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Ground Water Currents

Developments in innovative ground water treatment

Biodegradation of TCE through Toluene Injection

by Perry L. McCarty, Sc.D., Stanford University

The Western Region Hazardous Substance Research Center (HSRC) recently completed a full-scale *in situ* demonstration of successful trichloroethylene (TCE) biodegradation in contaminated ground water at Edwards Air Force Base (AFB), CA. Through the addition of toluene and oxygen in treatment wells, cometabolism by toluene-using microorganisms caused TCE concentrations ranging between 1,000-1,400 µg/l in the influent aquifer water to fall by 85% with each pass through the wells. Following several passes at flow rates of 25-38 liters per minute, TCE concentrations in ground water ranged from 25-50 µg/l, indicating 95-98% TCE removal.

This 12-month demonstration project encompassed a 22-meter-square treatment zone and a 60-meter-wide influent ground water plume. Stanford University researchers designed a two-well treatment system spanning two aquifers. Toluene, gaseous oxygen, and hydrogen peroxide were injected into each well and mixed with pumped-in contaminated ground water from one aquifer. The mixture then entered the other aquifer, where toluene and TCE biodegradation occurred. Ground water circulated between the two wells and between the two aquifers.

Static mixers at each well dissolved 7-14 mg/l of toluene and a mixture of pure oxygen and hydrogen peroxide to provide the dissolved oxygen concentration of 30-40 mg/l required for toluene degradation. Hydrogen peroxide, added to prevent excessive bacterial growth near the well screens, dissociated in the aquifer to provide part of the required dissolved oxygen. The system added oxygen and peroxide continuously, with additions of toluene in a pulse only once per day over a 2-hour period to achieve more uniform distribution away from the treatment well.

Prior to initiation of this project, regulatory agencies required positive assurance that toluene was actually biodegraded to a level below regulatory concern. Results of an earlier pilot demonstration conducted at Moffett Federal Air Field in Mountain View, CA, showed that this system reduced toluene through biological activity to below 1 µg/l.

In the Edwards AFB demonstration, toluene concentrations leaving the treatment zone averaged 1.6 µg/l, with a maximum measurement of 18 µg/l, which was far below health effects standards (100 µg/l for California and 1000 µg/l for EPA) and below taste and odor thresholds (25-40 µg/l).

The HSRC conducted this demonstration in cooperation with the Armstrong Laboratory, U.S. Air Force; Edwards Air Force Base; Earth Tech; Woodward-Clyde; and EPA's Robert S. Kerr Research Laboratory. For additional information, contact Dr. Perry L. McCarty (Western Region HSRC) at 650-723-4131 or e-mail McCarty@CE.Stanford.edu.

About this Issue

This issue features results of field- and full-scale demonstrations of *in situ* processes under study for their potential effectiveness in cleaning up sites contaminated with solvents, nonaqueous phase liquids (NAPLs), and dense nonaqueous phase liquids (DNAPLs).

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NAPL Solubilization through Single-Phase Microemulsion and Cosolvents

by Stephanie Fiorenza, Ph.D., Rice University, and Michael Annable, Ph.D., University of Florida

University of Florida researchers completed a field-scale demonstration of the effective use of a surfactant/cosurfactant mixture. The surfactant/cosurfactant solution forms a water-continuous, low-viscosity microemulsion when it comes into contact with a nonaqueous phase liquid (NAPL). This microemulsion can be diluted in water and transported through porous media as a single-phase, low-viscosity fluid. With microemulsification of a NAPL, complete solubilization of NAPL components should occur without selectivity.

The U.S. Department of Defense (DOD) Advanced Applied Technology Demonstration Facility (AATDF) program, the Strategic Environmental Research and Development Program (SERDP), Hill Air Force Base (AFB) in Utah, and EPA's National Risk Management Research Laboratory supported this single-phase microemulsion (SPME) project. The demonstration took place in a sheet pile-enclosed test cell at Hill AFB, Operable Unit 1. The 2.8-by-4.6-meter test cell extended to a depth of 11.7 meters below ground surface, 3.7 meters into a clay confining unit.

Researchers flushed nine pore volumes of a solution consisting of 3% surfactant—Brij 97 n(polyoxyethylene (10) oleyl ether)—and 2.5% cosurfactant—n-pentanol—through the test cell. Soil cores were collected before and after the addition of the surfactant/cosurfactant mixture, and testing of pre- and post-flush partitioning tracers was conducted.

