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Proven Soil, Sediment, and Groundwater Remediation Technologies

Field Profile
EHC®

Project Update June 2009

EHC Pilot Study for Oregon DEQ's Dry Cleaner Program at a Former Dry Cleaner Site, OREGON USA
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Summary

Groundwater at the former Serry's dry cleaner site in Corvallis, Oregon, was impacted with chlorinated volatile organic compounds (CVOCs). The key CVOCs found at the site include PCE, TCE, DCE, and VC, as high as 22,000, 1,700, 3,100, and 7 ppb, respectively. Field scale pilot tests were performed for the Oregon DEQ's Dry Cleaner Program to evaluate the performance of EHC®, an *in situ* integrated biological and chemical reduction (ISCR) technology. The method of injection was also evaluated to determine the effectiveness of the injection method in distributing EHC, given the low permeability of soils at the site (sandy silt and silty clay). Subsequent field monitoring has shown greater than 99.9% removal of total CVOC concentrations two years after the injections, **without the accumulation of catabolites or rebound of CVOCs**.

The Challenge

The groundwater flow direction at the site changes with seasonal conditions, and is either toward the south-east or the north-west. The groundwater velocity is unknown, but assumed to be low due to the type of soils at the site. No confirmed source of PCE has been found, however groundwater concentrations suggest that there may be two hot spots on site: the north-west corner and south-east corner of the building. The building is currently occupied and access is difficult to obtain. The primary goal of the pilot-scale treatment is to reduce groundwater concentrations at the southeastern hot-spot that may have historically contributed to indoor air vapor intrusion at nearby residences.

Test Injection

A test injection was conducted prior to full-scale implementation to evaluate the effectiveness of direct push methods in distributing EHC in the low permeability soils. A total of 450 lbs of EHC was injected from 13 to 25 ft bgs (4 discrete layers, spaced 4 ft apart) using GeoProbe's pressure activated injection tip. A high pressure pneumatic grout mixing and pumping system was used to mix and pump the EHC to the injection tip. Six soil cores were obtained around the injection point (from 0.5 to 5 ft from the injection point) to assess the radius of influence of the injection (**Figure 1**). EHC fractures were found at the farthest sampling points indicating that the radius of influence was up to at least 5 ft. **Figure 2, 3, 4** and **5** show some of the EHC bands or fractures observed in the soil cores.

The following lithology was observed from the soil sampling:

- Brown sandy, clayey silt from 8 to 20 ft bgs;
- Stiff brown silty clay from 20 to 22 ft bgs;
- Stiff gray clay below 22 ft bgs;
- Water bearing and loose sand layers were encountered at approximately 26 ft bgs.

