"Green" DNAPL Remediation using the Emulsified Zero-Valent Iron (EZVI) Technology

Presented by:

J. Greg Booth, Ph.D.

TEA INC.

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Who is TEA, Inc.?

- 14 yr old Louisiana company with corporate office in Baton Rouge
- Professional environmental consulting firm with seasoned scientists and engineers
- Specialize in solving large and/or complex environmental problems using cost effective, green and sustainable solutions
- Continually striving to be at the leading edge of remediation technology development for critical environmental issues

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Who is TEA, Inc.?

Achievements:

- Designed & Implemented the largest EISB system in the U.S.A.
- Commercialized NASA's EZVI technology for DNAPL remediation
- Developing & Commercializing NASA's AMTS technology for PCB remediation
- Leading provider of Engineered Phytoremediation Systems
- Developing standards for Green and Sustainable Site Assessment and Cleanup Guide (GASSAC) for the American Society of Testing and Materials International (ASTM)

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What is "Green" Remediation?

- The incorporation of certain practices, processes and technologies into a remedial action in order to generate beneficial impacts on the environment, the economy, and the society through the judicious optimization/balancing of limited resources and resulting impacts.
  -(American Society for Testing and Materials International (ASTM) Green and Sustainable Corrective Action draft guidance)

- The evaluation of all environmental effects of remedial options and selecting options that maximize the **"net environmental benefit"** of cleanup actions. *- (USEPA)*

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What is "Green" Remediation?

- **Net Environmental Benefit** is defined as producing favorable environmental results including but not limited to the following;
  - Minimization of energy consumption and consumption of natural resources including water;
  - Permanent and complete contaminant mass and waste reduction and reduction of emissions;
  - Reduction in contaminant mass releases and bioavailability to the environment through adequate source and plume control;
  - Utilization and promotion of natural processes during remediation; and
  - Promotion of land reuse and recycling, and improvement of other socioeconomic factors.

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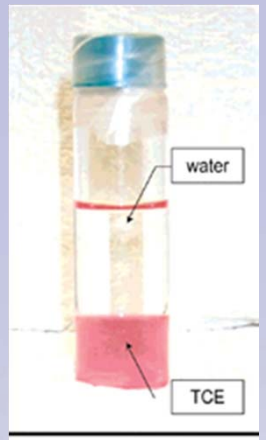
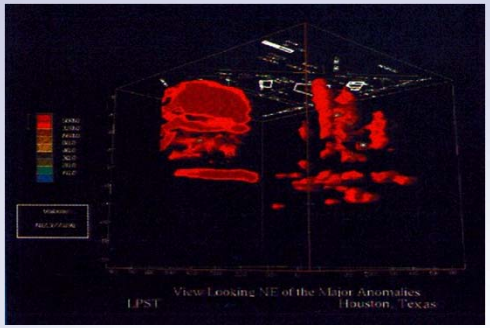
What is a DNAPL ?

- DNAPL – **D**ense **N**on-**A**queous **P**hase **L**iquid
  - Heavier-than-water organic liquid that is only slightly soluble in water.
  - Chlorinated solvents (e.g. PCE, TCE, VC, CT)
  - Characteristics of chlorinated DNAPLs
    - Dense (“sinkers”)
    - Low viscosity (for chlorinated solvents)
    - Low solubility (persistent, hydrophobic)
  - The EPA has reported that DNAPLs are present at 60% to 70% of all sites on the Superfund National Priorities List



Brooks, 2000



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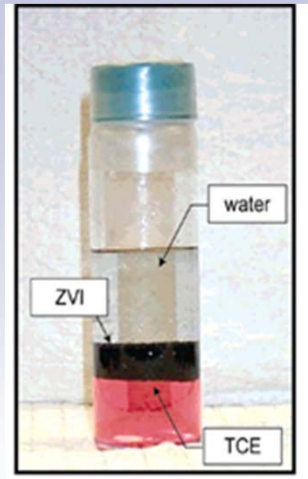
Technology Rationale

