

Things You Wished you Knew When Planning an In-Situ Injection Project

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INTRODUCTION

This poster provides an overview of some issues that occasionally ruin someone's day when they find out about them in the field during remedial action. An overview of some relevant factors in each of these potentially troubling in-situ injection scenarios is presented:

1. **Transient observation of catabolites** related to the injection that you may run across (e.g., acetone, carbon disulfide and MEK)
2. **Metals mobilization**
3. **Concentration spikes after injection** – an exploration of some possible factors.
4. **Daylighting/short-circuiting** (injectate surfacing) – thoughts on how to manage or eliminate it.

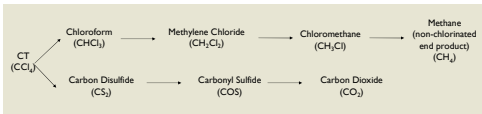
Transient Catabolites - Carbon Disulfide

We observed carbon disulfide (CS₂) at a reductive dechlorination site in Kansas using our EHC product. A peak concentration of 79 µg/L was observed when treating a Carbon Tetrachloride (CT) plume with concentrations in excess of 2 mg/L.

CS₂ concentrations quickly tapered off following its discovery at the site a few months after injections, and have remained below criteria (generally not detected) for over two years.

CS₂ has been shown to form in some cases during reductive dechlorination of carbon tetrachloride during the sulfate reduction phase (Devlin and Muller, 1999).

Conclusion: Consider monitoring for CS₂ at your CT site if tracking this transient compound is of interest.



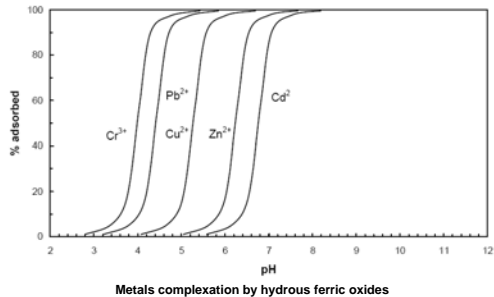
Metals "Mobilization"

Reductive anaerobic dechlorination is effective in reducing chlorinated solvent concentrations in groundwater, but may result in a release of metals bound within iron oxides, manganese oxides or other clay minerals in the aquifer material. This process may occur via reductive dissolution or desorption from those mineral phases, as a result of changes to pH and redox potentials. Examples of such metals include As, Se, Fe, and Mn (AFCEE, 2004).

Our EHC product maintains a near-neutral pH, as the acidity of carbon substrate degradation is offset by the alkalinity resulting from zero-valent iron (ZVI) corrosion. This minimizes some of the metals dissolution effects relative to carbon-only substrates. One mechanism for such metals to be sequestered through the use of EHC is the complexation of the cations with hydrous ferric oxides (HFOs). The figure below shows some sorption rates for various metals on HFOs. Naturally, the presence of ZVI in EHC enables this mechanism through a continuous generation of iron oxides and oxyhydroxides from the corrosion of ZVI particles.

For even better performance and, in fact, treatment of metals, our EHC-M product includes the use of sulfur and other compounds to enhance metals precipitation and long-term immobilization.

Conclusion: Evaluate soil chemistry and groundwater geochemistry, track field parameters.



Transient Catabolites - Acetone and MEK

Soil microorganisms can produce MEK (i.e. 2-butanone). Acetone has been observed to be produced in samples under standard preservation techniques. This Navy link provides good evidence and references (<http://www.navylabs.navy.mil/Archive/afmda-2005/2-3-1.pdf>). Field data showing occasional transient presence of acetone and/or MEK seem to occur when alkanes are present, along with high organic carbon, methanogens, and sub-oxic environments. We assume that we get MEK production before the system goes fully anoxic, right after we inject the reductive dechlorinating agent, generally EHC.

Conclusion: Consider monitoring for MEK and acetone at your CT site if tracking these transient compound is of interest.

