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## Chapter 18

### REMOVAL OF PERCHLOROETHYLENE WITHIN A SILT CONFINING LAYER USING HYDROGEN RELEASE COMPOUND

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#### ABSTRACT

The Site is a former dry cleaning operation where a release of perchloroethylene (PCE) to soil and groundwater had occurred. Hydrogen Release Compound® (HRC) is being used for source control to mitigate vapor intrusion to the existing building. The Site is located in the Connecticut River basin with PCE up to 250 mg/L in perched groundwater above a silt-layer aquitard. Site risk is driven by the soil vapor intrusion pathway into the commercial building. Soil vapor extraction was implemented to mitigate vapor intrusion, with no appreciable change in the perched groundwater conditions and rapid rebound of PCE in soil gas to pre-treatment levels in four months. Our evaluation of soil data following multiple HRC applications over an 8-year period into the perched groundwater on top of a Connecticut River basin silt deposit finds that treatment in the sandy unit above the aquitard achieved significant reduction of PCE in the silt layer below. This discovery changed the project Conceptual Site Model and led to further evaluation of the source of PCE feeding into soil gas. With decreased groundwater concentrations of PCE but persistent soil gas concentrations, Membrane Interface Probe (MIP) work was done to further assess the extent of additional area within the perched groundwater that required treatment. The results indicated that the extent of significant concentrations of PCE was in a peripheral area around the initial treatment zones. Following the MIP results, additional in-situ HRC treatment in the perched aquifer over a broader area than previous injections was implemented with the intent of removing a significant mass of PCE. As we expected, there was a PCE source in the silt layer below the

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treatment area. Subsequent data show further decreases in PCE concentrations measured in perched groundwater and soil gas.

Keywords: vapor intrusion, soil, silt, aquitard, perchloroethylene, PCE, tetrachloroethylene, Hydrogen Release Compound®, HRC, in-situ, Membrane Interface Probe, MIP.

## **1. INTRODUCTION**

The Site is the former location of a dry cleaning establishment that operated at the property from about 1958 to 1965. A release to soil and groundwater involving tetrachloroethylene (a.k.a. perchloroethylene or PCE) was discovered in 1989. The Site has since been subject to ongoing assessment, and implementation of a remedy involving soil vapor extraction (SVE) of soil gas that began in 1997. Additional remedial actions include excavation and off-Site disposal of approximately 45 tons of impacted soil and installation of a vapor-barrier membrane that was applied to the ground prior to installation of the concrete slab during reconstruction activities. Application of a liquid-based vapor sealant that utilized a reactive catalyst resulted in the formation of a pliable membrane that was able to seal utility penetrations into the building. The use of this technology allowed for the mitigation of the primary sources of subsurface vapor intrusion to buildings, cracks in the floor and utility penetrations.

The Connecticut River is located approximately 400 feet east of the Site, flowing in a southeast direction in the vicinity of the Site. It is not used as a drinking water resource. The Site has a perched layer of groundwater in a sand matrix over an aquitard of silt and clay. HRC was effective in reducing PCE concentrations in this layer. However, although the original spill strongly impacted this perched layer of groundwater, Membrane Interface Probe (MIP) results confirm that higher concentrations of PCE are directly on top of and within the silt layer in the area around the initial treatment zone. This new discovery was the cause of small quantities of PCE continually coming up from this reserve by diffusion. Although the PCE passes through the groundwater to reach soil gas, the significant pathway for possible risk posed to humans is through the soil gas rather than in the groundwater because there is no consumption or use of groundwater at the Site. Operating the SVE system controls the PCE in the soil gas and is still necessary, but does little to change the diffusion of PCE from the silt layer. Past injections of HRC have been completed in the perched groundwater zone and have been effective in reducing groundwater concentrations. HRC also appears to have decreased concentrations in the underlying silt layer even though injections were made at a shallower depth.

Additional contaminant mass reduction is expected with injection of more HRC over a larger area, resulting in source control in the periphery.

