TECHNOLOGY NEWS AND TRENDS

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

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Innovative Methods Used to Integrate Soil and Ground-Water Remediation

The Hastings Ground-Water Contamination Site consists of six industrial subsites used for coal gas production, grain storage, manufacturing, and landfilling within the city of Hastings, NE. This Superfund site also encompasses the former Naval Ammunition Depot (NAD) subsite, which is located on 48,000 acres outside the city. Over the past 11 years, soil and ground-water remediation activities have begun or been completed at each of the seven subsites. "Lessons learned" at individual subsites have led to site-wide cleanup plans that are better equipped to maximize use of technologies shown effective within the site's hydrogeologic setting. In addition, updated cleanup plans now reflect a streamlined sequencing of treatment technologies and an increased use of technologies that integrate treatment for both ground water and soil.

Ground water within the upper aquifer at the site is contaminated with a range of volatile organic compounds (VOCs) to depths as great as 165 ft below ground surface (bgs). The upper aquifer consists of Pleistocene-aged sand, silt, and gravel units extending from a depth of about 120 to 225 ft bgs, the top of the Niobrara Formation. Ground-water flow rates in the upper aquifer are estimated to be 0.5-1.5 ft/day.

Due to the vast size and complexity of the Hastings site, cleanup activities are managed in three primary treatment areas: the Central Industrial Area, the Commercial Area and City Landfill, and the East Industrial Park and Former NAD. Treatment technologies used or planned for soil and/or ground-water remediation at one or more of the subsites include soil vapor extraction (SVE), ground-water extraction with ex-situ air stripping, in-well aeration (IWA), in-situ chemical oxidation, clay caps, traditional pump and treat systems, soil excavation/incineration, and in-situ air sparging.

Central Industrial Area

The U.S. EPA's Region 7 and Robert S. Kerr Environmental Research Center conducted a pilot study on the use of SVE for removing carbon tetrachloride (CCl_4) from soil adjacent to a former grain storage facility at a subsite known as "Well #3." With support from the Nebraska Department of Environmental Quality (NDEQ), Region 7 initiated a full-scale SVE system at the subsite in 1992. The SVE wells were designed to withdraw air from discrete depths within the vadose zone. Soil gas extracted through the wells was treated with activated carbon prior to discharge. After one year of treatment, laboratory analyses indicated that SVE had reduced CCl_4 concentrations by 99.8%. Contaminant extraction rates during that time decreased from 0.6 lbs/hr to less than 0.001 lbs/hr.

Based on the success of SVE for removing CCl_4 from soil, two ground-water extraction systems were installed, one of which utilized a former municipal supply well. Extracted ground water was treated through an air stripping process. Within six

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FRTR Plans Conference on Long-Term Remediation

On June 15-17, 2004, the Federal Remediation Technologies Roundtable will sponsor a new conference, *Accelerating Site Closeout, Improving Performance, and Reducing Costs through Optimization*, in Dallas, TX. The conference aims to help remediation program managers, system operators, regulators, and vendors by:

- Outlining long-term remediation liabilities and optimization needs,
- Disseminating optimization strategies and tools,
- Communicating lessons learned, and
- Discussing the use of remedial optimization in site-wide and multi-site management plans.

More information is available on the Technology Innovation Program's CLU-IN website at http://cluin.org/siteopt/siteopt.htm.

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years of treatment, the maximum contaminant level (MCL) for CCl_4 in ground water (5 µg/L) was reached.

Recognizing the large volume of wastewater produced by air stripping, Region 7 installed a park irrigation system in 1997 to beneficially reuse the extracted water. More information on the irrigation system is available in the EPA SITE program report entitled *Sprinkler Irrigation as a VOC Separation and Disposal Method* (EPA/540/R-98/502) available at http://www.epa.gov/ORD/SITE/reports/r98502.html.

EPA released its final record of decision for the subsite in May 2001, determining that continued operation of the converted municipal supply well was needed to address another contaminant plume migrating from a local manufacturing plant but containing trichloroethene (TCE), dichloroethene (DCE), and perchloroethene (PCE). To date, concentrations of TCE, DCE, and PCE in ground water have decreased 99%, 99%, and 98% respectively, as a result of treatment. The system will continue to operate until MCLs for ground water are met—likely within 15 years.

