Influence of sulfate reduction and biogenic reactive minerals on long-term PRB performance in a sulfate rich, high flow aquifer

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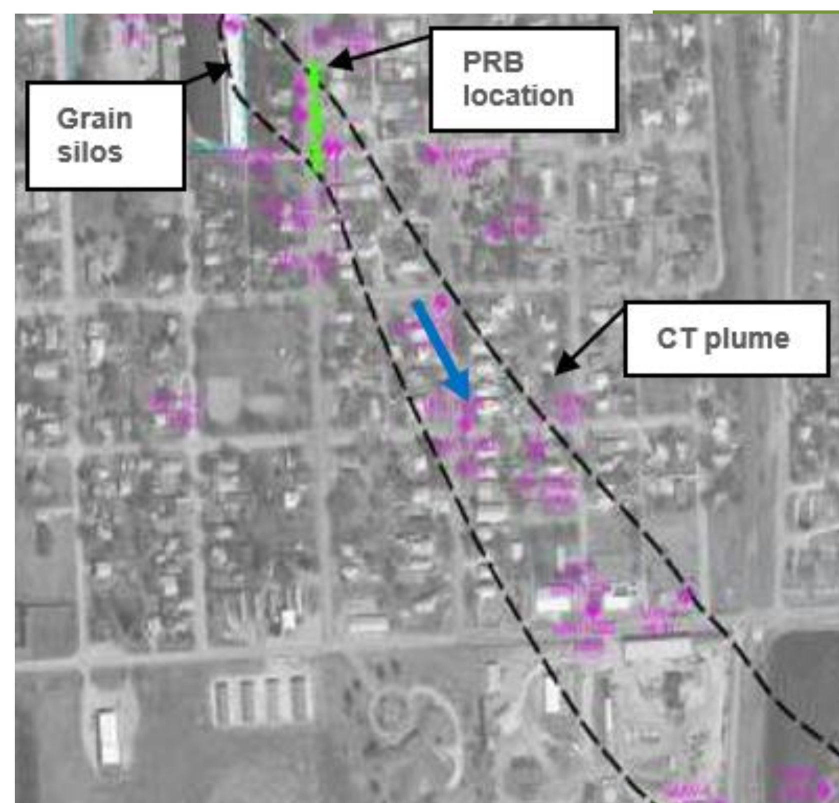
INTRODUCTION

Groundwater emanating from a former grain storage area is impacted with carbon tetrachloride (CT). The plume extends approximately 2,500 ft (760 m) from a grain elevator where it discharges into a small creek. The CT source area is elusive, and access restrictions due to residential housing further complicate source clean-up. Therefore, as an interim measure to prevent further plume migration, a permeable reactive barrier (PRB) was installed across the plume in April 2005. The PRB was created by injecting EHC® *in situ* chemical reduction (ISCR) reagent in a line of direct push injection points installed along the first available roadway located downgradient from the source area. This project represents the first full-scale application of EHC into a flow-through reactive zone and the purpose of this presentation is to assess long term performance of the PRB over time.

REMEDIAL GOAL

The remedial goal is to treat CT to <5 ppb, chloroform (CF) to <100 ppb, Chloromethane (CM) to < 20 ppb and methylene chloride (MC) to <5 ppb. The target goal for the PRB set forth in the Voluntary Clean-up Plan developed for the site is to maintain a removal efficiency of at least 95% reduction in CT compared to baseline concentrations at compliance points located 21 and 43 m downgradient from the PRB.



IMPLEMENTATION

April 2005, a total of 48,000 lbs (21,818 kg) of EHC was injected into an area measuring approximately 270 ft (83 m) long x 15 ft (5 m) wide x 10 ft (3 m) thick on average. The reactive zone was installed along the side of a road and extended across the plume. The EHC powder was mixed with water on site into slurry and injected using direct push technology. The injections specifically targeted the two saturated sand and gravel units identified during the pre-injection field investigation. Injections were not attempted into the surrounding clay layers as these were not deemed to be water bearing. The EHC was emplaced at an average application rate of 1% to soil mass within the sand units.

At the initiation of the field implementation, after one injection point had been completed, verification borings were collected around the injection point to confirm EHC placement. Fractures were detected in soil cores collected up to 5 ft (1.5 m) away from the injection location suggestion a radius of influence of at least 5 ft (1.5 m). Horizontal as well as vertically rising fractures were observed with an increased dip observed with distance from the injection location. Based on observations from the soil coring an injection spacing of 10 ft (3 m) was employed. Furthermore, it was decided to install individual borings for each injection depth at each location to ensure proper vertical distribution and to avoid injecting the majority of the EHC slurry into the bottom intervals.