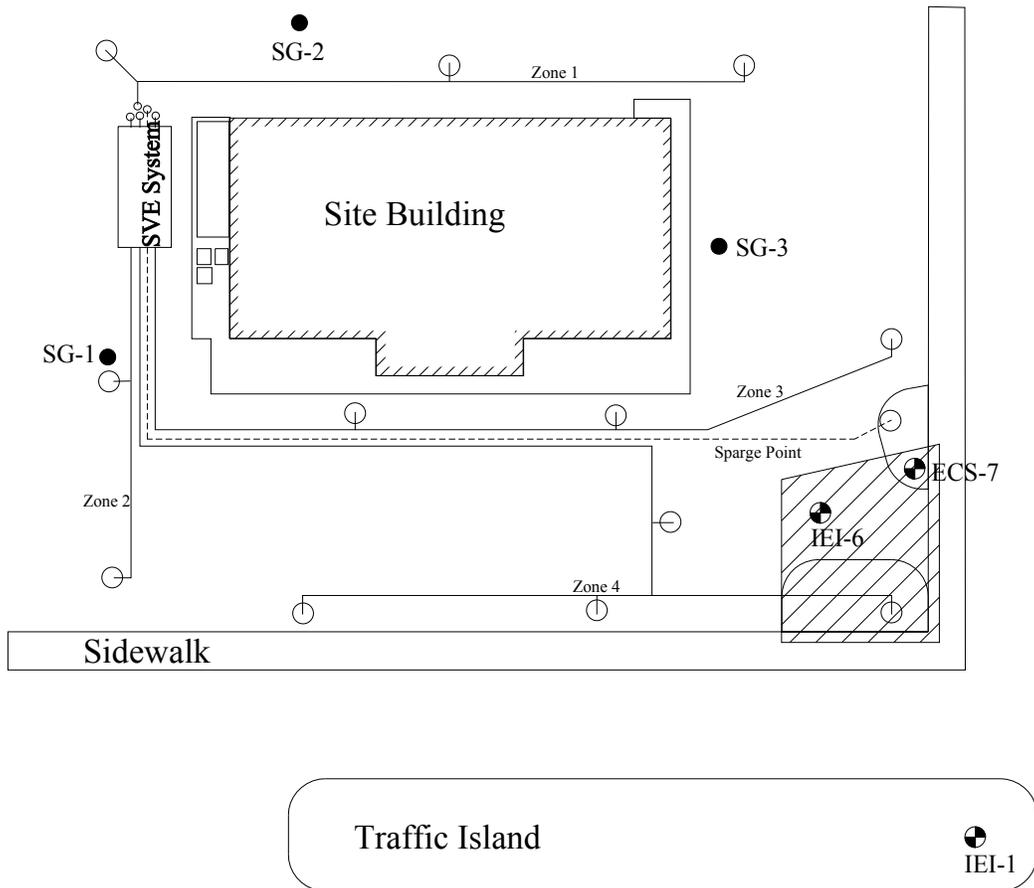


Figure 1. Site Map showing soil gas sample locations, groundwater monitoring wells, soil borings, and SVE System components. The area of the two initial HRC applications is illustrated by the hatched box.

## 2. MATERIALS AND METHODS

### 2.1 Hydrogen Release Compound<sup>®</sup> Application

Injection of over 2,000 pounds of Hydrogen Release Compound<sup>®</sup> (HRC) was conducted on three occasions over an 8-year period at 60 locations in an area

covering approximately 3,000 square feet. HRC was heated for lower viscosity and pumped through a grout pump for injection to target locations. The HRC was injected into the subsurface using four direct-push Geoprobe<sup>®</sup> units working simultaneously.

Hollow stainless steel rods were advanced to a depth of 15 feet below ground surface (bgs), which penetrated the surface of the silt layer underlying the Site. The HRC was applied through the end of the probe tip while the rod was retracted to a final depth of 5 feet bgs. Thirty pounds of HRC was applied at each location over a vertical profile of 10 linear feet.

## **2.2 Membrane Interface Probe**

The Membrane Interface Probe (MIP) is a technology we used to address the question of PCE distribution in the subsurface. It provided relative contaminant concentrations with near continuous vertical resolution. Its high productivity also had an effect on horizontal resolution, in that it allowed for more assessment locations than could be obtained by traditional soil sampling.