Concentration Spikes after Injection

Concentration spikes following injection can result from a number of sources. The figure below shows one of our EHC sites, where seasonal groundwater table fluctuations result in flushing of compounds from the unsaturated site soils. Other factors that can result in concentration changes include:

Dissolution of residual NAPL, if present, can cause concentration spikes.

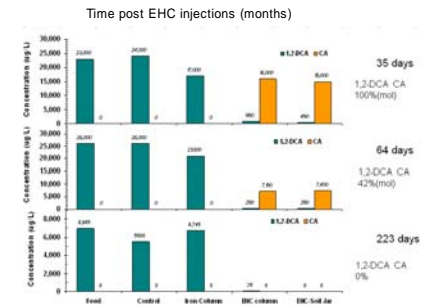
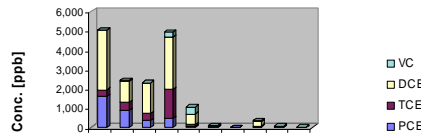
Pore volume (PV) displacement for some amendments – Depending on injectate volume and aquifer porosity, water table increases may occur during injection, flushing compounds from unsaturated soils. This may also cause artificial concentrations drops if plume displacement is occurring. We have not seen water table increases with EHC, as we typically displace 2 to 10% of PV.

Changes in geochemistry – Metals concentrations may change with changes in groundwater pH and ORP. This is highly dependant on aquifer geochemistry and the injectate used. EHC, for instance maintains relatively neutral pH with alkalinity from ZVI corrosion offsetting volatile fatty acid formation.

Compound degradation chemistry – Increases in daughter products of many organic compounds can be observed immediately following an injection before low redox conditions are established. Adventus EHC is especially good at taking these reactions to completion after low redox conditions are established, as shown in the figures below (second figure shows complete destruction of 1,2-DCA with no production of daughters at 223 days).

Conclusion: Residual NAPL, injection volumes v. pore space, geochemistry changes, and degradation chemistry are important items to consider. Do some homework before you select an amendment.

NE Corner Sampling Cluster



Daylighting and Short-Circuiting

Daylighting is the surfacing of injectate – when the path of least resistance is for material to come to upwards to the surface. We've found the following to be helpful in minimizing potential daylighting:

Minimize injected volume – with EHC, typical source area injection volumes of 2 to 10% of PV are used. In some PRB (non-source area) installations, a maximum of 20% of PV is displaced. Many other injectates require significantly more PV displacement.

Reduce pressure and flow-rate – site-specific, but the lowest pressure for a sustainable low-flow rate (< 10 gpm) seems generally best.

Ideal borehole abandonment – slurry grouts won't do, unless time is allowed for set-up. Best is some form of bentonite pellets, such as HoleBlok®. If historical boreholes were not properly abandoned, you'll likely find them during the injection process.

Ideal viscosity – field experience shows that a rather thick slurry (~29 wt%) is generally optimum for injecting EHC and similar slurries. Again, site-specific results may vary.

Bottom-up injection protocol – The Geoprobe injection tooling used in bottom-up fashion generally works well for optimum distribution of EHC or other slurries. Again, site-specific results may vary.

Allow pressure dissipation – Use of multiple rods and moving around the injection grid help to enable localized subsurface pressures to dissipate.

Conclusion: Use an injection contractor experienced with and/or prepared to work over a range of pressures, flow-rates, and installation approaches. It's best to plan for a flexible implementation and to start with what works best for most sites.



REFERENCES

- AFCEE, 2004. Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents
- Devlin J.F. and Muller, D., Field and Laboratory Studies of Carbon Tetrachloride Transformation in a Sandy Aquifer under Sulfate Reducing Conditions, in Environmental Science and Technology, 1999, v. 33, p 1021-1027.
- Dzombak, D.A. and Morel, F.M.M., 1990. Surface Complexation Modeling: Hydrous Ferric Oxide. New York: Wiley Science