- Zero-Valent Iron (ZVI) is a proven remedial alternative for CVOC degradation
  - Primarily used in PRB applications to address dissolved phase concentrations
- ZVI ***in water*** acts as a temporary electron donor for the reductive dehalogenation process
- ZVI in slurry form is not capable of direct DNAPL source material degradation
- EZVI does provide direct source material degradation due to hydrophobic miscibility and aqueous micelles



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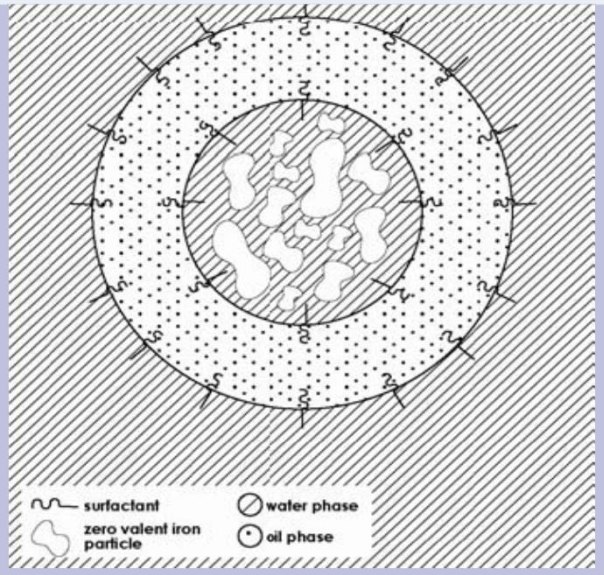
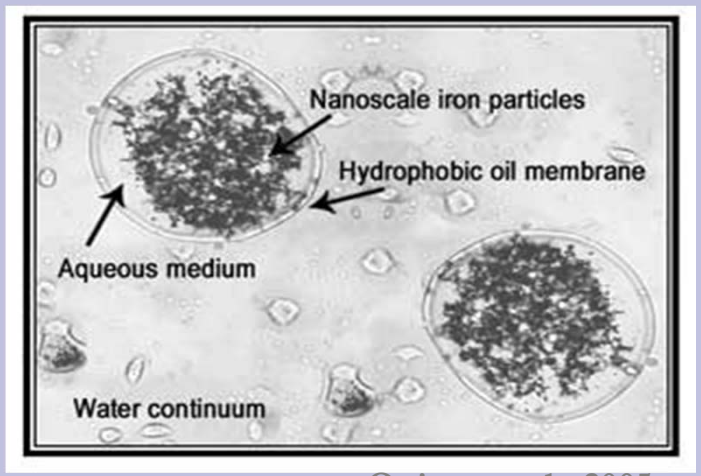
The EZVI Technology





Quinn et. al., 2005

Emulsified Zero-Valent Iron (EZVI)

EZVI involves placing nano-scale and/or micro-scale zero-valent iron particles into a surfactant-stabilized, biodegradable water-in-oil emulsion. This emulsion is injected into DNAPL-contaminated zones of the subsurface. The DNAPL then phase partitions into the outer hydrophobic membrane of the emulsion. The next step is dissolution into the aqueous interior of 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 ethene and other benign end products. These by-products are further degraded through biological activity in the subsurface.

