



Enhanced In-Situ Bioremediation of VOCs in a Low Permeability Source Area

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Abstract

A full-scale in-situ bioremediation application at a trichloroethene (TCE)-contaminated source area was implemented at a former manufacturing facility in Livermore, California in August 2003. Onsite ground water contains TCE, 1,1,1-trichloroethane (1,1,1-TCA), xylenes, and Freon 113. The impacted area consists primarily of low permeability silty clay with a very low estimated seepage velocity of approximately 9 feet per year. Partial dechlorination of TCE was observed in portions of the plume in which TCE and Xylenes were co-mingled, resulting in high persisting concentrations of cis-1,2 dichloroethene (cis-1,2-DCE) and vinyl chloride (VC). HRC® was injected using direct-push technology into the A (uppermost)-zone on a closely spaced grid to stimulate complete dechlorination. Twelve months after HRC® injection, 99% volatile organic compound (VOC) concentration reductions were achieved in the center of the former source area. However, no significant reductions in VOC concentrations were observed in the fringes of the plume. Additional HRC® was re-injected in limited areas of the source zone and the HRC® injections were expanded into the Site's B-Zone in October 2005. The injections are followed by performance monitoring, which is expected to last one year.

➤ Significant progress towards cleanup has been made at the Site, particularly since the 2000 source area excavation. The next steps at the Site are to negotiate closure goals with local and state regulators and apply for Site closure.

Site Hydrogeology & Geology

Characterized by A- and B-zones with discontinuous A/B aquitard.

A-Zone:

- Alluvial sediments, low permeability (5 – 25 ft bgs)
- Hydraulic conductivity = 4.5×10^{-4} cm/sec
- Horizontal gradient = 0.004 ft/ft
- Average ground water velocity = 9 ft/yr
- TCE concentrations = 25 – 310 µg/L (March 2003)
- Total VOC concentrations = 43 – 3,000 µg/L (March 2003)

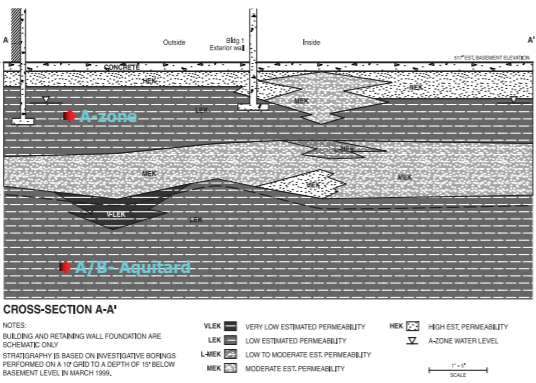


Figure 2. Cross-Section of the Source Area showing A-zone and A/B aquitard only.

Site History

- 1972-1976: Solvents containing TCE, Xylenes, Freon 113, and TCA entered subsurface through cracks in a sump (Figure 1).
- 1982: Site investigation identifies two VOC contaminated water-bearing zones: A- and B-zones.
- 1983: Limited source removal (excavation; Figure 1).
- 1986-2000: Pump and treat system no longer effective after removing 38 lbs of VOCs and 25 million gallons of ground water.
- 2000: Bench-scale testing of reductive dechlorination and source area excavation of all accessible contaminated soil (328 cubic yards)
- 2003: Injection of 1,500 lbs of HRC® into A- zone.
- 2005: Additional 600 lbs of HRC® injected into the A- zone and B-zone.

B-Zone:

- Alluvial sediments, moderate permeability (35 – 50 ft bgs)
- Hydraulic conductivity = 4.7×10^{-3} cm/sec
- Horizontal gradient = 0.005 ft/ft
- Average ground water velocity = 122 ft/yr
- TCE concentrations = 8 – 54 µg/L (March 2003)
- Total VOC concentrations = 16 – 227 µg/L (March 2003)

Remedial Design

Phase I HRC Injections (August 2003):

- Injection of 1,500 lbs of HRC® at 4 lbs/ft in the injection interval
- 41 Direct-push injections (bottom-up) into A-zone
- Injection points located on a 10-ft by 10-ft grid
- Injection area approximately 65 ft by 70 ft