RESULTS

Following the installation of the PRB, performance monitoring was conducted on a quarterly bases for the first three years and then bi-annually since April 2008. CT removal rates peaked 16 months after installation with >99 percent removal observed 21 m downgradient of the PRB (from a baseline of 1,000 ppb to <5 ppb). Two years after installation these rates decreased slightly to approximately 95-98 percent removal and stabilized there for 7 more years. In October 2014, 9.5 years after the PRB installation, breakthrough started to be observed with the 95 percent guideline set forth in the Voluntary Clean-up Plan not being met for the first time. However, in the most recent sampling event available, conducted in October 2017, removal rates were back at 95%. Concentrations at the second compliance well, located 43 m downgradient from PRB and at the edge of the plume, has remained non-detect (100% removal) for all analytes since August 2005.

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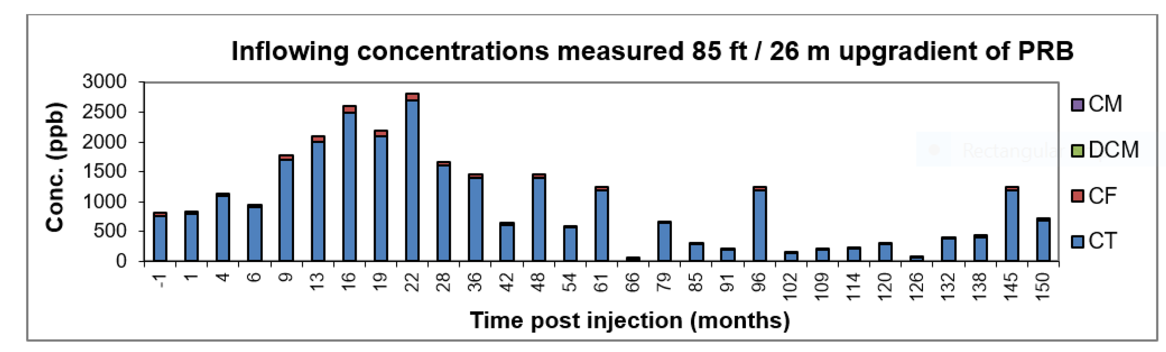
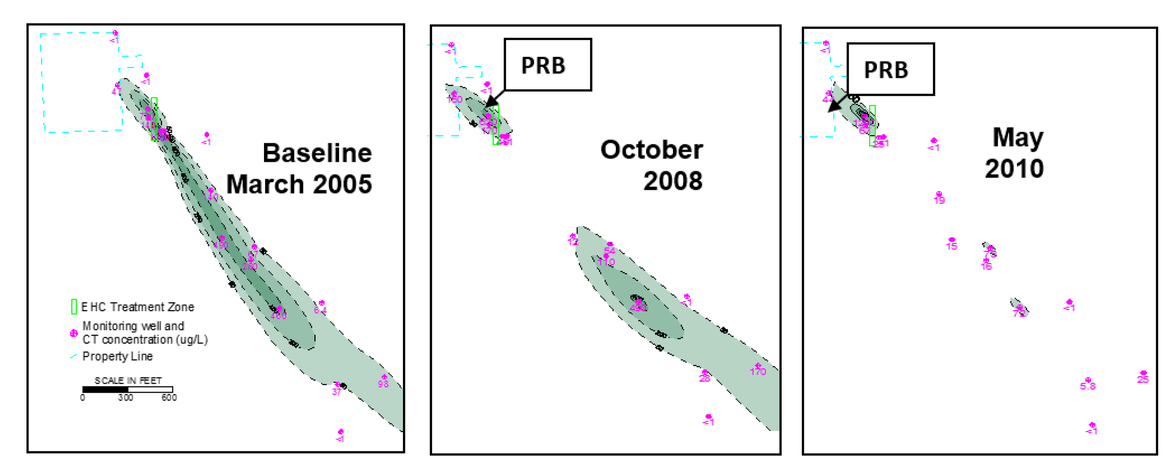
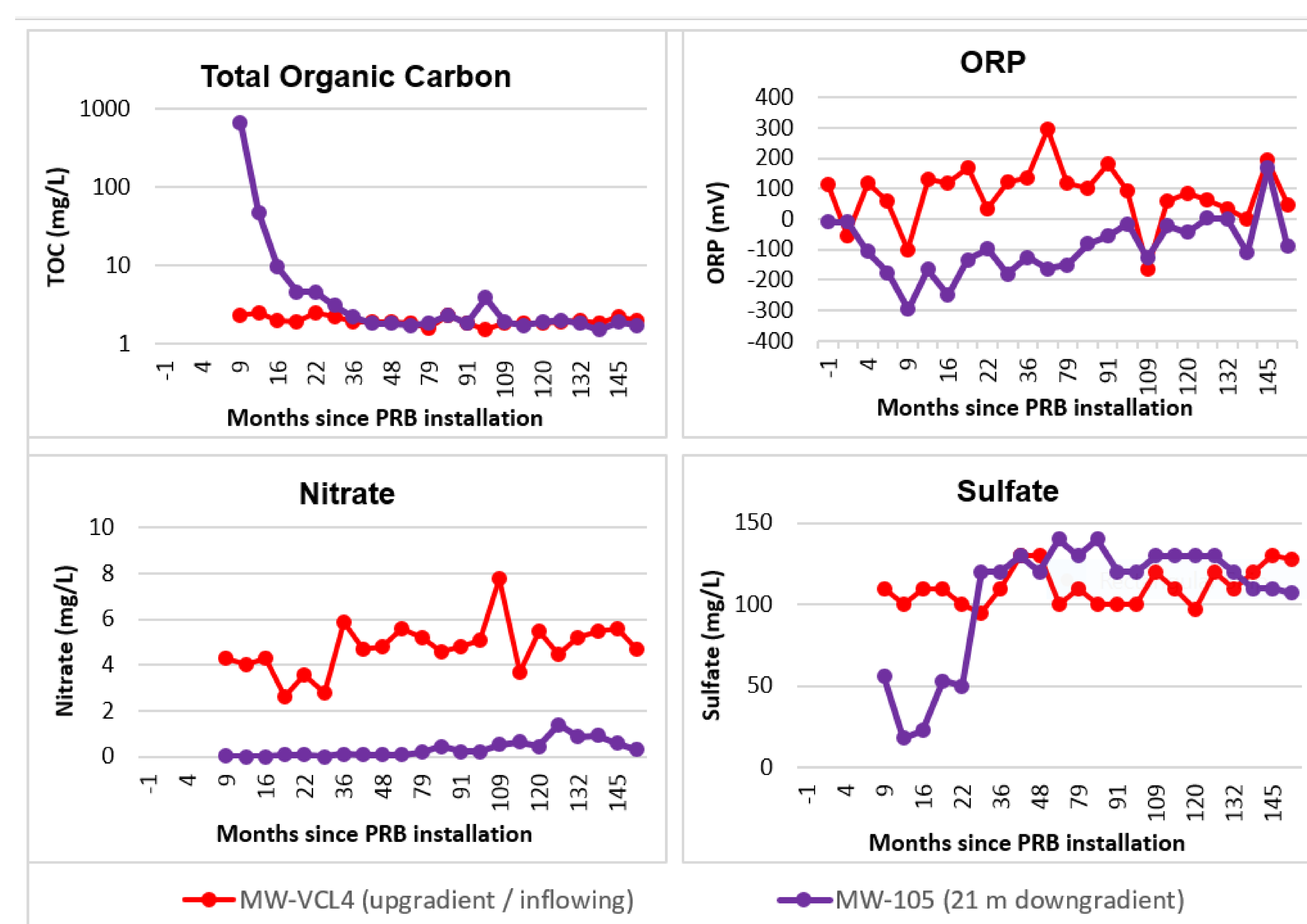