NAPL removal was estimated using soil core data, tracer test data, and the mass of target analytes collected in extraction wells. Comparison of target analyte concentrations in pre- and post-treatment soil cores yielded an estimated 91-96% reduction in the three most dominant NAPL constituents (decane, 1,3,5-trimethylbenzene, and undecane). Initial examination of tracer test data indicated an average NAPL removal of 75%. When the mass of target analytes recovered at the extraction wells was compared to initial NAPL mass estimates provided by soil core data or partitioning tracer data, the estimated removal of NAPL was >90% or 60-80%, respectively.

At a recent meeting of the Remediation Technologies Development Forum *In Situ* Flushing Action Team, AATDF and SERDP researchers compared these SPME results with a cosolvent test conducted in a different cell at the same operable unit. The flushing agent used in the cosolvent test consisted of 70% ethanol and 12% pentanol.

Upper and lower layers of the cell showed different performance levels. For example, 99% removal of 1,2-dichlorobenzene was observed at a 16.25-foot depth, while 75% removal was detected at a 20-foot depth. Researchers believe this difference is attributable to higher NAPL saturations in the lower zone and the difficulty of directing a low-density flushing agent to reach deeper layers.

Comparison of the SPME and cosolvent studies concluded that the efficacy of the two methods is comparable, but the flushing agent in the cosolvent study contained more chemical additives that increased costs. For additional information about these two studies, contact Dr. Michael Annable (University of Florida) at 352-392-3294.

Eleven additional projects are nearing completion under the four-year AATDF program. Processes under evaluation through the program include the use of a surfactant/foam process for aquifer remediation and passive and semi-passive techniques for ground water remediation.

DOD initiated the program in 1993 by awarding a $19.3 million grant to a university consortium of research centers led by Rice University. Participating universities include Stanford University, the University of Texas, Rice University, Lamar University, the University of Waterloo, and Louisiana State University. For additional

Calendar

Remediation Technologies Development Forum (RTDF) Permeable Reactive Barriers Action Team Meeting; September 18-19, 1997; Sheraton OceanFront Hotel, Virginia Beach, VA; 617-674-7347 or the World Wide Web at *http://www.rtdf.org* (click on Permeable Reactive Barriers Action Team).

Water Environment Federation 70th Annual Conference & Exposition; October 18-22, 1997; McCormick Place, Chicago, IL; 800-666-0206, confinfo@wef.org (e-mail), or World Wide Web at http://www.wef.org.

Groundwater Foundation "Priming the Pump" Workshop and Annual Groundwater Guardian Designation Conference; November 22-24, 1997; McDonald's Corporation, Oak Brook, IL; 800-858- 4844 or the World Wide Web at *http://www.groundwater.org.*

IBC's Annual Natural Attenuation Conference; December 8-10, 1997; Raddison Resort Scottsdale, Scottsdale, AZ; 508-481-6400 ext. 281, pcanney@ibcusa.com (e-mail), or the World Wide Web at *http://www.ibcusa.com/conf/attenuation.*

The Eighth Annual West Coast Conference on Contaminated Soils and Ground Water; March 8-12, 1998; Embassy Suites Hotel, Oxnard, CA; 413-549-5170, bknowles@aehs.com (e-mail), or the World Wide Web at http://www.aehs.com.

Electronic Information Sources

Commonly referenced World Wide Web sites containing additional information on hazardous waste issues include:

EPA	**http://www.epa.gov**
EPA Superfund Program	**http://www.epa.gov/superfnd**
EPA/Technology Innovation Office (TIO)	
Hazardous Waste Cleanup Information (CLU-IN) System	**http://www.clu-in.com**
EPA/Office of Research and Development (ORD)	**http://www.epa.gov/ord**
EPA/ORD Environmental Technology Verification (ETV) Program	**http://www.epa.gov/etv**
EPA Brownfields Program	**http://www.epa.gov/brownfields**
Ground-Water Remediation Technologies Analysis Center (GWRTAC)	**http://www.gwrtac.org**

information on the AATDF program, contact Dr. Stephanie Fiorenza (Rice University) at 713-527-4725.