In conducting MIP work, a heated probe was driven into the ground with a direct-push Geoprobe<sup>®</sup> unit. The probe has a resistive heating element to vaporize volatile compounds coupled with a membrane. Contaminant vapors diffuse through the membrane and enter a sweep gas stream which carries them to the surface where they are fed to an electron capture detector (ECD) and a photoionization detector (PID). At low concentrations the ECD has good response to chlorinated compounds (e.g. PCE), and the PID identifies organics in general. In this case, PCE concentrations tended to exceed the scale of the ECD, so the PID data was more useful for identifying the locations with the highest PCE concentrations.

Finally, the gas stream can be analyzed using a gas chromatograph (GC). A solid phase extraction needle captures contaminants from the stream and can be injected into a GC. The GC analysis provides accurate relative concentrations of different contaminants, but is not very accurate when total concentrations are compared to groundwater samples analyzed in the laboratory. For this reason, the data collected is not useful for risk characterization. The data is more suited to characterization of subsurface conditions.

The probe also had a conductivity sensor which gives some vague indication as to the presence of water and hydraulic conductivity on a near continuous vertical profile. These three parameters (contaminant concentration, groundwater, and hydraulic conductivity) are each shown on the same page for a given assessment location.

### 3. RESULTS AND DISCUSSION

Following two HRC applications into the perched groundwater table (less than 15 feet bgs), decreases in PCE concentrations in groundwater were observed. However, PCE concentrations in soil gas reached equilibrium to pre-treatment levels. This supported our conceptual site model that PCE from this region was diffusing up through the perched groundwater, causing the soil gas levels that were observed during SVE system shutdown periods. The MIP data also indicate that the PCE impact area may have been larger than the HRC application zones.

Membrane Interface Probe work to determine the spatial distribution of chlorinated compounds identified PCE in the silt layer below 15' bgs and above 30' bgs. An important finding was that the treatment of the shallow zone penetrated the silt confining silt layer.

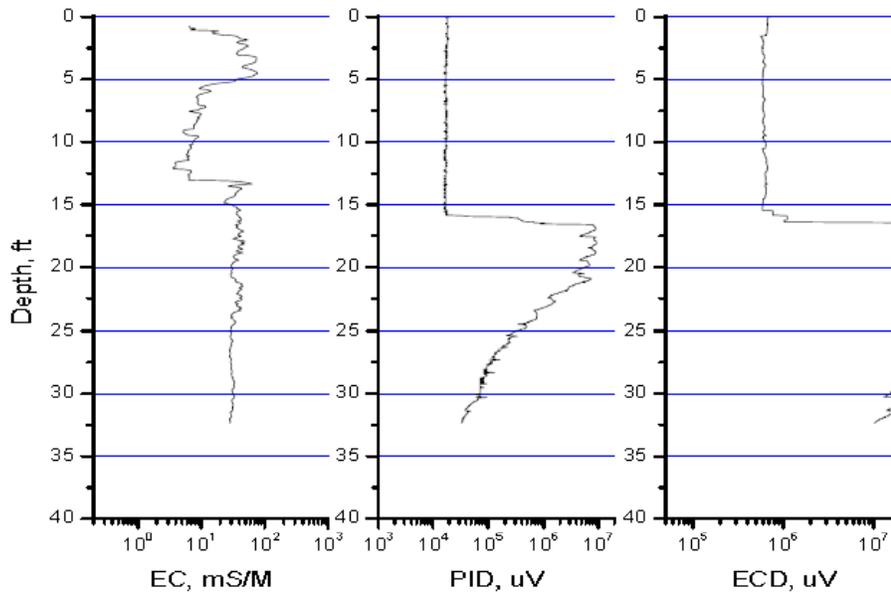


Figure 2. MIP results at IEI-103 assessment location (see Figure 4). The graphical representation illustrates increased PCE concentrations in the silt layer at approximately 15 feet below ground surface.

The data from nine MIP assessment locations were used to create a cross-section of the release area to illustrate the profile of PCE in the subsurface.