Figure below shows the progression of the CT plume prior to and after installation of the EHC PRB. Groundwater levels measured over time did not indicate a change in groundwater direction following the installation of the PRB.





Effect on geochemistry downgradient from EHC PRB shown relative to inflowing conentrations over time.

COST AND TIMELINE

The EHC material cost for the PRB measuring 83 m long x 3 m thick on average was around $100,000, resulting in a cost of (US$395/m^2) of PRB cross-section. The installation was completed in 12 days (between March 30 and April 10, 2005). Using an estimated linear groundwater flow velocity of 1.8 ft/day (1.6 to 2.2 ft/day estimated) and a porosity of 30%, the PRB is treating an estimated total of 14,600 m^3 of groundwater per year. With a confirmed life of at least 12 years, the PRB has treated an estimated total of 175,000 m^3 of groundwater during its life-time at a product cost of < US$0.57/m^3.

CONCLUSIONS

1. Removal Efficiency: Groundwater sampling results have shown up to 99.5% decline in CT concentration at the core of the plume 70 ft (21 m) downgradient of the PRB (from an initial concentration of 1,000 ppb to 5 ppb measured in August 2006), without accumulation of catabolites.

2. Longevity: A single application of EHC has remained active for a period of 12+ years, continuously supporting >90% removal of CT, without the accumulation of catabolites.

3. Plume Impacts: Since PRB installation it has served to significantly reduce the size and concentration of the downgradient plume.