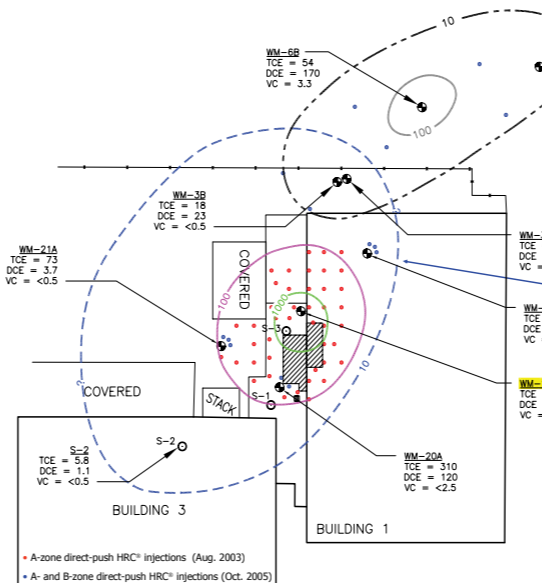
Phase II HRC Injections (October 2005):

- Injection of 600 lbs of HRC® at 4 lbs/ft in the injection interval
- 14 Direct-push injections (bottom-up):
 - 8 Injection points in A-zone
 - 6 Injection points in B-zone

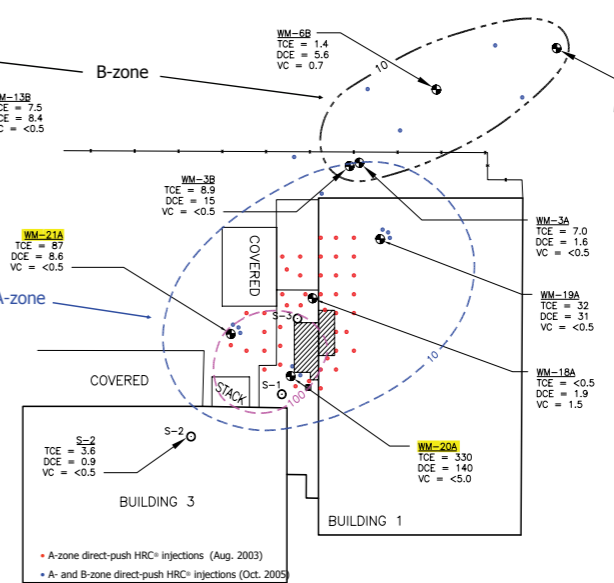
➤ Site-access limitations were a challenge during implementation



VOC Concentrations (µg/L) prior to HRC Injections



VOC Concentrations (µg/L) after HRC Injections



Results

Source Zone (Well-18A):

- Reductive dechlorination already occurring prior to HRC® injection.
- 99% VOC reduction after 1 year of HRC® injections.

Conclusions

A-Zone Plume

After 2003 injections:

- Presence of nitrate & sulfate and absence of volatile fatty acids (VFAs) indicate that necessary redox conditions for complete TCE dechlorination were not created.

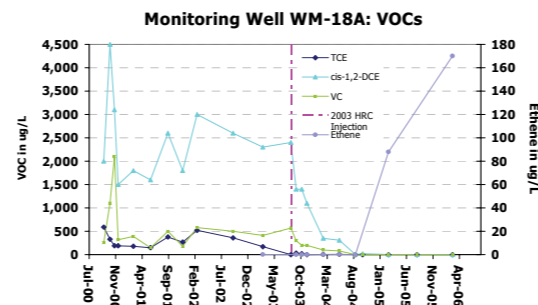
After 2005 injections:

- Significant dechlorination not yet observed despite HRC® injection in close proximity to monitoring wells.
- Given low ground water velocities more time maybe needed to observe positive effects of HRC® in A-zone wells.
- In-Situ remediation of low permeability sediments limited by diffusion-controlled fluid movements.
- Co-location with existing hydrocarbon contamination important in areas where HRC® successfully reduced VOCs.

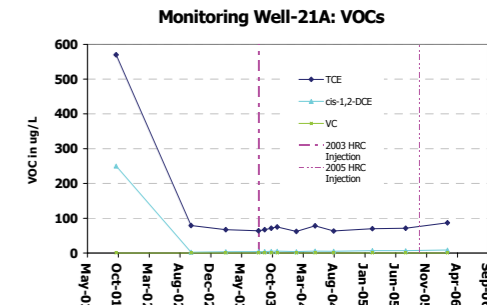
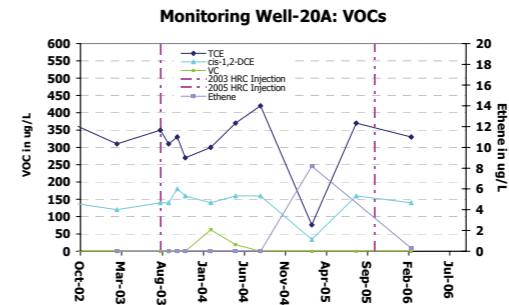
B-Zone Plume

- Reductive dechlorination effective in well WM-6B.

