TECH TRENDS
Ground Water Currents

TECHNOLOGY NEWS AND TRENDS

A newsletter about soil, sediment, and ground-water characterization and remediation technologies

Mulch Biowall Used to Treat TCE-Contaminated Ground Water

The U.S. Air Force Center for Environmental Excellence (AFCEE) completed pilot-scale testing of a permeable reactive biowall in August 2000 at Offutt Air Force Base (AFB) near Omaha, NE. Field tests were conducted to determine the efficacy of organic mulch as an electron donor for promoting biological reductive dechlorination of ground water contaminated with trichloroethene (TCE). Performance data indicated that the biowall is a low-maintenance, cost-effective, in-situ treatment wall technology. Based on these results, a full-scale 500-ft biowall was installed at Offutt AFB in July 2001.

The pilot test took place at a site used between 1942 and 1945 to manufacture military aircraft. The resulting ground-water contamination consists of a 3,000-ft plume with TCE concentrations reaching 2.2 mg/L. Soil in the area comprises alluvial silt and clay, with ground water located approximately 6 ft below ground surface. Hydrologic testing indicated that the underlying 30-ft aquifer has an average flow velocity of 84 ft/yr, a gradient of 0.01 ft/ft, and a hydraulic conductivity of 3.5 ft/day.

Mulch was selected as the electron donor for the biowall due to evidence of reductive dechlorination under an adjacent agricultural field where the soil contains a high level of naturally occurring organic carbon. The low costs associated with obtaining mulch also were considered. Mulch was generated onsite using shredded trees and leaves, and mixed with coarse sand in a 50:50 ratio to enhance the permeability and stability of the biowall. Using a continuous trencher, a 1 ft-thick wall was installed and filled simultaneously to a length of 100 ft and depth of 23 ft. Two upgradient, four downgradient, and two control wells were sampled in five events during the 31-month pilot test.

Sampling results indicated depressed oxygen concentrations and oxygen-reduction potentials due to the consumption of organic matter and oxygen by aerobic bacteria. Nitrate and sulfate levels also declined. Methane production was observed, providing further evidence of the establishment of reducing conditions. Over 31 months of treatment, the mean TCE removal 20 ft downgradient of the biowall was approximately 70% (Figure 1). Upgradient TCE concentrations were variable (0.3-2.1 mg/L), but downgradient TCE concentrations were consistently between 0.2 and 0.6 mg/L. The ratio of *cis*-dichlorothene (DCE), a degradation byproduct, to TCE downgradient of the wall increased by a factor of 820 after 5 months of treatment. This ratio subsequently dropped as *cis*-DCE was converted to vinyl chloride, ethene, and ethane. The control plot showed no decrease in TCE concentrations.

Demonstration findings suggest that this technology is appropriate at sites with shallow (less than 8 ft) ground water and biowalls extending less than 30 ft below

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About This Issue

This is the first issue of *Technology News and Trends*, a technology newsletter for environmental professionals published by EPA's Technology Innovation Office (TIO). *Technology News and Trends* is replacing *Tech Trends* and *Ground Water Currents*–TIO's technology newsletters for the past 10 years. The new newsletter features a combination of articles on innovative, in-situ technologies for the characterization and treatment of soil, sediment, and ground water. TIO welcomes your suggestions for news features and articles for *Technology News and Trends*. *(See page 5 for how to contact us.)*

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ground surface. Costs for installing the Offutt AFB biowall were approximately $140-360/linear ft. If not generated onsite (at no cost), mulch for applications at other sites is estimated to cost approximately $20/yd^3. Additional performance data for this technology will be collected over the next two years during full-scale operations at Offutt AFB. Prior studies by others indicate that a mulch-based biowall will last approximately 10 years.

AFCEE plans to construct a 500 ft-long, 25 ft-deep mulch biowall at Altus AFB, OK, later in 2002, and is seeking implementation of this technology at two additional Air Force sites.

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Full-Scale Bioremediation of Organic Explosive-Contaminated Soil

In August 2001, the U.S. Army Corps of Engineers (USACE) initiated full-scale bioremediation of 6,000 yd^3 of organic explosive-impacted soil at the Iowa Army Ammunition Plant (IAAP). Daramend® bioremediation was selected due to its low soil bulking, effectiveness in the presence of elevated heavy metal concentrations, and potential cost savings over alternative technologies. Following treatment over an 8-week period, RDX, HMX, and TNT concentrations were reduced by 98.9%, 92.4%, and 93.7%.

