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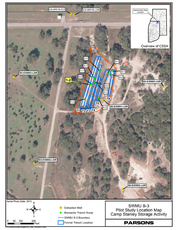
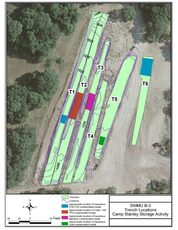
Observations following 10 years of Bioreactor Operations in a South-Central Texas Fractured Bedrock Aquifer

Background & Design

Site Description/Background

Camp Stanley Storage Activity (CSSA) is a U.S. Army post located in South Central Texas. The primary groundwater source is the Middle Trinity Aquifer consisting of the Glen Rose formation and deeper Cow Creek formation. Soil cover is minimal with an underlying fractured, limestone groundwater source with some karst development. In the early 1990's, a chlorinated solvent plume containing Tetrachloroethene (PCE) and its degradation products was discovered in an old landfill area later designated Solid Waste Management Unit B-3. The trenches in the landfill range in depth from 5-15 feet and are approximately 350 400 feet long and 12 feet wide. In 2007, an in situ pilot scale bioreactor was installed to begin remediation on contaminated groundwater by first removing waste in the trenches and then backfilling with a gravel/mulch substrate. To stimulate biodegradation, a conveyance and distribution system was constructed within the backfilled trenches and twelve monitoring sumps were installed.



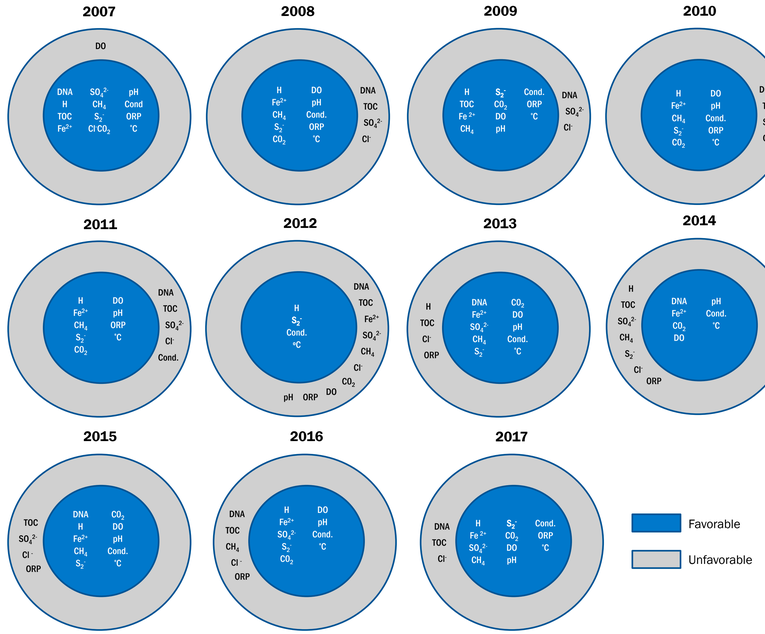


Objectives

- Utilize long-term data sets to evaluate success of the bioreactor treatment system over a 10-year period (2007-2017)
- Examine performance parameter expectations to help determine the overall effectiveness of the bioreactor system in achieving remedial objectives and operational endpoints
- Determine if current monitoring protocol should be revised to include data specific to multiple degradation mechanisms

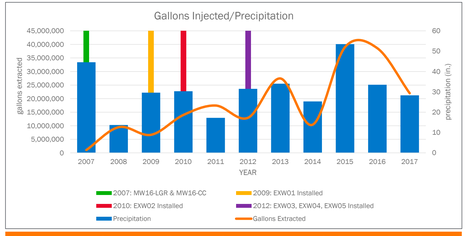
Bioreactor Treatment Zone

Performance Parameter Evaluation (2007-2017)