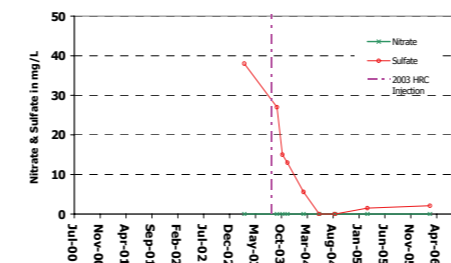
Dechlorination readily observed in Well 18A ...



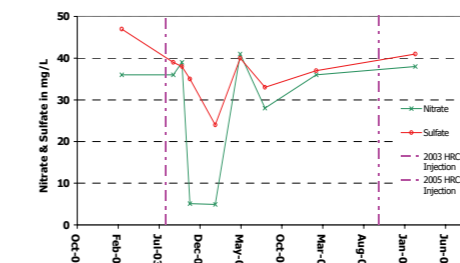
... but significant dechlorination not yet observed in Wells 20A and 21A, despite HRC® injection in immediate vicinity



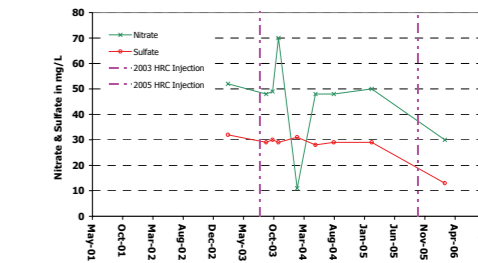
Well-18A: Nitrate & Sulfate



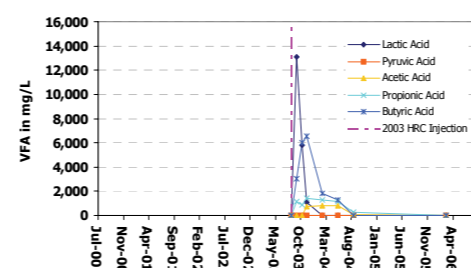
Well-20A: Nitrate & Sulfate



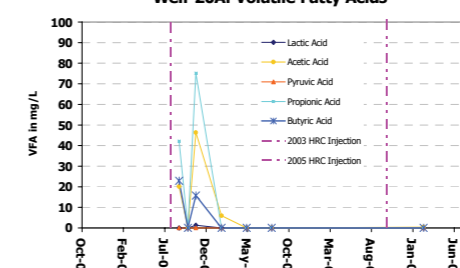
Well-21A: Nitrate & Sulfate



Well-18A: Volatile Fatty Acids



Well-20A: Volatile Fatty Acids



Well-21A: Volatile Fatty Acids

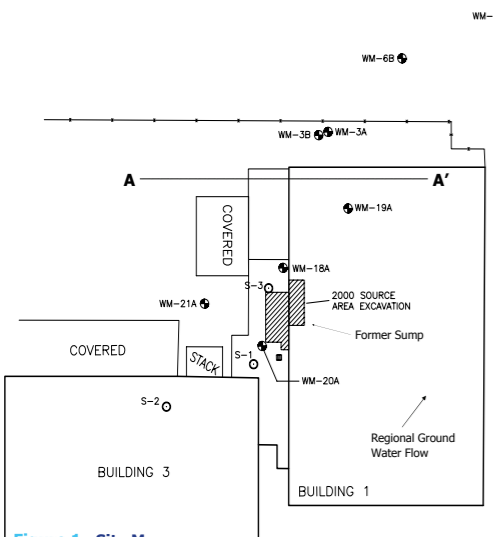
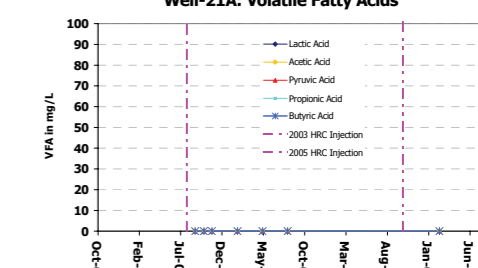


Figure 1. Site Map