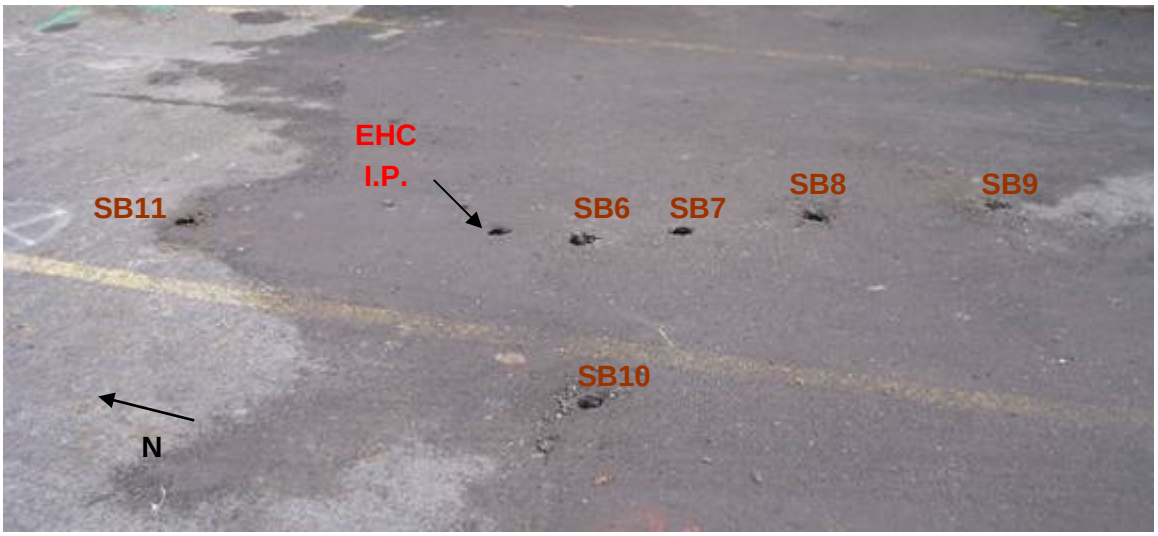


Figure 1: Soil sampling locations around EHC injection point.

Figure 2: EHC fracture at 17.5 ft bgs (SB6).

Figure 3: Vertical EHC fracture at 26.8 ft bgs (SB6).

Figure 4: EHC fracture at 17 ft bgs (SB7).

Figure 5: Vertical EHC fracture at 17 ft bgs (SB9).

Field-Scale Pilot Study

In August 2006, a total of 10,250 lbs of EHC was injected into an area measuring approximately 825 ft^2 x 20 ft deep (from 10 to 30 ft bgs), which resulted in an average application rate of 0.6% to soil mass. The EHC was supplied as a dry powder in 50-lb bags and mixed with water on site into slurry containing about 29% solids (**Figure 6**). Using conventional direct push technology, the EHC slurry was injected at 3 to 6 GPM at a pressure of approximately 200-400 psi. The depth interval targeted was from the groundwater table (*ca*. 10 ft bgs) to approximately 30 ft bgs, where a less permeable layer was encountered. The EHC was injected in discrete layers using the Geoprobe pressure-activated injection tip and high pressure grout mixing unit.

Figure 6: Chem Grout's Mixing Unit CG-500.

The EHC was added to a total of 32 injection points (**Figure 7**), including nine additional points south of the building. The additional points were added due to issues with surfacing: it was not possible to achieve the originally planned application rate of 1% to soil mass in the tight soil formation at the targeted flow rate of approximately 5 GPM due to pressure build-up in the subsurface. The treatment area was therefore increased resulting in a lower application rate of 0.6% to soil mass within the treatment area. In addition, a relatively tight injection spacing of 5 ft was used for the EHC injections based on the results from the test injection. Approximately 18 lbs of EHC was added per vertical foot on average.