Production of conventional ammunition at the IAAP, located near Burlington in southeast Iowa, began in 1941. Past operations resulted in soil and ground-water contamination through the discharge of wastewater containing explosives and explosive byproducts, and through open burning and land disposal of production wastes. Soil at the site is characterized as clayey glacial till amenable to bioremediation. Currently, no technology is in place to address the site's contaminated ground water.

Daramend bioremediation involves the generation of repeated and sequential anoxic and oxic conditions through the application of organic amendments and powdered iron at low doses (0.5-2% by weight). The amendments are formulated with the specific particle size distribution and nutrient profile needed to create optimal microbiological conditions in the soil. This technology can be applied in-situ to surface soils when contamination does not extend beyond the upper 2-3 ft. For deeper contamination zones, ex-situ applications are employed through a land treatment or aerated windrow process. Land treatment typically is less expensive than aerated windrows; however, windrows often require less space.

Contaminated soil at the IAAP was excavated and treated ex-situ in two high-density, polyethylene-lined land treatment units identified as Trench 6 and Trench 7. These trenches contain 5,500 yd^3 and 500 yd^3 of unprocessed soil, respectively. Amendments were applied to the soil surface and blended to a depth of 2 ft using a tractor-driven rotary tilling system, which helped to achieve uniform amendment distribution and increased soil aeration. Water then was applied to reach the target soil moisture content of 42% (dry weight). These steps were repeated in 7- to 10-day treatment cycles. Five treatment cycles were conducted in Trench 6, while six cycles were required for Trench 7 due to higher initial contaminant concentrations.

Treatment progress was monitored with an immunoassay field test kit measuring the combined concentration of RDX and

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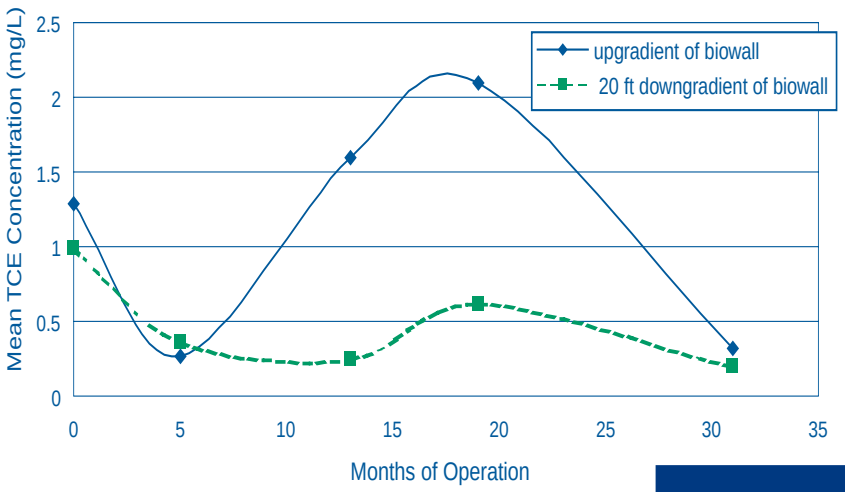
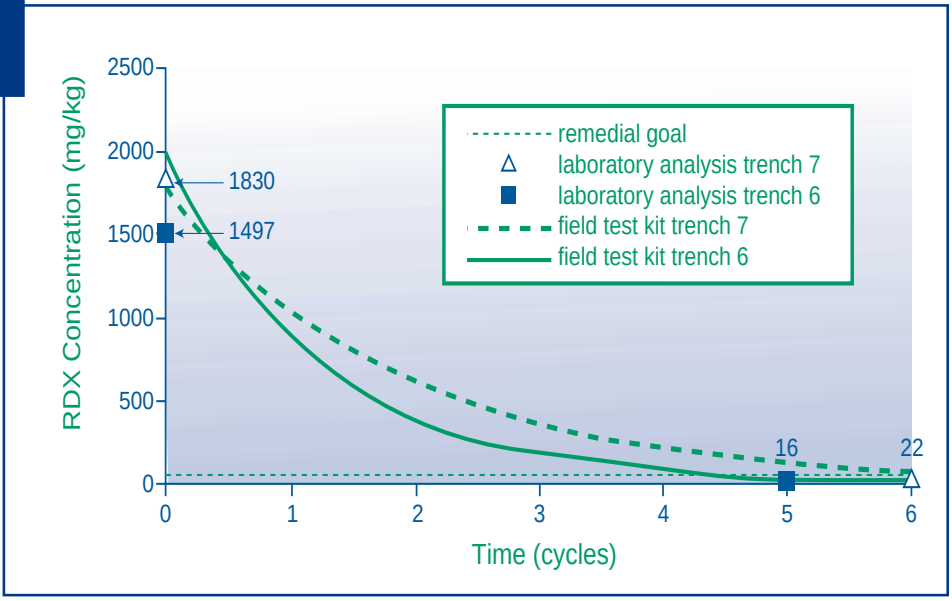


