CES
CURRENT ENVIRONMENTAL SOLUTIONS

TECHNOLOGY COMPARISON
Of DNAPL Technologies

Client: US DOE

Launch Complex 34
Cape Canaveral, FL

August 1999-July 2000

"CES' SPH VOTED BEST IN CLASS FOR EFFECTIVENESS, SPEED AND COST"

The Six-Phase Heating (SPH) technology was demonstrated at Launch Complex 34 at Cape Canaveral, Florida, as part of a multiple technology demonstration for the in situ remediation of dense non-aqueous-phase liquids (DNAPL). Representatives of the US Department of Energy, US Environmental Protection Agency, National Risk Management Research Laboratory, National Aeronautics and Space Administration, and the US Air Force formalized the Interagency DNAPL Consortium (IDC) in April 1999 to evaluate remediation techniques for their application to DNAPL. A technical advisory group (TAG) evaluated promising DNAPL remediation by requesting detailed bids from selected technology vendors to demonstrate their commercially available technology at a federal DNAPL site. The TAG ranked the top five technologies in consideration of cost, schedule, and regulatory issues, with results published as shown in the table below. Rating range from one (best) to five (worst). The TAG's overall acceptance was also a consideration. The three technologies selected by the TAG for demonstration were SPH, potassium permanganate injection, and steam injection.

Technology and Ranking	Cost	Schedule	Regulatory	TAG	RANK
1. Six-Phase Heating	2	1	1	1	1
2. $KMnO_3$ injection	1	3	3	1	2
3. Steam injection	4	2	1	2	3
4. Fenton's reagent	3	1	2	5	4
5. Surfactant flushing	5	5	5	3	5

SITE

The site consisted of fine sands to about 23 feet above an irregular layer of clayey fine sands Below the clayey sands was another layer of silty fine sand from 30 to 45 feet below grade (bg). The TCE DNAPL plume primarily residing along the surface of a clay aquitard at a depth of 45 ft. Three areas were demarcated as test cells to enable side-by-side demonstration of the three technologies. Each test cell measured 75 ft × 50 ft. The SPH and potassium permanganate injection technologies were demonstrated over roughly the same time period within the two end cells, approximately 70 ft apart. The last technology, steam injection, was planned for demonstration at a later date in the center test cell.

APPLICATION

The SPH system consisted of 13 electrodes completed to a depth of 43 feet bg. Vapor treatment was accomplished using a 20,000-lb vessel of granular activated carbon (GAC),

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with a final polish by potassium permanganate impregnated onto silica to remove any vinyl chloride. Construction of the SPH system was completed over a three-week period.
The system was operated intermittently over an 11-month period, from August 18, 1999 through July 12, 2000. Beginning six weeks after operations were initiated, Cape Canaveral experienced two hurricanes (Floyd and Irene) and a tropical storm, resulting in unusually heavy rainfall from mid-September 1999 through the end of October 1999. The weather impacted SPH operations by damaging equipment, causing significant delays, and necessitating the redesign of vapor capture systems.

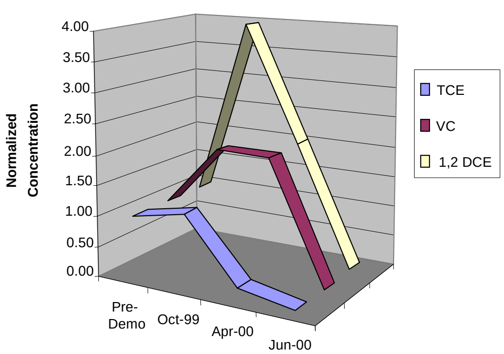
RESULTS

The demonstration was successful in that 97 % of the DNAPL mass was removed. However, the effect of SPH on dissolved-phase fractions of the contaminant could not be quantified because of large influxes of contaminated groundwater caused by tropical storms, and the nearby injection of nearly 2.7 pore volumes of an oxidant solution which created an artificial gradient adjacent to the SPH test area. Attempts to perform a total mass balance on the contaminants were similarly confounded.

Based on the production of elevated levels of chloride ion and other degradation byproducts throughout the demonstration, decontamination took place as follows:

- 44 % was removed via the primary route, an in situ degradation pathway
- 19 % was removed in the vapor phase by steam stripping
- Approximately 2 % was mobilized to the surrounding aquifer during a single flooding
- event caused by a tropical storm that occurred early in the demonstration
- The remaining 33 % could not be accounted for, but is likely to have been degraded in place
- Sampling wells and soil borings beyond the perimeter of the treatment area revealed a
- net decrease in contaminant levels, indicating that treatment extended beyond the boundaries of the test cell

The total cost of the SPH deployment was \$569,000, including all costs for electricity, reporting, secondary waste treatment, equipment mobilization, and significant system modifications and repairs prompted by severe weather. This corresponds to a total unit cost of \$91/yd^3. Of this, the net cost for CES' SPH implementation (design, installation, operations, demobilization) was \$65/yd^3, and the cost of electricity was \$12/yd^3. For comparison, the total cost of the permanganate-injection demonstration was approximately \$1,000,000, or 1.8 times the cost of the SPH technology. The DNAPL removal efficiency achieved by the permanganate treatment was 84 % compared with 97% achieved by SPH. The planned total cost for the steam injection demonstration was also around \$1,000,000.



Typical monitoring well results

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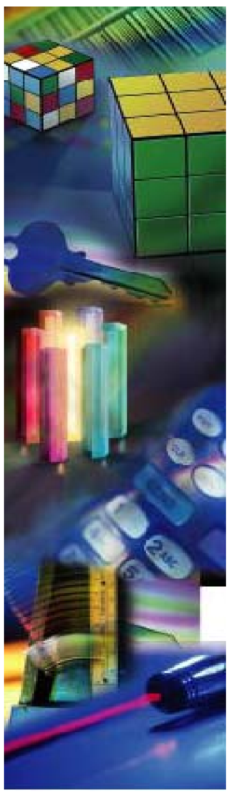

The IDC

Prior to Field Testing…

Rating of Deployment Technologies in Consideration of Cost, Schedule, and Regulatory Issues

Technology (and Ranking)	Cost	Schedule	Regulatory	TAG	TOTAL
1. Six Phase Heating	2	1	1	1	4
2. Permanganate	1	3	3	1	8
3. Steam	4	2	1	2	9
4. Fenton's Reagent	3	1	2	5	11
5. Surfactant Flushing	5	5	5	3	18

"Rating ranged from lowest score (best) to highest (worst). The Technology Advisory Group's (TAG's) acceptance was also a consideration."

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Results of Field Testing:

The three leading DNAPL technologies were demonstrated in 1999/2000 with the following results:

Technology (and Ranking)	Cost	Cost Score	% DNAPL Cleanup	Performance Score	Met Cleanup Goals?
1. Six Phase Heating	$562K	1	97%	1	yes!!
2. Steam Injection (DUS)	$1100K	2	89%	2	no
3. Permanganate (ISCO)	$1200K	3	83%	3	no

(Cleanup Goal – CUG -- was 90% DNAPL mass removal)

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