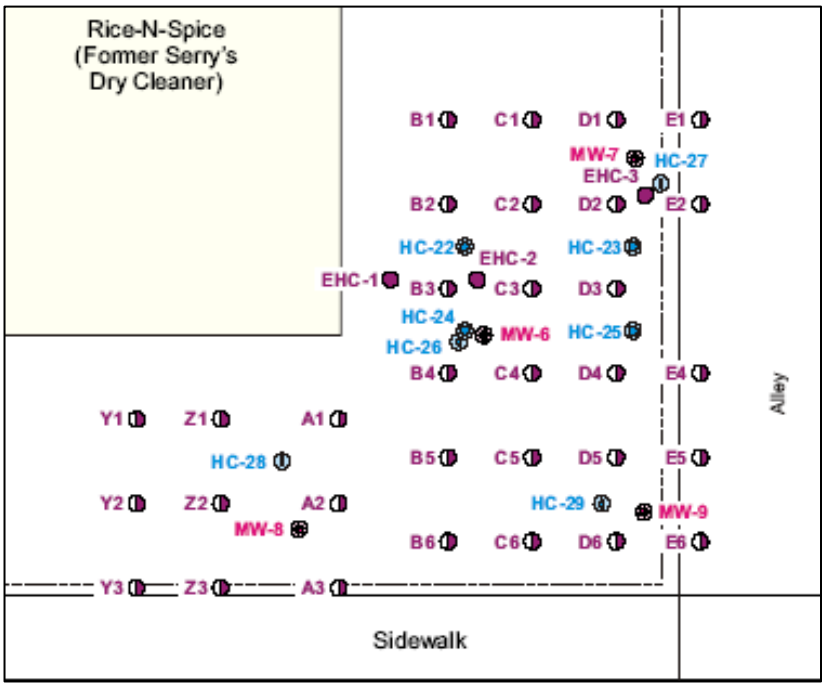
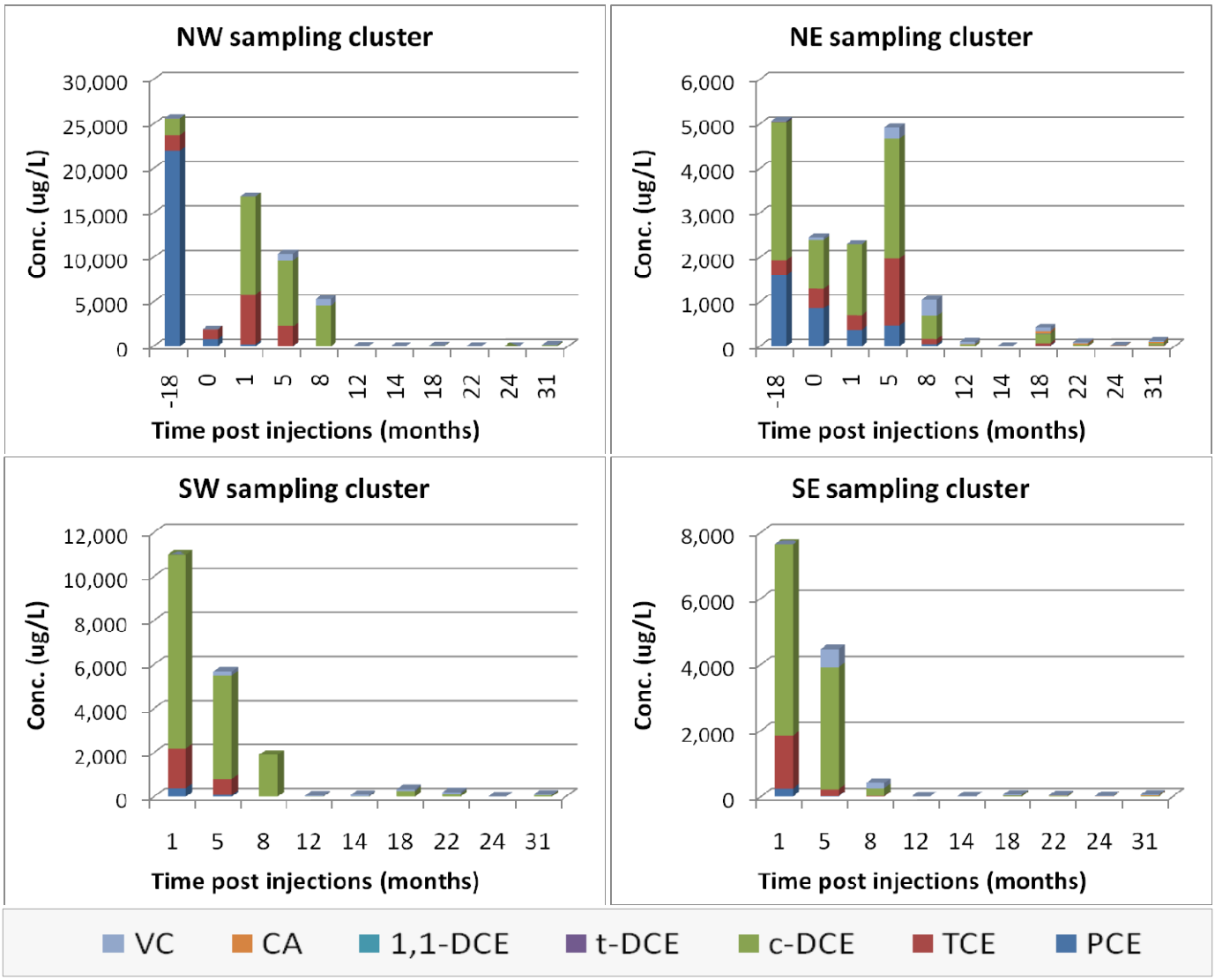