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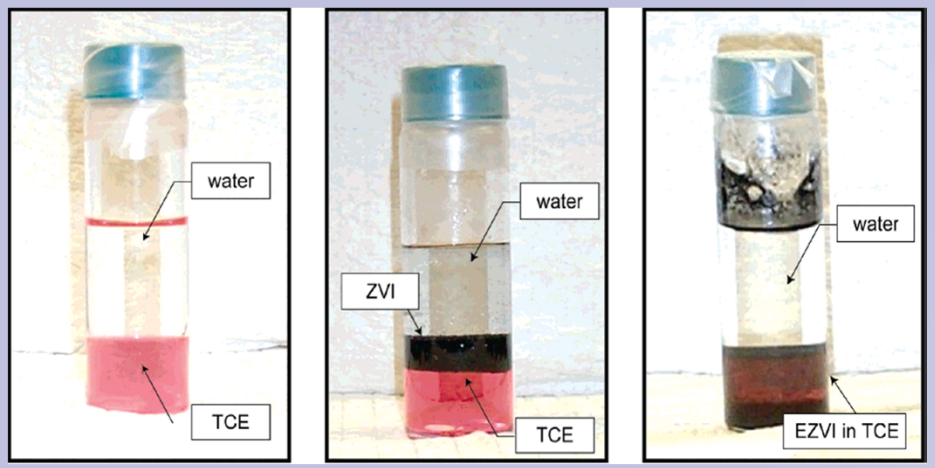
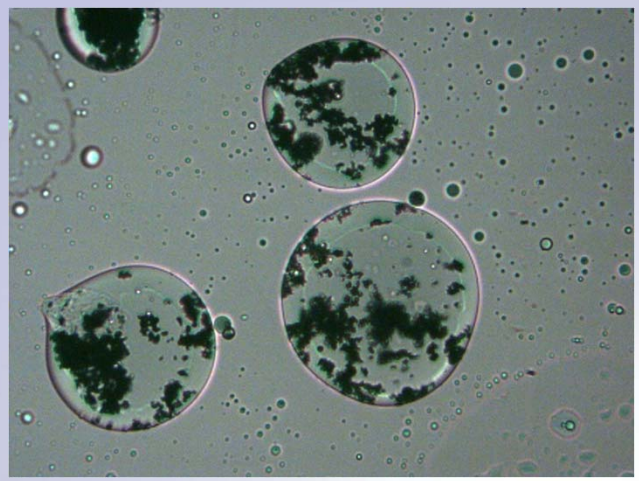
EZVI Characteristics

- EZVI acts as a DNAPL
- Hydrophobic exterior membrane mimics DNAPL characteristics
- EZVI is miscible with DNAPL globules, stringers, pools



Brooks, 2000

Miscible with DNAPL



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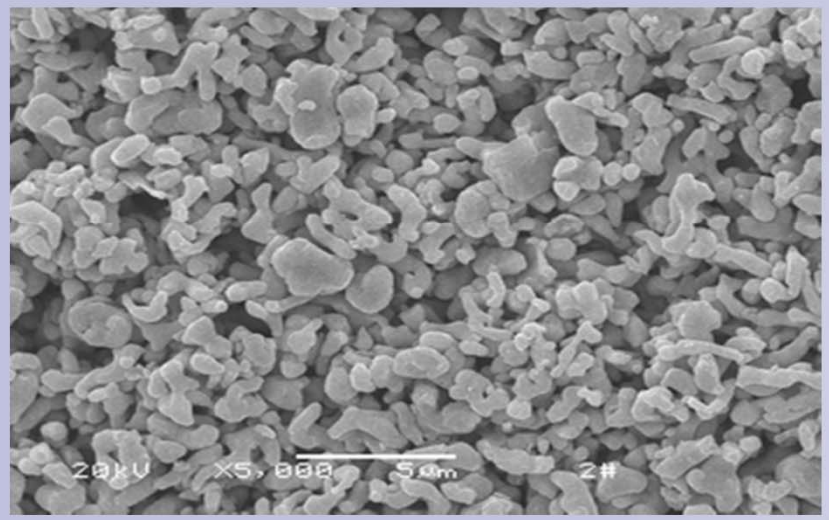
TEA's ZVI Powder

TEA utilizes a custom manufactured blended ZVI powder (nano-micro blend) to provide:

- **a consistently stable and reactive emulsion;**
- **enhanced surface area and reactivity of ZVI;**
- **the only EZVI product using blended ZVI; and**
- **lower costs for the EZVI technology.**



Electron Microscope (SEM) image of TEA's blended ZVI.

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EZVI Implementation

- Designed as an *in-situ* source treatment technology
- Delivered to subsurface soil/groundwater zones that are contaminated with source material(s)
- Effective in vadose soils (unsaturated soils)
- Effective in saline and oxidized environments

