed results, with decreases in the aqueous concentrations of some priority PAHs and increases in others. Some of the 16 priority PAHs were below regulatory standards (for Ontario, Canada) but others remained above, even after heating to 320 °C for 10 days.