Parameter	Performance Expectation
Dehalococcoides (DNA)	> 1.E+04 cells/mL (baseline)
Hydrogen (H)	2-11 nm/L
Total Organic Carbon (TOC)	> 20 mg/L
Ferrous Iron (Fe^{2+})	> 1 mg/L
Sulfate (SO_4^{2-})	< 20 mg/L
Methane (CH_4)	> 0.5 mg/L
Sulfide (S_2^-)	< 20 mg/L
Chloride (Cl^-)	> 100 mg/L
Carbon Dioxide (CO_2)	> 50 mg/L
Dissolved Oxygen (DO)	< 0.5 mg/L
pH	6.5-7.5
Conductivity (Cond.)	> 0.500 m-mho/cm
Oxidation Reduction Potential (ORP)	< -100 mv
Temperature (°C)	< 35 °C

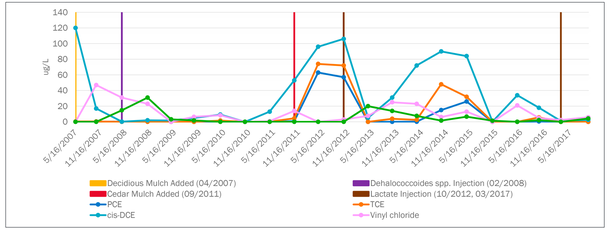
Ref: Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents. (2004)



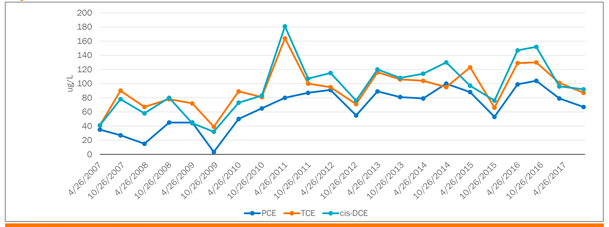
Gallons extracted from surrounding extraction wells correlate with increases in rainfall and the installation of additional extraction wells since bioreactor start-up in 2007.

1. The flood test in 2009 revealed the underlying area beneath the trenches fills regionally from the bottom up and responds to significant rainfall very rapidly.
2. Bioreactor construction included the installation of injection lines, sumps, geotextile fabric, and a mulch pea-gravel substrate to stimulate anaerobic bioremediation. The trenches were recharged with cedar mulch in 2011 and new improved injection lines were installed.
3. In 2008, bioaugementation of KB-1 Dehalococcoides spp. was injected into Trench 1.
4. The latest substrate injection in March 2017 included pumping 1,590 gallons of lactate and 265 gallons emulsified vegetable oil within the subsurface of the trenches and nearby shallow injection wells to seed Dehalococcoides microbes.

T1-2: VOC Concentration/Refresh Event Timeline



Injected Groundwater VOC Concentrations



Geochemical data comparing injected groundwater VOC concentrations with products in trench 1-sump 2 (T1-2) indicates decreasing concentrations of chlorinated solvents and increasing concentration of degradation products (cis-DCE, Vinyl chloride, and Ethene) in the bioreactor trenches.

Observations/Conclusions

- Increases in vinyl chloride and ethene indicates reductive dechlorination is occurring in the bioreactor treatment zone
- Lag periods in Dehalococcoides DNA are possibly due to competing terminal electron acceptors (other halorespiring bacterium)
- Refresh events (mulch, bioaugmentation, lactate) seem to be tied to favorable performance indicator expectations
- Unfavorable TOC concentrations suggest this may be a performance parameter which could be removed from the performance monitoring suite–Similarly H^+, Cl^-, and SO_4^{2-} may be considered for reduced data collection
- Data indicates some performance parameters indicative of the geochemical environment naturally present in the treatment zone have remained stable since 2007 (pH, conductivity, temperature and dissolved oxygen)
- Some parameters (Fe^{2+}, S_2^-, CO_2, conductivity, and pH) may play more of a diagnostic role rather than supportive role in performance monitoring of the bioreactor
- Ten year performance monitoring program of the bioreactor has provided better insight on the relation between hydrology, geochemistry, and biology in order to successfully achieve biodegradation of chlorinated ethenes in a karst aquifer

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