Pilot Scale

Full Scale

EZVI and VO staged for field implementation

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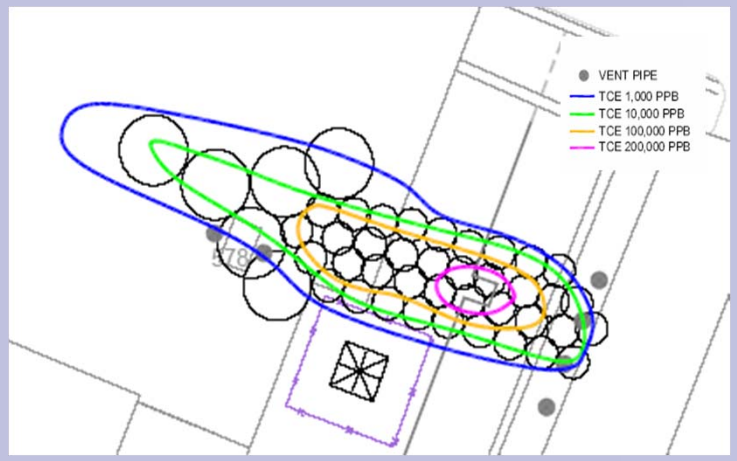
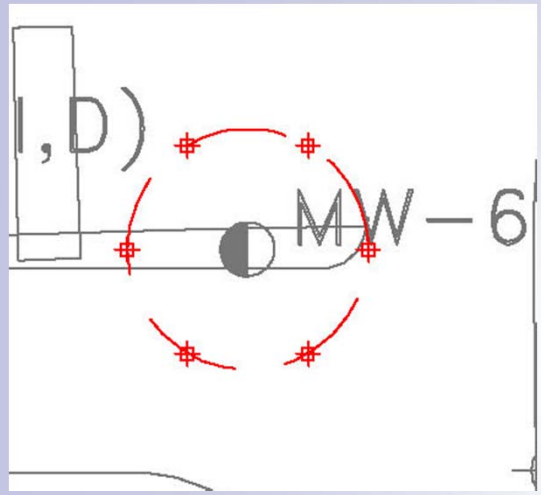
EZVI Implementation

- Injection pattern typically “outside-in” and “bottom-up”
- Injections performed using commercially available injection equipment or soil mixing equipment





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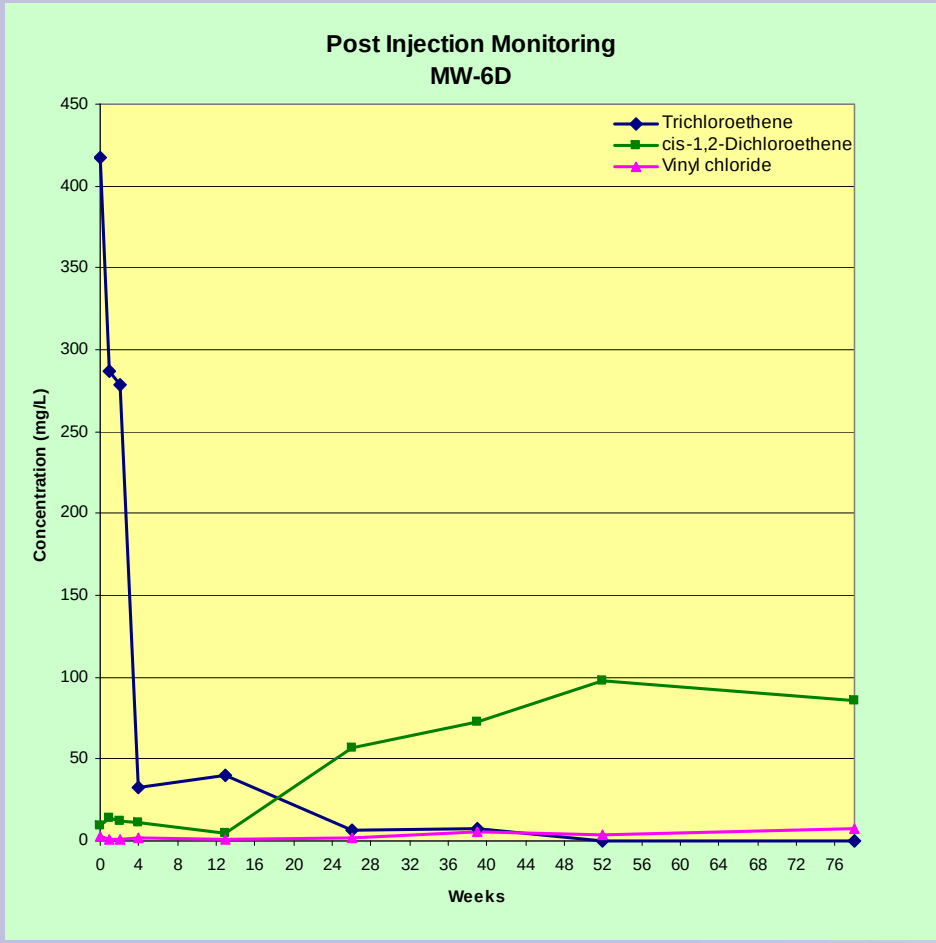
EZVI Performance