In Situ Oxidation Destruction of DNAPL

by Karen Jerome, Westinghouse Savannah River Company

The U.S. Department of Energy (DOE) Office of Science and Technology (Subsurface Contaminant Focus Area) recently completed a full-scale demonstration of the use of hydrogen peroxide and iron to convert chlorinated solvents and hydrocarbons to nontoxic end products such as carbon dioxide, chloride ion, and water (Fenton's reaction). Through a cooperative venture that included Westinghouse Savannah River Company and Geo-Cleanse International, Inc., DOE achieved a destruction efficiency of 94% on a 64,000-cubic-foot site containing nearly 600 pounds of dense nonaqueous phase liquid (DNAPL) at the Savannah River Site in Aiken, SC. A cost evaluation concluded that "hot spot" treatment yields the most cost-effective use of this technology for treating DNAPL.

Researchers determined that a DNAPL pool at a depth of 155 feet should contain 11,000 pounds or more of DNAPL for this technology to be considered more cost efficient than a conventional pump-and-treat system, a baseline technology for DNAPL-contaminated ground water. If time is a key factor in the decision-making process, however, this technology can remove contamination faster than pump-and-treat methods (weeks versus years).

The demonstration deployed this technology to destroy DNAPL below the water table. The DNAPL, consisting of solvents such as trichloroethylene (TCE) and tetrachloroethylene (PCE), was located approximately 140 feet below ground surface in unconsolidated sediments.

Address Change for Technology Practices Manual Requests

Rice University requests that readers interested in obtaining copies of the *Technology Practices Manual for Surfactants and CoSolvents* (referenced in the April 1997 issue) fax the following information to Donald F. Lowe, Ph.D. (Rice University) at 713-285-5948:

name
company
mailing address
telephone number
fax number
e-mail address

The first edition of the manual is currently available on the World Wide Web at *www.ch2m.com/ch2mhill/services/environ/RICEMANUAL/TOC.htm*. The second edition is scheduled for release in Fall 1997.

Treatment involved incremental injection of a total 4,200 gallons of hydrogen peroxide, along with ferrous sulfate. Increased chloride concentrations in ground water and decreased concentrations of TCE and PCE in both ground water and soil served as indicators of DNAPL destruction.

Chloride ion concentrations increased from an initial concentration of 4 ppm to a final concentration of 25 ppm. Post-treatment analysis indicated that PCE and TCE concentrations in ground water fell to nearly zero from 120 mg/l and 20 mg/l, respectively. Pre- and post-tests showed that the total estimated DNAPL quantity dropped from 593 pounds to 36 pounds.

Under its DNAPL remediation program, DOE's Subsurface Contaminant Focus Area soon will complete demonstrations of three additional technologies. At the Portsmouth Gaseous Diffusion Plant, field tests are evaluating the use of potassium permanganate to degrade pure-phase TCE in saturated aquifer sediments using recirculation as a reagent delivery technique. Additionally, researchers are studying the use of stacked horizontal fractures propped with a new permanganate particle grout to form a permeable reactive barrier at the Portsmouth Plant. At a commercial wood treatment facility in California, DOE also is testing the use of hydrous pyrolysis/oxidation for use on DNAPLs and dissolved organic components. Contact Karen Jerome (Westinghouse Savannah River Company) at 803-725-5223 for additional information on the Savannah River Site demonstration, and

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View or download it from CLU-IN at:

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Ground Water Currents welcomes readers' comments and contributions.
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Dr. Thomas Early (Oak Ridge National Laboratory) at 423-576-2103 for information on DOE's *in situ* oxidation work.

New TIO Publications

EPA's Technology Innovation Office (TIO) recently issued three new publications. The eighth edition of *Innovative Treatment Technologies: Annual Status Report* (EPA 542-R-96-010) provides information on Superfund sites at which innovative technologies are in use or are selected for use. The companion information system, *Innovative Treatment Technologies: Annual Status Report Database* (ITT Database) (Version 2.0) (EPA 542-R-96-002) will be released later this Fall.

TIO also updated *Cleaning Up the Nation's Waste Sites: Markets and Technology Trends* (EPA 542-R-96-005), which describes the future demand for remediation services on all major cleanup programs in the U.S., including Superfund, RCRA corrective actions, underground storage tanks, DOE, DOD, and other federal or state programs.

Partnerships for the Remediation of Hazardous Wastes (EPA 542-R-96-006) provides potential private sector partners interested in development of new and innovative hazardous waste technologies with information on opportunities for entering into joint public-private development projects.

Copies of these publications may be obtained from EPA's National Center for Environmental Publications and Information at 513-489-8190 or downloaded from TIO's CLU-IN site at http://www.clu-in.com.

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