Figure 7: EHC injection locations, groundwater sampling locations, and monitoring wells.

Figure 7 also shows the locations of four new monitoring wells (MW-6 to MW-9) installed in January 2007. Previous monitoring performed in February 2005 and August and September 2006 was conducted via direct push probe exploration locations (HC-22 to HC-29).

The Result

Following injection of EHC into the suspected source area, PCE was decreased to below the detection limit of 1 ug/L and total CVOCs decreased from a maximum of 25,606 ug/L to below 100 ug/L at all locations within 12 months (**Figure 8**). The PCE degradation resulted in an initial build-up of TCE, DCE (primarily cis-DCE) and VC, indicating that sequential dehalogenation was occurring (biological pathway). However, conversion rates were less than Stoichiometric and concentrations of all constituents appeared to decrease simultaneously, suggesting that abiotic treatment mechanisms also occurred at significant rates. Observed generation of VC was limited, indicating that abiotic beta-elimination was a primary pathway for cis-DCE degradation. A smaller concentration of chloroethane (CA) was also observed (maximum concentration of 44 ug/L measured in February 2008 – 18-month data), suggesting that hydrogenation of VC might be occurring.



Note: The data from Feb 2005, Aug 2006, and Sep 2006 was obtained via direct push probe exploration locations. Subsequent monitoring was conducted via groundwater monitoring wells installed close to each of the previous direct push sampling clusters.

Figure 8: Influence of EHC injections on PCE and daughter products in groundwater.

Historically, CVOC concentrations in groundwater fluctuate heavily with the seasons in the study area. **Figure 9** shows the groundwater elevation and total CVOCs concentrations measured since the well installations. Transient rebound was observed during the rainy season (18-month data), presumably due to the introduction of CVOCs from the smear zone as a result of a 6 to 7 ft (1.8 to 2.1 m) increase in the groundwater table. While the groundwater table remained high through June 2008 (22-month data), total CVOC concentrations decreased, suggesting continued treatment via resident, active EHC. By August 2008 (dry season), PCE and TCE both decreased to below the detection limit of 1 ppb at all locations. The rebound observed during the following wet season (March 2009) was much smaller than the previous year, suggesting that treatment of the smear zone is being achieved as desorption is promoted.

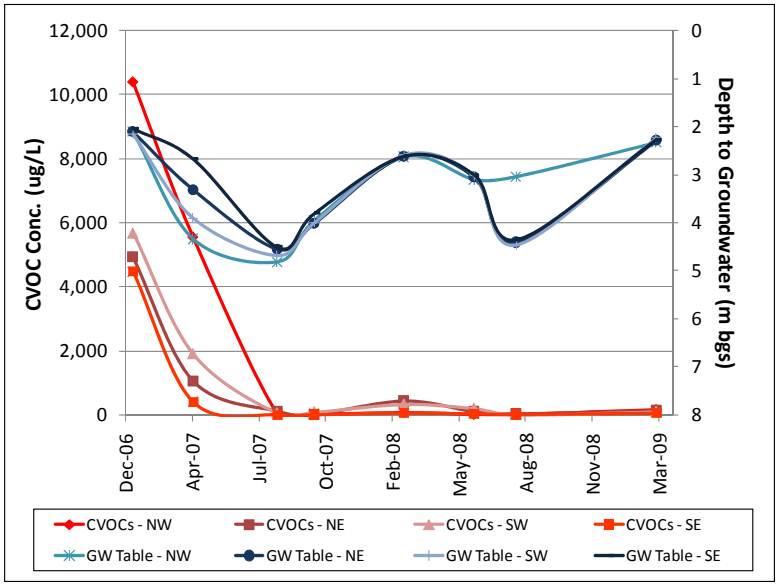


Figure 9: Total CVOCs and depth to groundwater.