- Typical groundwater concentration reduction of >90% within 3 - 6 months

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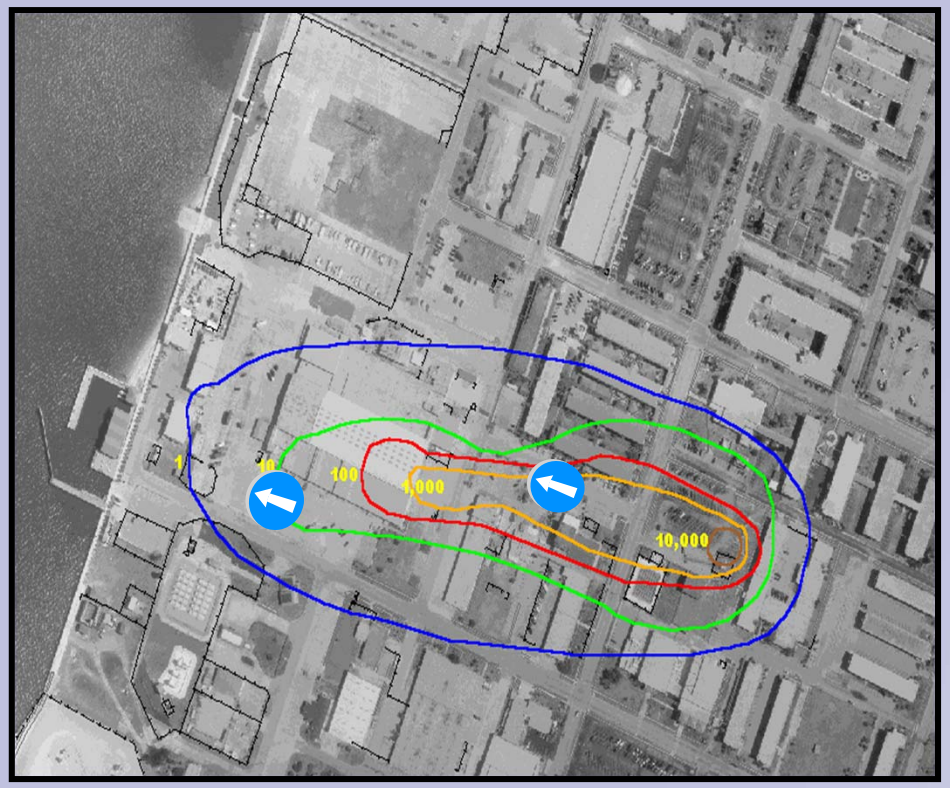
Return on Investment



In 2000, it was estimated that contamination would persist for at least *250 years* before cleanup levels could be attained utilizing monitored natural attenuation (MNA).