Figure 1. *Over 31 months of treatment at Offutt AFB, the mean TCE removal was approximately 70%.*

Figure 2. *Following Daramend bioremediation treatment, RDX concentrations in soil at the IAAP decreased more than 93%.*



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HMX, and verified through laboratory analysis (Figure 2). RDX served as the driving contaminant in this application due to its high initial concentration (819-2,270 mg/kg) relative to its remedial goal (53 mg/kg). Following treatment, RDX concentrations ranged from 3 to 32 mg/kg, while the mean concentration was reduced by almost 99% (from 1,530 to 16.2 mg/kg). Similarly, the mean concentration of HMX was reduced by 92.4% (from 1,112 to 84.5 mg/kg), and the mean TNT concentration was reduced by 93.7% (from 95.8 to 6.1 mg/kg). Concentrations of other contaminants, including biodegradation intermediates, also were reduced to levels below remedial goals in the 20 zones that were sampled. An estimated 42,000 pounds of explosive compounds were treated by the process.

The treatment cost for full-scale bioremediation at the IAAP was $167/yd^3, excluding costs for soil excavation or construction of the land treatment units. This compares favorably with alternative treatment technologies such as composting or thermal treatment. Daramend bioremediation has been applied successfully at other U.S. Department of Defense installations, including the Joliet Army Ammunition Plant, the Yorktown Naval Weapons Station, and the Hawthorne Army Depot.

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Treatment of Chlorinated Organics Using Injected Zero-Valent Iron Powder

The U.S. National Aeronautics and Space Administration (NASA) has completed a pilot-scale field test of the Ferox^{SM} zero-valent iron (ZVI) process to address trichloroethene (TCE) in ground water at the Marshall Space Flight Center (MSFC) in Huntsville, AL. Over a period of 4 weeks, more than 11,000 lbs of ZVI powder were emplaced in the subsurface at 29 locations throughout a 1.5-acre area of the MSFC. Since the July 2000 ZVI injections, levels of TCE in monitoring wells previously showing the highest concentrations have decreased by more than 95%.

Field studies took place in an area of the MSFC used for testing rocket engine components and propellants. Contamination originated from a waste holding pond where TCE was used to clean engine components after testing and where unexploded ordnance was disposed. Contamination is found primarily in a geologic stratum called the "rubble zone," which comprises heterogeneous aggregates of clay, sand, and chert of various grain sizes. The 5- to 7-ft rubble zone is sandwiched between 30 ft of an overlying clayey residuum and an underlying limestone bedrock formation. An aerobic aquifer with dissolved-oxygen levels of 5-7 mg/L is located at a depth of 22-34 ft. The slow velocity of the ground water (0.14 ft/day) allows for a long TCE residence within the iron-impregnated soil matrix, which increases the opportunity for iron to reductively dehalogenate the TCE.

Application of ZVI powder through an injection process was selected at the MSFC over installation of a ZVI-containing permeable reactive barrier (PRB) due to the site's deep ground water and to the injection method's ability to address source contamination directly.

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The depth to ground water, which reaches 80 ft below ground surface, exceeds the depth at which a PRB could be installed and maintained cost-effectively. Direct injection also allowed treatment of ground water below existing utility structures and a shallow subsurface that was suspected of containing unexploded ordnance.

The Ferox process employs a driven casing/nozzle system or open borehole to create an in-situ, iron-enriched zone of soil above or below the ground-water table. Using potable water and ZVI powder, the slurry is fed into the nitrogen gas stream, which atomizes the water and iron particles to produce a fine mist. This transformation results in dispersal of the iron powder within the subsurface over significant horizontal distances using relatively low injection pressures (Figure 3).