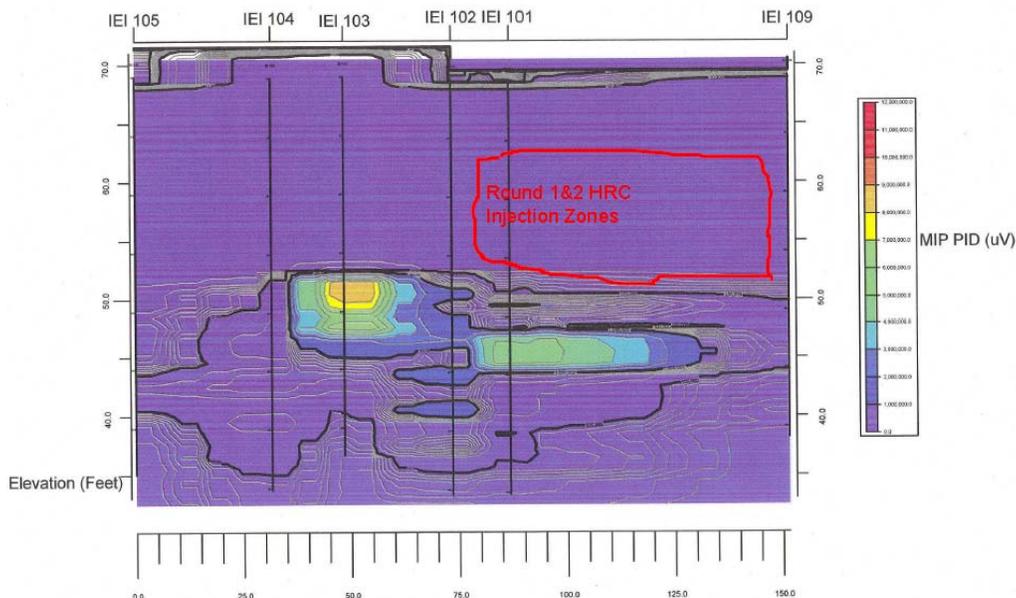


Figure 3. Cross-section of MIP results illustrating the treatment of PCE in the silt layer following an HRC application to the perched aquifer. The MIP data identify an area of higher PCE concentrations in the silt layer outside of the initial application areas.

Our evaluation of data following the second HRC injection indicated that decreasing PCE concentrations were measured in both soil gas and perched groundwater in the HRC application area compared to results collected prior to the first HRC injection. The ratio of TCE and DCE (PCE break-down products) to the amount of PCE in the source area increased following the second HRC application suggesting degradation, but subsequently dropped off suggesting that the HRC had been expended. Also, field screening of shallow monitoring wells in the source area for dissolved oxygen (DO), oxygen reduction potential (ORP), sulfate, and nitrate indicate that the HRC injected was likely expended. Groundwater results indicate that the HRC remedy was generally successful at reducing groundwater concentrations of PCE in the application area.

The results indicate that PCE is present in the silt layer and the extent of significant concentrations of PCE in the silt layer is broader in area than the initial HRC injection zone. IEI-101 and IEI-102 are the MIP points in the HRC injection area. We note the results in IEI-103 and IEI-108 were higher than in IEI-101 and IEI-102. Although a MIP baseline was not conducted before the HRC injection, we suspect that prior to HRC treatment, these concentrations would have been reversed, and that HRC injection into the perched groundwater caused PCE removal in the top part of the silt layer around IEI-101 and IEI-102.

