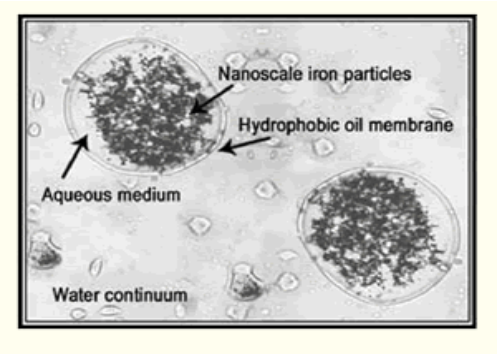
EZVI & ZVI POWDERS

Emulsified Zero-Valent Iron (EZVI)



Thousands of sites across the United States have been identified that are contaminated with dense non-aqueous phase liquids (DNAPLs). However, few technologies exist that can treat DNAPLs in a timely and cost-effective manner. For example, traditional pump-and-treat methods can require decades of treatment time and operational costs. Other methods that treat DNAPLs in place, such as steam injection and radio-frequency-heating, are expensive and can cause contaminant mobilization. NASA's Emulsified Zero-Valent Iron (EZVI) technology overcomes these limitations by providing a method that is quick, effective, and cost-competitive.

How It Works

EZVI involves placing nanoscale zero-valent iron particles into a surfactant-stabilized, biodegradable oil-in-water emulsion. This emulsion is injected into the DNAPL-contaminated zones of the subsurface. The DNAPL is then pulled into the emulsion where the contaminant reacts with the zero-valent iron. Through a process known as reductive dehalogenation, the DNAPL and its daughter products are degraded into ethane and other hydrocarbons. These by-products are finally broken down through biological activities in the subsurface.

Benefits

• **Directly treats contaminant source:** Numerous methods are available for treating dissolved-phase contaminants, but EZVI is one of the few technologies that can effectively treat the DNAPL source.
• **Does not mobilize contaminants:** Many DNAPL treatment methods, such as solvent flushing and thermal techniques, can mobilize DNAPLs to previously uncontaminated areas. In contrast, EZVI treats contaminants in place with no mobilization.
• **Requires less treatment time:** Although traditional pump-and-treat systems can require decades of operation for complete DNAPL removal, remediation with EZVI takes only two to three months. This

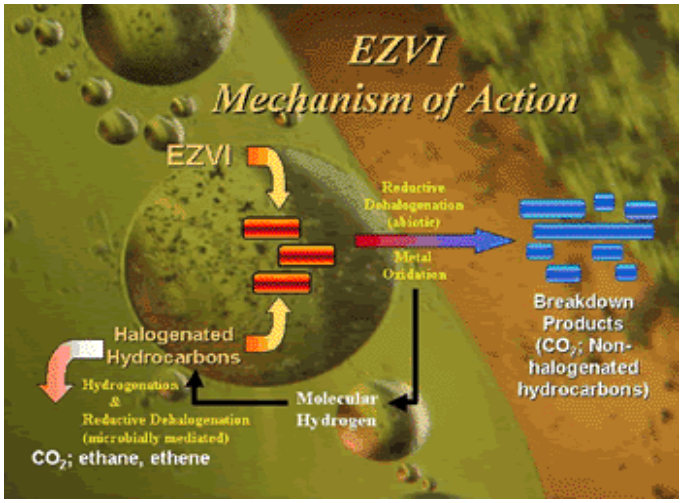
time frame also includes equipment set-up and tear-down.

• **Reduces treatment costs:** EZVI is estimated to cost between $25 to $48 per kilogram of DNAPL treated, depending on emulsion formula and purchase volume, making it cost-competitive with pump-and-treat, thermal treatment (e.g., steam injection, six-phase heating), and in-situ chemical oxidation.

• **Produces less toxic and more easily degradable by-products:** Other technologies, such as in-situ chemical oxidation, can generate chlorinated daughter products (e.g., vinyl chloride) that can be harmful to the environment. In contrast, EZVI produces small quantities of hydrocarbons, such as ethene, that are relatively nontoxic and naturally degraded.

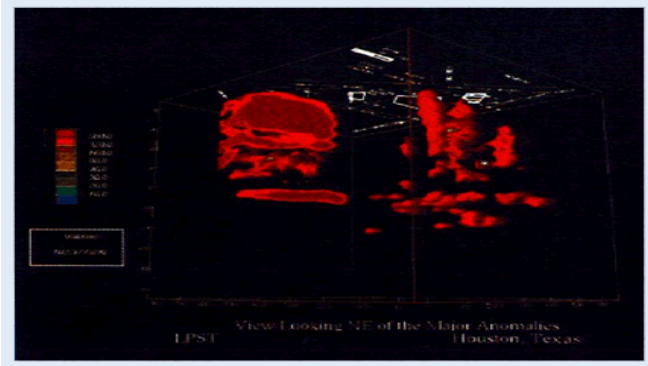
• **Is environmentally safe:** EZVI is made from environmentally friendly and biodegradable materials.

• **Is being evaluated by the U.S. Environmental Protection Agency (EPA):** Based on the success of bench-scale tests, EZVI is being field tested by the EPA under the SITE Demonstration Program. ZVI



ZVI Treatable Contaminants Include:

• Tetrachloroethene (PCE), Trichloroethene (TCE), cis 1,2-Dichloroethene (cDCE), trans 1,2-Dichloroethene (tDCE), 1,1-Dichloroethene (1,1 DCE), Vinyl Chloride (VC), Hexachloroethane (HCA), Carbon Tetrachloride (CT), Trichloromethane (DCM), Tribromomethane (TBM), 1,2-Dibromoethane (1,2 EDB), Trichlorotrifluoroethane (Freon-113), Trichlorofluoromethane (Freon-11) COMPLIMENTARY



COMPLIMENTARY TECHNOLOGIES:

• TEA can provide 3-dimensional subsurface contaminant imaging through the use of proprietary techniques, and utilizing electrical resistivity characterization. An example of the deliverable product from this technique is included below, and represents DNAPL contaminant distribution in the subsurface. See our Non-Destructive Testing section for additional subsurface characterization technologies.