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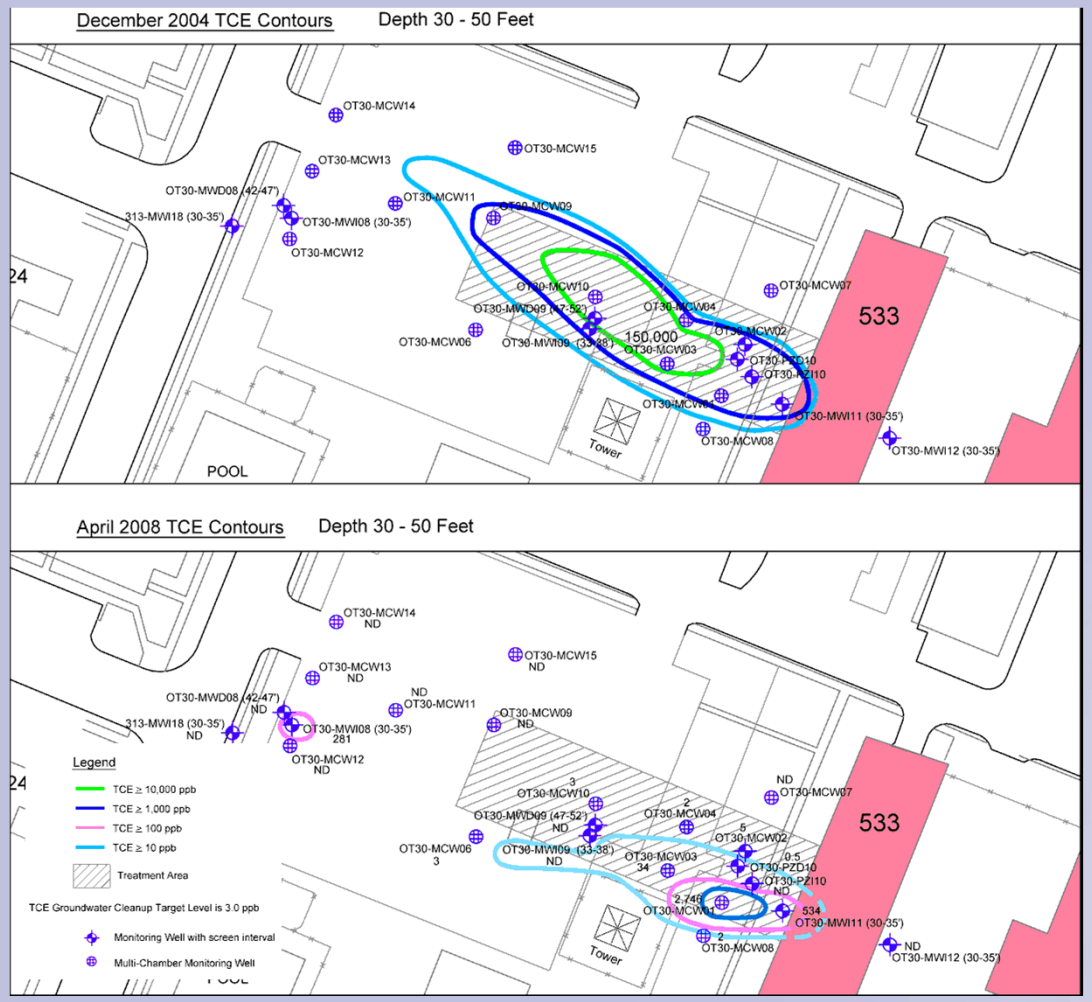
Return on Investment



After implementing EZVI in the source area, the current estimate to reach cleanup goals is *less than 50 years*.

Less than $4 million investment in source area remediation reduced remediation time frame > 100 years and will save in excess of $30 million in O&M expenditures at the site.

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Why EZVI?

Benefits

- Directly treats contaminant source
- Does not mobilize contaminant
- Requires less treatment time
- Cost competitive
- Generates less toxic & more easily degraded by-products
- Is environmentally friendly "GREEN"
- Is effective in oxidative or saline environments

Success Highlights

- Field-tested by the U.S. EPA under the SITE Program
- Used at commercial and government sites to treat both TCE and PCE
- Applied in multiple states, including; FL, AR, NC, TN, IL, OH, TX, LA, WV, MA
- 2005 Award for Excellence in Technology Transfer by Federal Laboratory Consortium
- 2005 NASA Invention of the Year
- 2006 NASA Commercialization Invention of the Year
- 2007 NASA "Space Technology Hall of Fame" Inductee

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Other "Green" Technology Offerings

- **PCB remediation technology- (AMTS)**
  - Construction debris, painted surfaces
  - Soils/Sediments
- **Engineered Phytoremediation- (EnPhySys℠)**
  - Hydraulic containment & treatment
- **Crude Oil Absorbent- (PowderSorb)**
  - Oil spill remediation on land or water

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Questions ???

Source Area Remediation

EZVI Technology

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