Degradation end products. An increase in ethene and ethane levels confirms that complete degradation is occurring (Figure 10); ethene levels of up to 760 ug/L were measured in July 2007 (11-month data) which constitutes an increase of 96% compared with the maximum concentrations measured in August 2006. As total dissolved concentrations of chlorinated ethenes decreased within the treatment zone, the concentration of dissolved gases has also decreased. However, concentrations of ethane remain above baseline levels, suggesting that a smaller concentration of sorbed CVOCs remain and that degradation is still ongoing. A spike in ethane concentrations were observed at the NE and SW monitoring wells during the rainy season (18-month data), as CVOCs sorbed to the smear zone entered the system and became available for degradation.

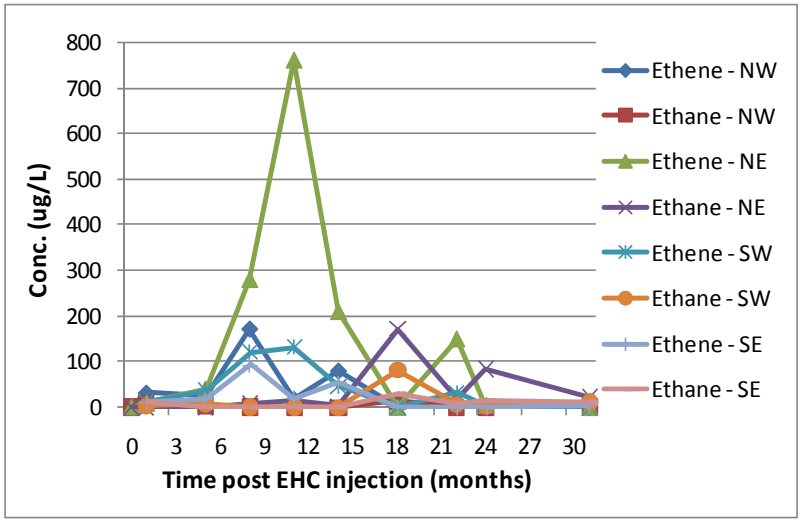


Figure 10: Degradation end products.

EHC indicator parameters. To assess whether the wells are in fact under the EHC zone of influence, the groundwater was sampled for total organic carbon (TOC) and ferrous iron (Fe(II)). A significant increase was observed at all sampling locations, confirming that successful product placement and sufficient distribution had been achieved. TOC and Fe(II) has been measured at a maximum concentration of 2,800 and 130 mg/L respectively.

Redox indicator parameters: Following the EHC injections, the oxidation-reduction potential (ORP) decreased within the injection zone. Sulfate concentrations decreased from a baseline concentration of 7 to 34 mg/L to below the detection limit of 0.1 mg/L, suggesting that sulfate reducing conditions was established within the injection zone. Furthermore, an increase in methane suggests methanogenic conditions and an excess amount of dissolved carbon. As dissolved carbon concentrations declined over time, ORP has increased. However, methane levels remain high, suggesting that reducing conditions are maintained within the treatment zone.

