Leveraging Warm Water from a Source Area Thermal Remedy for Synergistic Biotic and Abiotic Degradation of a Downgradient CVOC Plume

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Background/Objectives

Warm water migrating downgradient during and after a source-area thermal remedy was leveraged to enhance degradation of residual chlorinated VOCs in the proximal portion of the downgradient plume at a New Jersey site. The warm water is expected to increase desorption as well as enhance natural biodegradation already occurring at the site. A combined ZVI and fermentable solid carbon source (Provect-IR) was injected to leverage the enhanced biological activity anticipated from the warm water. The ZVI component also provides an abiotic reaction mechanism to ensure continued degradation as a contingency in the event that groundwater temperatures became too warm. The Provect-IR was injected to construct two permeable reactive treatment zones in accessible portions of the property immediately downgradient of where the source-area thermal remedy was deployed.

Conceptual Site Model and Treatment Design

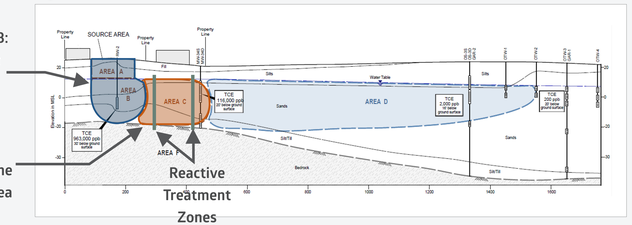
Treatment zones were installed on each side of a warehouse building on the immediately downgradient property (Fig. 1). The treatment targeted a transmissive unit between less permeable upper and lower till units (Fig. 2) with the highest VOC concentrations. TCE, cis-DCE, and VC were detected in the treatment area at maximum concentrations of 194, 120, and 3.69 mg/L, respectively. DNAPL was not observed or suspected in the treatment area; the high VOC concentrations reflect transport from DNAPL in the source area. Biodegradation was occurring based upon the VOCs and other chemical data, but not at a sufficiently high rate to mitigate offsite migration. A groundwater plume extends approximately 2,000 ft downgradient.

Fig. 1: Site Layout

Fig. 2: Cross Section Along Plume Axis

Areas A and B: Source Area (Thermal Remedy)

Areas C: Proximal Plume Treatment Area

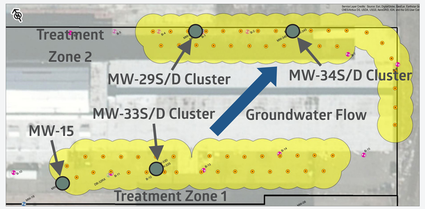


Field Injection

The reagent was injected by direct-push as a 30% solids slurry (Fig. 3). A total of 148,500 lbs of Provect-IR was injected at 325 injection intervals in 57 borings, between 14-57 ft below grade. Injection depths were adjusted for depth of the bounding till units using boring logs and direct-push resistance.

Fig. 3: Direct-Push Injection

Fig. 4: Injection Locations



Results and Discussion

The thermal remedy was operated from December 2017 through July 2018. The Provect-IR injection was conducted in two mobilizations, February and April 2018. Performance monitoring data are available through January 2019.

Groundwater Temperature Data

A maximum temperature of 35-40°C is desired because microbial activity is inhibited at higher temperatures. Six months after heating ceased, elevated groundwater temperatures are observed in shallow wells in Treatment Zone 1 (Fig. 5). Temperature appears to have plateaued in both wells, with increases of about 3°C and 22°C above ambient in MW-33S and MW-15, respectively. No temperature shift is observed in Treatment Zone 2 (Fig. 6); a delayed response is expected due to distance from the thermal treatment area.

Fig. 5 Treatment Zone 1 Temp

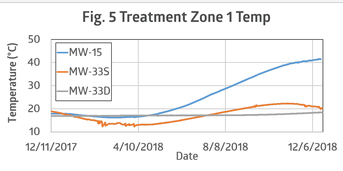
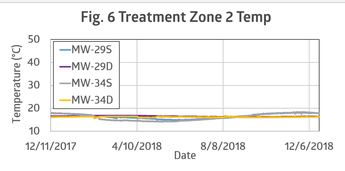


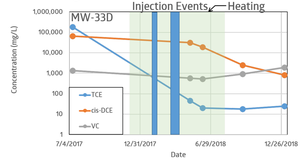
Fig. 6 Treatment Zone 2 Temp



Groundwater VOC Data

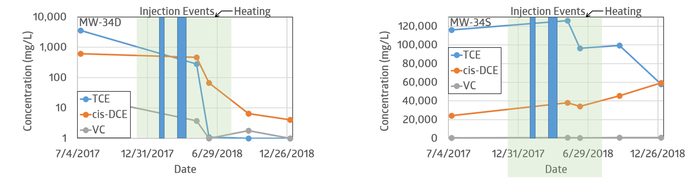
VOC concentrations in MW-33D (deep well in Treatment Zone 1) are shown in Fig. 7. TCE and cis-DCE have decreased by two to four orders of magnitude while VC concentrations have remained constant. VC will likely decrease once the cis-DCE is more fully degraded. VOCs in MWS-15 and MW-33S are historically <100 ug/L and below MCLs in the latest event, thus not shown.

Fig. 7: Treatment Zone 1 VOCs



In downgradient Treatment Zone 2, VOC concentrations in deep wells also exhibit orders of magnitude reductions (e.g., MW-34D; Fig. 8). VOC concentrations in shallows wells (e.g., MW-34S; Fig. 8) exhibit large reductions in TCE (~50%) but increased cis-DCE formed from either biotic or abiotic degradation of TCE. The VC concentration has remained relatively constant. Concentrations of cis-DCE and VC in the shallow zone are expected to decrease once the TCE has more fully degraded, as observed in the deep zones.

Fig. 8: Treatment Zone 2 VOCs



Key Lessons Learned

1) Groundwater temperatures have increased in the upgradient zone but not uniformly. A plateau may have been reached approximately 4-5 months after heating ceased. No temperature change has been observed yet in the downgradient zone, but an increase is expected due to groundwater advection.

2) VOCs have been more effectively addressed in the deep zone than in the shallow zone. This is primarily attributed to reagent distribution. Some short-circuiting did occur in the shallower intervals.

3) The site is entering a monitoring phase to evaluate long-term results.