Advancements to the EZVI Technology: Process Optimization and Improved Implementability

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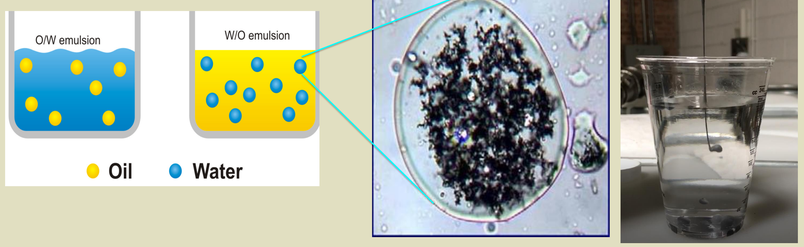
INTRODUCTION

The remediation of dense non-aqueous phase liquids (DNAPLs) is complicated by their physical and chemical properties (EPA, 2004). By definition, DNAPLs are compounds that have specific gravities greater than water (> 1 g/cm3), low water solubility, and therefore, a hydrophobic physical chemistry. The presence of DNAPL at a site can act as an ongoing source of contaminant to groundwater for decades. Chlorinated solvents are present as DNAPLs at many superfund sites (EPA, 2004). The potential effectiveness of ZVI for remediation of groundwater impacted by chlorinated solvents has been documented since the early 1990s (Gillham, 1994). As described by Arnold and Roberts (1998), chemical transformation via ZVI occurs on particle surfaces and therefore involves at least three steps: (a) adsorption of the substrate to reactive sites on the ZVI particle surface, (b) reaction at the surface, and (c) desorption of the transformation product.

The ZVI mediated transformation processes described above are relevant for dissolved phase contaminant destruction, as the ZVI requires a hydrogen donor (e.g. H_2O) for the abiotic reactions to proceed (Brown *et al.*, 2009). Because DNAPL is not in the dissolved phase and has a hydrophobic physical chemistry, injection of hydrophilic ZVI slurries into source areas will not provide direct destruction of source material. The EZVI technology provides a solution to this problem, and is engineered to enable maximum contact with source materials, while including ZVI with a hydrogen donor (suspended within water) so that direct DNAPL destruction is possible using ZVI technology.

WHAT IS GENUINE EZVI?

EZVI is a surfactant stabilized, water-in-oil emulsification with small micron (< 5 μm) ZVI particles suspended in the interior aqueous phase of the emulsion. The EZVI product is a DNAPL (hydrophobic, sinker).



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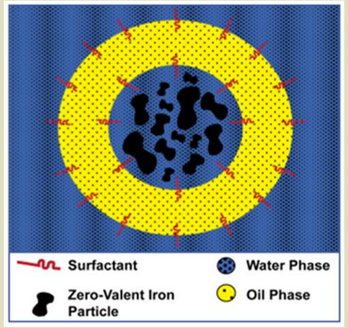
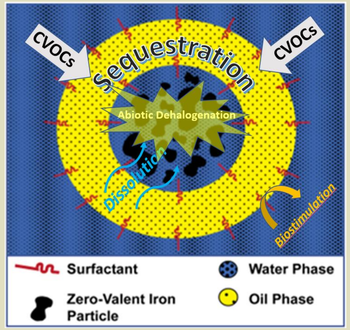
EZVI combines food grade vegetable oil (VO) with a surfactant, elemental iron and water in a specific physical structure to enable direct DNAPL destruction utilizing a combination of abiotic and biotic processes.

EZVI REMEDIATION PROCESSES



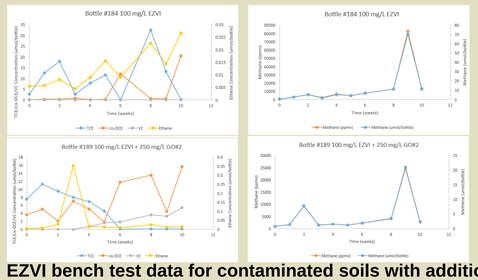


The key innovation surrounding the EZVI technology is the structure of the emulsion (Quinn et al., 2005). In order for the NASA patented technology to perform as designed, the emulsion structure, which is a water-in-oil type emulsification, is critical. The structure of the EZVI technology enables DNAPL treatment to proceed via 3 primary steps;

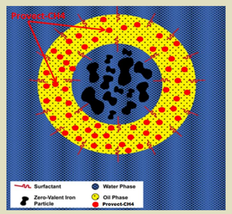
- Sequestration (into outer lipophilic membrane);
- Dissolution (into interior aqueous phase);
- Reductive dehalogenation (utilizing abiotic and biotic processes).

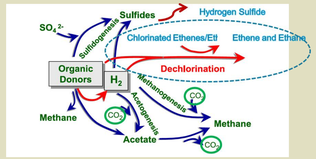
OPTIMIZATION OF BIOTIC PROCESS - EZVI-CH4

- Formulated for a given site
- 5% to 20% (wgt basis) ZVI content (1 to 3 micron)
- Typical AMR (Provect-CH4) at 3% to 8% Fermentable C
- Multiple types of AMRs can been utilized
- Micelle diameters range from ca. 5 to 20 micron
- Ships in 55 USG drums or 330 USG totes
- Made in USA under license by NASA



EZVI bench test data for contaminated soils with addition of TCE. The top graphs show results using EZVI with no AMR. The bottom graphs show results with AMR (Provect-CH4 EO).

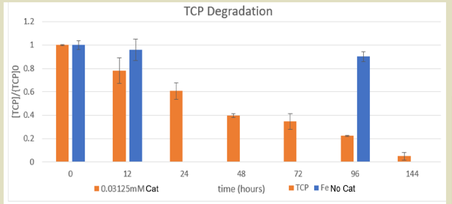


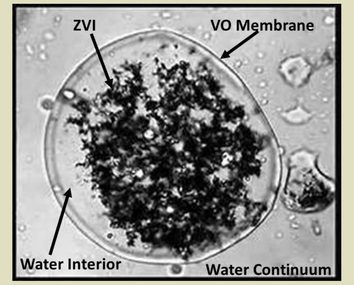


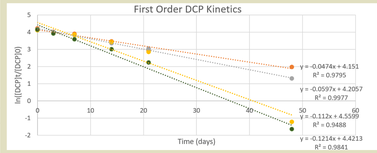
Significant decrease in methane (> 80% reduction over 2.5 months).

OPTIMIZATION OF ABIOTIC PROCESS

Provectus has formulated pH stabilized and catalyzed EZVI products which contain additives that will hydrolyze and provide acidity over time to the interior of the micelle. In addition, additives that will catalyze ZVI electron transfer processes, as well as, act to directly reduce iron oxides on the ZVI surfaces.







BENEFITS:

- Increased reactivity
- Expanded range of catalysis

ENHANCED IMPLEMENTABILITY

- EZVI viscosity can become an issue during subsurface injections into less permeable formations
- NASA patented formulations viscosity range is ca. 1200 – 1900 cP
- Provectus can provide decreased viscosity formulations when necessary with viscosity range ca. 850 – 1200 cP
- Provectus R&D into viscosity adjustment is ongoing
- EZVI ships in 55 USG drums or 330 USG totes
- 5% to 20% (wgt basis) ZVI content (1 to 3 micron)

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