An SVE system also was installed in 1996 at the Central Industrial Area's "Colorado Avenue" subsite. Field staff retained by the potentially responsible party (PRP) used computer modeling results compiled earlier by the Kerr laboratory for the Well # 3 pilot study. The system's "Phase I" SVE wells are designed to remove TCE, 1,1,1-trichloroethane, 1,1- DCE, PCE, and other chlorinated VOCs in deep and intermediate zones of approximately 800,000 yd^3 of soil.

In addition, in-well aeration treatment systems inject air into the Colorado Avenue subsurface through seven IWA treatment wells located in more concentrated areas of the contaminant plume. SVE and the in-well aeration system together have achieved order-of-magnitude contaminant reductions in ground water near the contaminant source. "Phase II" SVE wells will be installed in 2004 to remediate areas not addressed by the Phase I wells, but additional ground-water treatment will be necessary to contain the plume and minimize further contaminant migration.

At the "Second Street" subsite, SVE and in-situ air stripping technologies have been employed since 1997 to remove benzene from soil and ground water. The SVE system was constructed using shallow, intermediate, and deep wells in a design similar to that of the Colorado Avenue subsite. Results of recent sampling indicate that benzene concentrations in the soil gas have decreased significantly, but concentrations in a pumping well remain above the removal action target level (100 µg/L).

An IWA ground-water treatment system installed at the Second Street subsite in 2001 is expected to decrease the overall time required for remediation. Long-term cleanup actions are needed, however, to address a benzene plume that continues to migrate downgradient of the treatment area. While ground-water extraction and in-situ chemical oxidation were selected recently as final remedies, additional technologies are under investigation for enhancing natural biodegradation of organic contaminants in the aquifer.

Commercial Area and City Landfill

Two municipal landfills operated at the site in the 1960s and 1970s to dispose of municipal and industrial wastes. Following the detection of elevated concentrations of TCE, PCE, and vinyl chloride in soil, a clay cap was installed over one of the landfills in 1999 as a source control measure. The record of decision for the second landfill selected a cap followed by monitored natural attenuation.

EPA determined that the two closed landfills and the FAR-MAR-CO subsite, where agricultural products had been stored and handled for over 30 years, were the sources of ground-water contamination throughout the area. Although commingling of contaminated ground water from one landfill and the FAR-MAR-CO subsite occurred, ground-water sampling revealed

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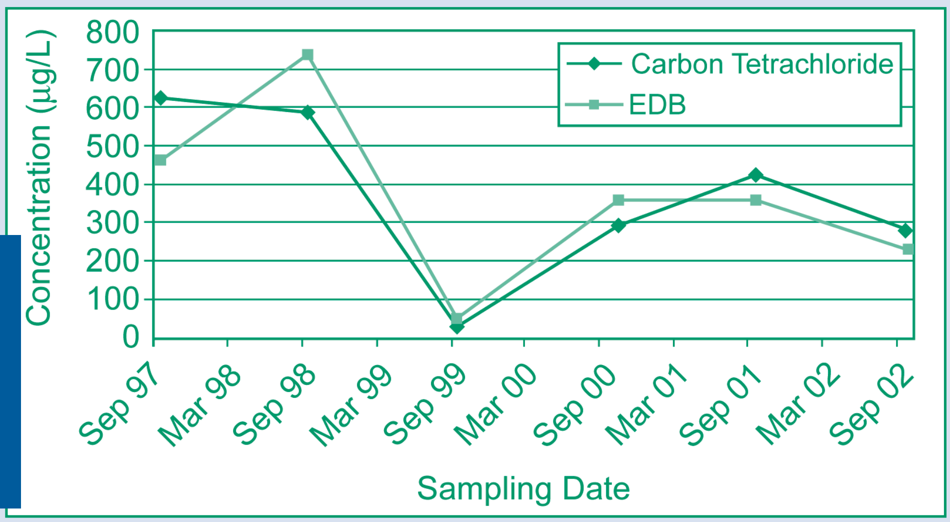

Figure 1: *Although significant increases occurred after treatment was suspended for 12 months, contaminant concentrations in ground water extracted by the combined efforts of SVE-plus and pump-and-treat technology dropped by almost one-half after five years.*

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commercial grain fumigants (primarily CCl_4 and ethylene dibromide [EDB]) were emanating from the FAR-MAR-CO subsite. An SVE pilot study conducted in 1990 successfully removed more than 1,200 lbs of CCl_4 and EDB.

