

## Surprises and Mysteries from the Installation and Performance of 2000-foot of Biobarriers in Brackish Water

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**Background/Objectives.** Hexavalent chromium [Cr(VI)] and volatile organic compounds (VOCs) have been detected at elevated concentrations in groundwater (both over 100 milligrams per liter) proximal to the Bay in Operable Unit 20 (OU 20) at Naval Air Station North Island (NASNI) in Coronado, California. The VOC plume is ½ miles long, the Cr(VI) is at the leading edge of the VOC plume. There is likely an additional VOC source area near the leading edge. Enhanced in situ bioremediation (EISB) technology was implemented in 2012 by direct push injection (DPI) of emulsified vegetable oil (EVO) for microbial reduction of Cr(VI) to Cr(III) and to support reductive dechlorination of VOCs in the portions of the plume with Cr(VI) over 5 mg/L and VOCs over 20 mg/L. EVO had been tested (along with other donors) on bench scale prior to field scale injections. Commercially available microbial cultures were also injected. To prevent re-contamination of the injection area by the upgradient plume, a 700-foot biobarrier was installed. Subsequent investigations indicated a much larger contamination footprint in the vicinity of the 2012 DPI area. A second biobarrier consisting of over 400 multiscreened injection wells spanning 1,700 feet was installed in 2015 approximately 100 to 200 feet upgradient of the Bay. In all, the biobarriers span over 2,400 feet, with all wells receiving EVO. In one portion of the second biobarrier, lactate was also injected in 2015 due to presence of elevated Cr(VI). Also, in 2015 a small portion with recalcitrantly high levels of VOCs received EVO combined with zerovalent iron (ZVI).

**Approach/Activities.** Activities included injection of electron donors and microbial cultures at 377 DPI locations and 78 injection wells in 2012; and at 52 DPI locations and over 400 injection wells in 2015. Nine rounds of groundwater monitoring have been completed since 2012 to evaluate EISB progress.

**Results/Lessons Learned.** EISB is capable of addressing elevated levels (in some cases over 100 mg/L) of both VOCs and Cr(VI). However, TOC increases were not observed at several locations, which suggested that TOC was not a good metric for EVO distribution. Bench testing had indicated that Cr(VI) would need to decrease to < 10 mg/L before reductive dechlorination could occur, but this was not the case at all locations. The microbial culture was also found to be quite robust, despite elevated levels of contaminants and presence of brackish water. Injection of lactate in the portion of the second biobarrier resulted in substantial decrease in Cr(VI) within a few months.

At one of the injection areas, a groundwater monitoring well is located 60 feet downgradient of the 2012 injections. While the first 3 years of monitoring indicated no change in Cr(VI) or VOCs, data from the 4<sup>th</sup> year indicate a decrease in Cr(VI) and TCE coupled with increase in cis-1,2-dichloroethene at this location (prior to 2015 injections). This suggests that the minimum longevity of EVO in the saturated zone is at least 4 years.

Elevated levels of methane (gas) were observed in the head space at a number of monitoring and wells. Future injections into the biobarriers will include a comparison of traditional EVO and EVO mixed with anti-methanogenic reagents. In some injection wells, a gray oil-like substance was

found several years of injection, and is undergoing laboratory analysis to determine its nature. At one residual Cr(VI) hot spot, use of additional electron donors (such as coffee) is being evaluated.