In the field, two overlapping treatment zones were installed: a 3,000 sq-ft source-area treatment zone exhibiting TCE concentrations in ground water as high as 72 mg/L, and a 450- by 60-ft downgradient treatment zone. By applying the injections in 3-ft intervals using a downhole packer system, a total of 125 slurry injection events occurred at pressures ranging from 60 to 120 psig.

During injections, the influence of atomized iron powder was observed as far as 35 ft from the point of injection. No effect was observed at any of the nearby manufacturing buildings or buried utility lines. On several occasions the injected atomized slurry encountered unidentified old boreholes, which resulted in slurry appearing at the ground surface. Such an encounter halted the injection event until the old borehole was grouted or sealed with a pneumatic packer.

Quarterly ground-water sampling at the MSFC over the past 1.5 years shows that TCE concentrations in ground water at the MSFC decreased from a pre-injection level of 72,800 µg/L to a post-injection level of 2,500 µg/L. Ongoing reductive dechlorination is evidenced further by increased concentrations of chloride (from 3.29 to 44.4 mg/L) and *cis*-1,2-dichloroethene concentrations (from 100 µg/L to 9,900 µg/L) within the source zone wells.

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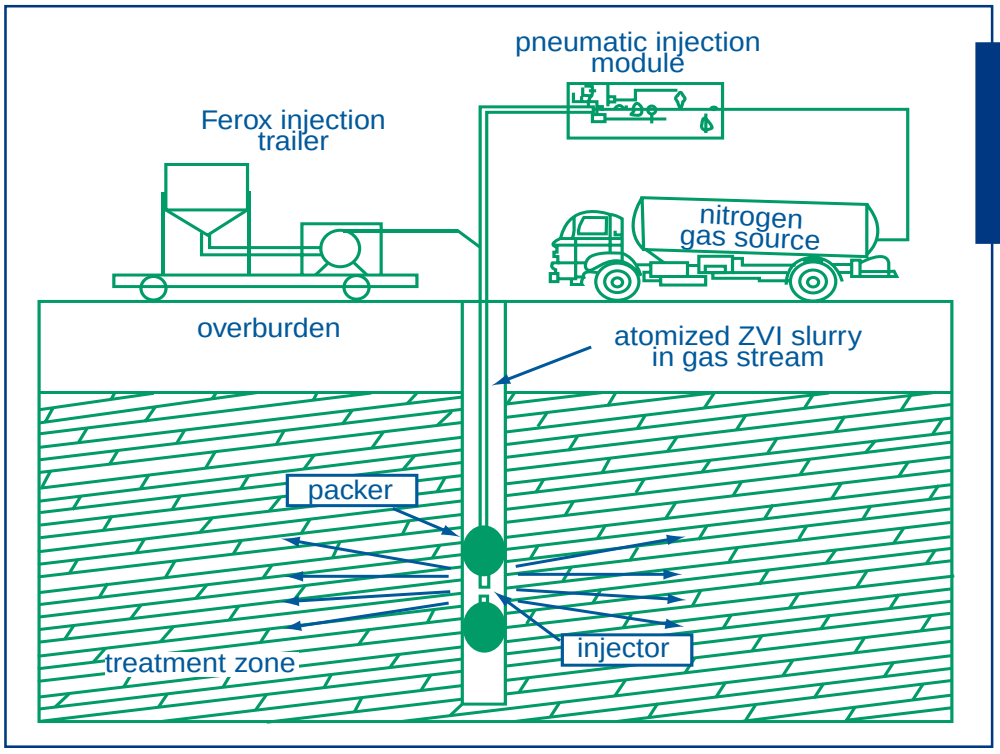

Figure 3. *The injected Ferox℠ process slurry produces a fine mist that disperses iron powder within the subsurface.*

DOE Evaluates Vertical-Melt Vitrification of Radioactive Mixed Waste

The U.S. Department of Energy (DOE) National Energy Technology Laboratory is evaluating a non-traditional in-situ vitrification (ISV) technology for treating radioactive mixed waste at the Los Alamos National Laboratory (LANL) in New Mexico. This technology, known as GeoMelt™, involves the melting of subsurface soil through the use of vertically oriented planar melts established between two pairs of electrodes. Initial seismic tomography data and continued site monitoring since ISV completion in April 2000 indicate that the vitrified waste at LANL is contained successfully within a 25- by 15-ft monolith. The monolith extends from 8 to 26 ft below grade, which is considerably greater than depths achieved through conventional ISV melts.