In 1995, PRPs for the landfills and industrial property began working together to plan remediation of the commingled plume. Joint field efforts began in 1997, when a full-scale SVE system was implemented to remediate soil on the industrial property. After 2.5 years of operation, remediation goals for chloroform (138 µg/L), CCl_4 (7.54 µg/L), and EDB (0.0016 µg/L) in soil were reached.

Operational periods were extended again in 2000 to allow treatment to advance to the phase of "SVE-plus," wherein SVE treatment reaches beyond typical soil remediation goals and begins to influence ground-water conditions. Operation of the system for two additional years provided an opportunity to address vadose-zone water that was determined to be the contaminant source. Soil vapor samples collected in November 2002 indicated that no contaminant rebounding has occurred.

A pump and treat system has operated since 1997 to address the CCl_4 and EDB ground-water plume migrating from the industrial property (Figure 1). Region 7 estimates that restoration of the aquifer to maximum contaminant levels for these contaminants will be achieved in 2012.

East Industrial Park and Former NAD

Contaminants of concern at the former NAD include VOCs, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and explosives. In 1995, the U.S. Army Corps of Engineers began remediating VOC-contaminated soil and ground water at the NAD by installing a full-scale air sparging system employing both horizontal and vertical wells. Remedy construction involved excavating soil with low levels of contaminants and incinerating soils with high concentrations of explosives and PAHs. SVE systems also were installed to remove volatile contaminants from soil at three portions of the East Industrial Park and former NAD area.

Cleanup Planning and Review

Region 7 and the NDEQ established an integrated action plan in 2001 to address ground-water contamination across the six industrial subsites. The plan specifies institutional controls, alternate drinking water supplies, well inventories, and extensive ground-water monitoring. In July 2002, EPA completed its second five-year review of cleanup progress at the entire Hastings site. The final report is available at www.epa.gov/region07/superfund.

Contributed by Diane Easley, EPA/Region 7 (913-551-7797 or easley.diane@epa.gov)

SVE and ISCO Used After Pump and Treat for Multimedia Removal of VOCs

EPA Region 1 recently completed its first five-year review of cleanup progress at the Union Chemical Company Superfund site near South Hope, ME. The 1990 record of decision (ROD) selected conventional technologies, including soil excavation with low-temperature aeration and ground-water pump and treat. Cleanup plans have since been modified to incorporate more innovative technologies for removing VOCs. In 1996, SVE augmented with hot air injection was implemented to enhance contaminant volatilization. Monitoring confirmed that by late 1998, two years after SVE treatment had begun, the soil had met project cleanup goals.

Once the soil was clean, the ground-water extraction system was enhanced with in-situ chemical oxidation (ISCO). Potassium and sodium permanganate were injected into the subsurface each summer for three years, resulting in substantial decreases of contaminant concentrations (Figure 2). After recognizing that the peak effectiveness of these injectants

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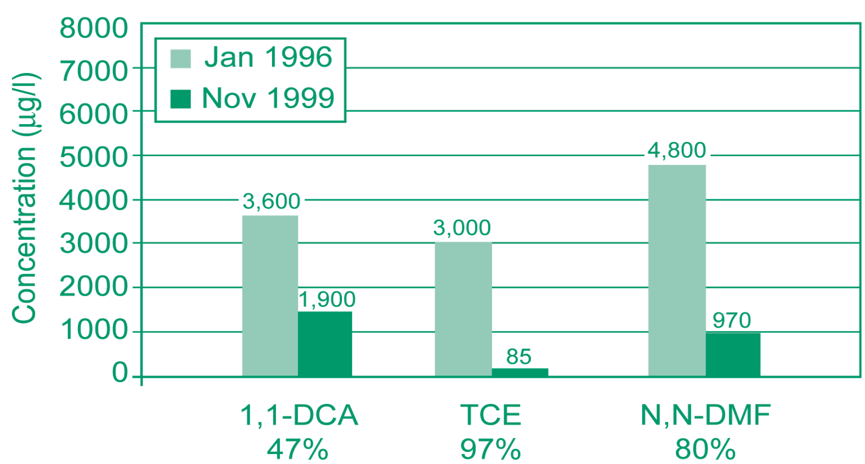