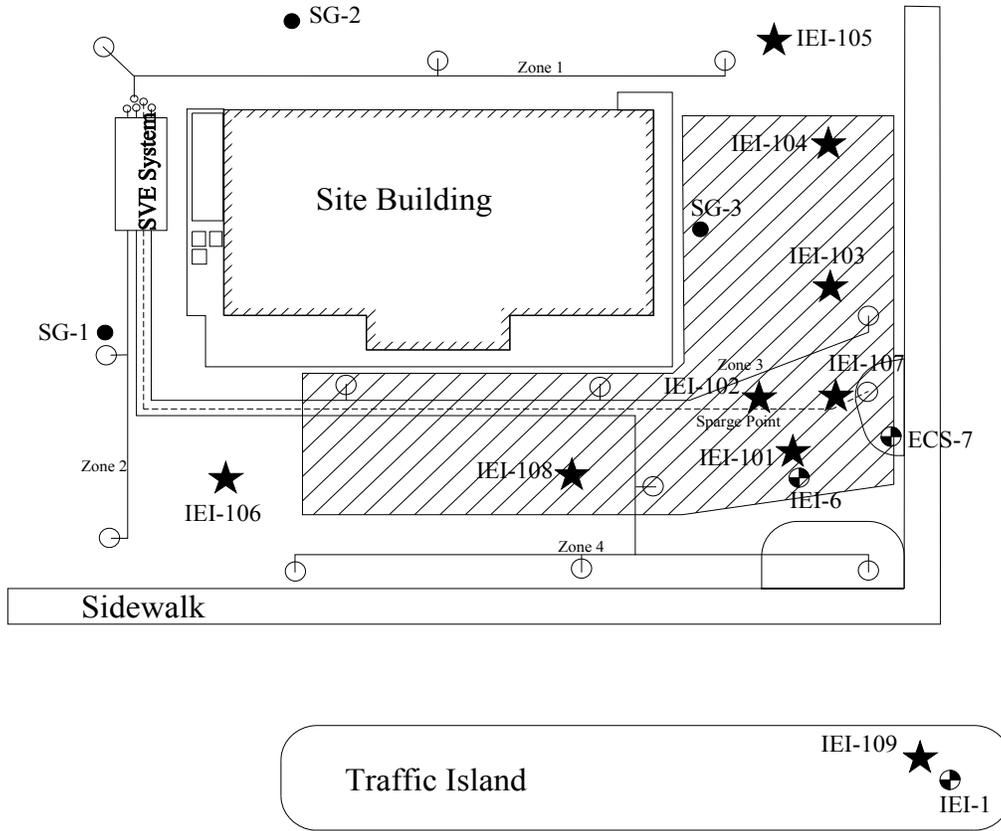


Figure 4. MIP assessment locations (star symbols) and HRC application zone (hatched area).

Table 1. PCE concentrations (milligrams per liter) in groundwater prior to 2007 full-scale HRC application (“Max PCE Since 2001”) compared to current PCE concentrations (“Post-HRC”).

Monitoring Well	Max PCE Since 2001	Post-HRC
IEI-1	41.8	17
IEI-6	22.4	1.8
ECS-7	40.6	0.03

Table 2. PCE concentrations (parts per billion by volume) in Soil Gas prior to 2007 full-scale HRC application (“Max PCE Since 2003”) compared to current PCE concentrations (“Post-HRC”).

Soil Gas Sample Port	Max PCE Since 2003	Post-HRC
SG-1	320	1.2
SG-2	380	11
SG-3	2,000	59

Operating the SVE system controls PCE in the soil gas and is still necessary, but does little to change the diffusion of PCE from the silt layer. Monitoring of environmental media is ongoing and additional contaminant mass reduction is expected following the recent application of HRC over a larger area.

#### 4. CONCLUSION

Vapor intrusion was controlled by installation of a passive vapor barrier under the on-Site building and operation of a soil vapor extraction (SVE) system. Application of HRC to the subsurface was done to treat the source of the contamination, with the goal of turning off the SVE system. Following two HRC applications into the perched groundwater table (less than 15 feet bgs), decreases in PCE concentrations in groundwater were observed. However, PCE concentrations in soil gas rapidly reached equilibrium to pre-treatment levels. The MIP data indicated that the PCE impact area may have been larger than the HRC application zones. Another important finding was that the treatment of the shallow zone penetrated the silt confining silt layer. Traditional assessment using monitoring wells would not have offered this level of assessment, illustrating that MIP technology is a useful and cost effective tool.

Our evaluation of data following a subsequent HRC injection indicated that decreasing PCE concentrations were measured in both soil gas and perched groundwater in the HRC application area compared to results collected prior to the first HRC injection. The ratio of TCE and DCE (PCE break-down products) to the amount of PCE in the source area increased following the second HRC application suggesting degradation, but subsequently dropped off suggesting that the HRC had been expended.

Further analysis of the MIP results indicated that PCE was present in the silt layer and the extent of significant concentrations of PCE in the silt layer is broader in area than the initial HRC injection zone. This information was used to

design a Site-wide in-situ remediation to address PCE both vertically and laterally in the subsurface. Of particular interest was the ability of HRC to treat PCE in the confining silt layer when it was applied into the overlying perched aquifer. PCE in soil gas will be monitored to evaluate the impact of the remedy on the source area. We expect there would be no need for an active SVE system if there is a slow rebound in soil gas, as the passive vapor membrane would mitigate vapor intrusion to the building.