This ISV approach differs significantly from traditional ISV, which typically melts a soil matrix in a "top-down" sequence with a horizontally oriented melt established at or near ground surface between four electrodes. In contrast to top-down ISV, the vertical melt provides a taller, narrower melt and improved control of melt progression. Two separate vertical melts begin in the subsurface, forming parallel melt planes that grow together horizontally during the treatment process to form a single monolith of the targeted treatment volume. In comparison with conventional top-down ISV, this subsurface approach uses approximately 30% less electrical power and decreases exposure potential for workers.

DOE's Subsurface Contaminants Focus Area sponsored the GeoMelt demonstration in cooperation with the Western Environmental Technology office of DOE. The demonstration took place at LANL's technical area 21, which contains three absorption beds located in a welded volcanic tuff matrix. Operations were conducted in a portion of a single absorption bed. From the 1940s to the early 1960s, the absorption beds received liquid effluent primarily from a radioactive laundry facility and intermittently from nearby laboratory and research facilities. Soil sampling indicated the presence of plutonium 239/240 in concentrations reaching 525 pCi/g. Other contaminants within the absorption beds included radionuclides (americium, cesium, strontium, and uranium) and heavy metals (cadmium, chromium, copper, and lead).

The demonstration commenced with the injection of a graphite-based mixture into the subsurface to form two vertical planes of melt starter material between two pairs of electrodes. Based on the local geology, an injection target depth of 9-12 ft below grade was established prior to the melt. Joule-heated melting occurred over a 21-day period, reaching a depth of 25 ft. During this period, the melting process operated for approximately 14 days at a power input averaging 2 megawatts. Melting operations were interrupted for 11 days while cavities of unsubsided overburden material were collapsed using vibratory equipment, but continued again without difficulty. Off-gases were contained within a hood covering the treatment area and drawn to a treatment system. Laboratory and field evaluations of the off-gas and treatment system showed no radiological contamination.

Due to the insulating properties of the surrounding volcanic tuff, cooling of the monolith has occurred more slowly than anticipated. From an initial temperature over 2,000°F, the top surface of the monolith cooled to 700°F within six months, 300°F after 12 months, and 100°F after 24 months. DOE is conducting additional analysis of the vitrified monolith in 2002 to verify that target compounds were incorporated into the melt and uniformly distributed. In addition, leaching tests will be performed to ensure that contaminants are immobilized within the glass matrix. By producing a final waste form that is more resistant to physical, chemical, and weathering changes, non-traditional ISV appears to provide an alternative to contaminant solidification or stabilization.

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Technology Comparisons Conducted on LNAPL

In collaboration with several universities and federal interagency programs, EPA's National Risk Management Research Laboratory (NRMRL) is evaluating technologies for treating ground water contaminated with light nonaqueous phase liquid (LNAPL). Side-by-side comparisons of nine technologies employing various remedial agents have been conducted since 1996 at Hill Air Force Base (AFB) near Ogden, UT. Tests were conducted in 3- by 5-m hydraulically isolated treatment cells containing a complex mixture dominated by fuel components but containing solvents, polychlorinated biphenyls, and pesticides.

Traditional pump and treat methods were compared against:

- Cosolvent solubilization (low molecular-weight alcohols)
- Cosolvent mobilization (high molecular-weight alcohols)
- Surfactant solubilization (hydrophilic fluids)
- Surfactant mobilization (hydrophobic fluids)
- Surfactant micro-emulsion (surfactants and alcohol cosolvents)
- Macro-molecule emulsion (cyclodextrin)
- Steam injection
- Air sparging and venting
- In-well aeration

Based on the evaluation results, Hill AFB is considering full-scale alternatives that will begin during 2002. *In Situ Enhanced Source Removal* (EPA/600/C-99/002), which is available from NRML at www.epa.gov/ada/research/featured.html, provides a comprehensive summary of these technology evaluations.

For more information, contact Dr. Carl Enfield, NRMRL (513-569-7489 or enfield.carl@epa.gov)

EPA is publishing this newsletter as a means of disseminating useful information regarding innovative and alternative treatment techniques and technologies. The Agency does not endorse specific technology vendors.

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