***Figure 2:** Contaminant concentrations in ground water at the Union Chemical site decreased 47-97% following injections of potassium/sodium permanganate solution.*

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had likely been reached, but cleanup goals had not yet been achieved, EPA agreed to incorporate enhanced bioremediation as a final step for ground-water remediation. Molasses and sodium lactate were injected between 2001 and 2002 to serve as carbon sources capable of creating reductive dechlorination conditions in an anaerobic environment.

From 1967 to 1984, Union Chemical used the 12-acre site to manufacture solvents and recover petrochemical-based solvents. Spills from an onsite boiler, disposal of wastewater into an adjacent stream and wetlands, and leakage from storage containers contributed to extensive contamination of the area's soil and ground water. Primary contaminants include TCE, PCE, and 1,1-dichloroethene (DCE) in concentrations reaching 84,000 µg/L, 73,000 µg/L, and 2,700 µg/L, respectively.

Surficial geology at the site consists of a glacial and marine till. The till thickens from less than 25 ft to the west (upgradient) of the site to about 80 ft in the vicinity of Quiggle Brook to the east. The hydraulic conductivity of the till is estimated to be 1×10^{-5} cm/s; the ground-water velocity under non-pumping conditions is approximately 15 ft/yr. A schist/gneiss bedrock containing granitic intrusions underlies the till. The upper 10 feet of the bedrock is weathered and has an estimated hydraulic conductivity of 8×10^{-5} cm/s. Seepage velocity through the bedrock fractures is approximately 300 ft/day. Contaminants were found in both the till and the weathered bedrock.

Conventional Technologies

The pump and treat system operated from 1996 through 1999, and on a limited basis for six months during 2000, to ensure permanganate containment and prevent it from contaminating Quiggle Brook. The system consisted of 28 extraction wells fully screened through the till and 109 monitoring wells. Above-ground treatment of the extracted ground water involved the removal of metals through precipitation and the removal of organic contaminants through air stripping, granular activated carbon absorption, and ultraviolet oxidation (to destroy dimethylformamide [N, N-DMF]). As of 2000, approximately 8.35 million gallons of ground water were treated. A total of approximately 950 pounds of VOCs, including 350 pounds of non-chlorinated VOCs, such as BTEX and ketones, were removed.

SVE Application

The SVE system consisted of 91 hot air injection points and 33 25-foot vapor extraction wells over an area of 1.5 acres. Before the injections began, dewatering took place in order to increase the volume of soil to be treated. Hot air was continuously injected to depths of 6-20 feet from February 1996 to March 1998, except for brief periods of system maintenance and repair. Vapors from both the SVE system and ground-water treatment units were destroyed by a propane-fired thermal oxidizer prior to atmospheric discharge. Soil sampling data collected at the end of August 1998 indicated that concentrations of TCE, 1,1-DCE, and PCE had decreased to below the site-specific target level of 0.1 mg/kg. SVE treatment of 48,000 $yards^3$ of soil resulted in the removal of nearly 9,000 pounds of VOCs.

ISCO Applications

Following the drop-off of contaminant removal via the ground-water extraction system, an ISCO pilot-scale test was performed in late 1997. Based on successful test results, a full-scale system began operating in 1998. Treatment involved the injection of a solution containing either potassium permanganate (2%) or sodium permanganate (20-40%). Injections were performed in both monitoring and extraction wells screened throughout the till and weathered bedrock. Over three summers, approximately 36,000 pounds of potassium permanganate and 7,300 pounds of sodium permanganate were injected. An application rate of 10 times the minimum amount estimated to oxidize the contaminants at each injection point was used across the site.

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Video Viewing on TIP's CLU-IN

The Technology Innovation Program's CLU-IN Internet "studio" hosts streaming videos on a range of topics concerning innovative site characterization and cleanup, such as:

- Introduction to Environmental Geophysics,
- Superfund Redevelopment: Realizing Possibilities
- The Clean Green–Phytoremediation,
- Biosolids Recycling: Restore, Reclaim, Remediate,
- Dynamic Workplans & Field Analytics: The Keys to Cost-Effective Site Cleanup.