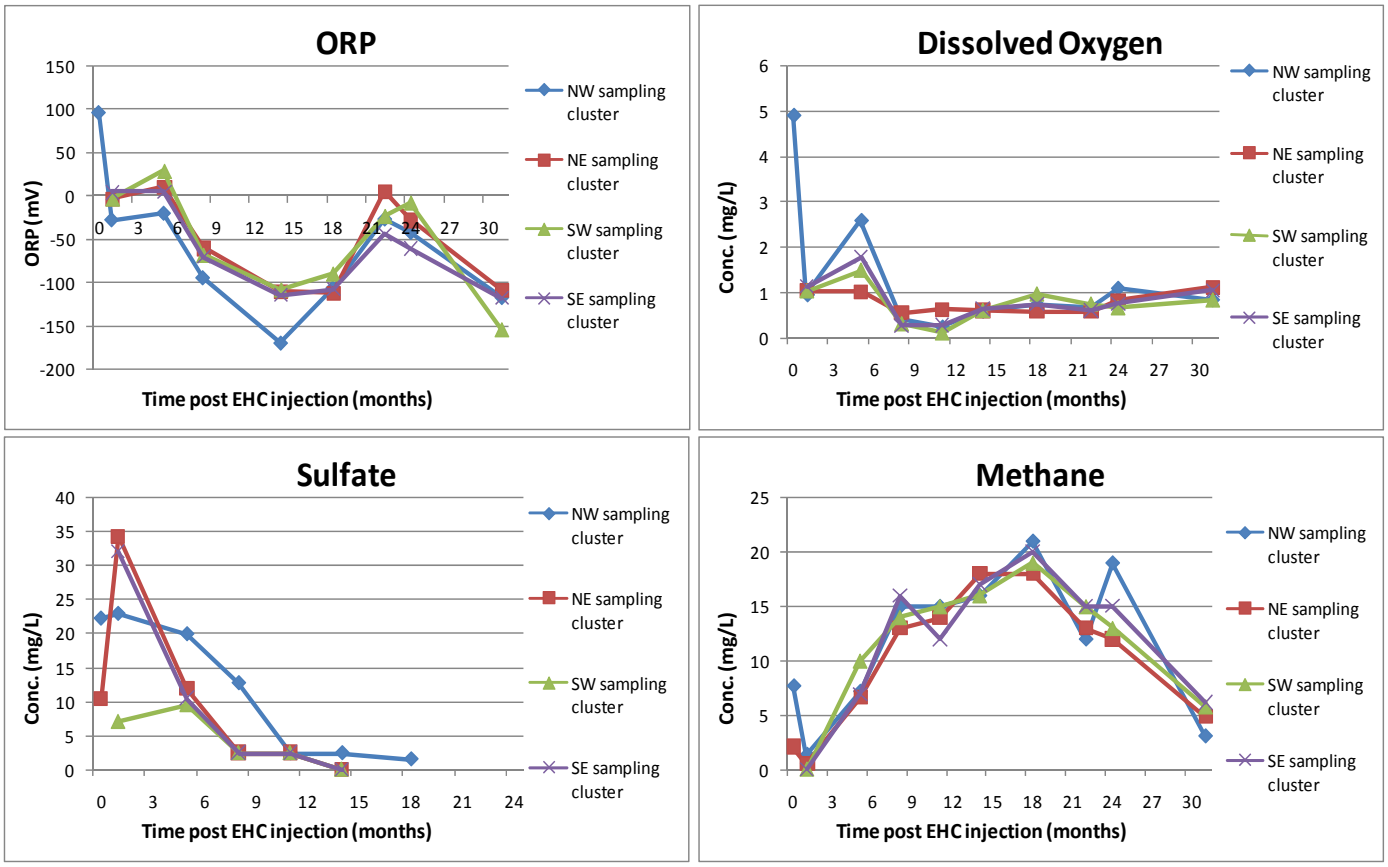


Figure 11: EHC effect on redox indicator parameters measured within treatment area.

The Cost

The material cost of using EHC was \$1.24/ft^3 (\$44/m^3). The injections were completed in 5 days. Results of this pilot study have shown that ISCR using the EHC technology offers a safe, effective and cost-efficient remedial solution for dry cleaning and related sites.

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