The studio is accessible at http://cluin.org/studio/video.cfm.

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Initial post-application data indicated VOC reductions of 30-99% in individual wells. Combined with the ground-water extraction system, the average concentrations of VOCs following permanganate injections in the till decreased from 620-8,050 µg/L to 7-875 µg/L. Similarly, average concentrations of VOCs in the weathered bedrock decreased from 55-725 µg/L to 6-420 µg/L. Ethene contaminants generally responded to the permanganate more readily than the ethane compounds, although some rebounding of TCE and DCE concentrations has occurred.

In August 2001, with DCA as the major remaining contaminant, the system was converted to an anaerobic environment in order to increase the rate of reductive dechlorination. Food-grade molasses and sodium lactate were injected as carbon sources into two separate areas of the site. In August 2002, sodium lactate was applied again, this time in all areas with elevated DCA concentrations. While post-application monitoring of water quality parameters indicated reductive conditions remained through the fall and winter, the April 2003 data were mixed. No significant DCA decrease could be attributed to the sodium lactate application, but a gradual increase of chloroethane (a daughter product of DCA) was observed.

It is estimated that approximately 475 pounds of the four primary contaminants remain in the subsurface. More than 10,000 pounds have been removed using this multiple-technology approach. Currently, the till's low permeability is recognized as the limiting factor in site cleanup completion. Contaminant data indicate that the plume footprints in the till and weathered bedrock have reached equilibrium and are not anticipated to migrate beyond the site boundaries. The installation of additional bedrock wells for field testing is underway to confirm these conditions. All performance standards have been met in the western (upgradient portion) of the site.

Total capital costs for the pump and treat and SVE systems were $9,500,000. The average annual operation and maintenance costs were $600,000 for the (combined) pump/treat and SVE systems and $150,000 for the ISCO system. Additional information on cleanup activities at this and other Region 1 sites is available online at http://www.epa.gov/region01/superfund/sites.

Contributed by Terry Connelly, EPA/Region 1 (617-918-1373 or connelly.terry@epa.gov)

Technology Innovation Program Formed in OSWER Reorganization

As of June 24, 2003, EPA's Technology Innovation Office (TIO) and the Office of Emergency and Remedial Response have joined to form the new Office of Superfund Remediation and Technology Innovation (OSRTI) within the Office of Solid Waste and Emergency Response (OSWER). TIO has changed its name to the Technology Innovation Program. In a second phase of the reorganization, TIP will join with the Environmental Response Team and the Analytical Services Branch to make up the Technology Innovation and Field Services Division, one of three divisions within OSRTI. This phase should be effective by January 2004.

The Technology Innovation Program or "TIP" now publishes the *Technology News and Trends* newsletter and will continue providing an information network for technology decision makers addressing contaminated soil and ground water. TIP's updates and links to its extensive on-line information network, CLU-IN, are available at http://www.epa.gov/tio.

The Agency anticipates that the organizational change will enhance and streamline OSWER's current activities and new initiatives. One such initiative is the One Cleanup Program (OCP), which envisions how different cleanup programs at all levels of government can work together to improve the coordination, speed, and effectiveness of site cleanups. More information about OSRTI activities is available on-line at http://www.epa.gov/superfund/partners/oerr.

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Ann Eleanor
Office of Superfund Remediation and Technology Innovation
(5102G)
U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Ave, NW
Washington, DC 20460
Phone: 703-603-7199
Fax: 703-603-9135

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Project Planning Resources Made Available for Brownfields Cleanup

EPA's Brownfields Technology Support Center assists project managers for local and state organizations and EPA staff addressing the unique issues of brownfield investigations and cleanup. On-line requests can be placed (at http://www.brownfieldstsc.org) for technical assistance in:

- Developing strategies for streamlining site assessment and cleanup,
- Identifying and understanding technology options,
- Evaluating contractor capabilities,
- Explaining technologies to communities, and
- Planning technology demonstrations.

Support is available in the form of site-specific technical assistance, traditional and on-line training seminars, professional conferences, news updates, and technical publications. Recent decision-making tools made available by the center include the primer, *Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup* (EPA 542-B-03-002).