Interagency DNAPL Consortium Project Update

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ABSTRACT. The U.S. Department of Energy, Office of Science and Technology (DOE-OST); U.S. Air Force Research Laboratory, Air Base and Environmental Technology Division (AFRL/MLQ); U.S. Environmental Protection Agency, National Risk Management Research Laboratory (EPA-NRMRL); National Aeronautics and Space Administration, Kennedy Space Center (NASA-KSC); and the U.S. Air Force 45th Space Wing (45th Space Wing) have combined resources to form the Interagency Dense Non Aqueous Phase Liquids (DNAPL) Consortium. From 1998 through 2001 the Interagency DNAPL Consortium will conduct demonstrations of DNAPL remediation and monitoring technologies. The objective of the demonstrations is to evaluate and compare the cost and performance of *in-situ* DNAPL remediation processes through concurrent testing under realistic, field-scale conditions and in similar geologic environments. The demonstrations are being conducted at Launch Complex 34 (LC34), Cape Canaveral Air Station (CCAS), Florida.

Potassium Permanganate Oxidation

Operations

The initial TCE mass estimate for the permanganate oxidation test cell was substantially lower than the final estimate. Therefore, the injection design was modified to allow additional permanganate applications. The injection program was carried out in a pilot test and three full-scale phases starting on August 12, 1999 and concluding on April 17, 2000.

Injection Phase	Duration (days)	KmnO4 (lbs)	Volume Injected (gals)
Pilot	3	1,402	8,980
Phase I	32	62,676	304,762
Phase II	8	13,825	87,483
Phase II	21	72,750	440,424
TOTAL	64	152,055	850,630

Performance

Battelle performed post-demonstration coring on the permanganate oxidation test cell approximately one month after the conclusion of injection. The results showed that approximately 82% of the total TCE and 84% of the DNAPL TCE had been removed or destroyed. However, the extended monitoring sampling conducted in February 2001 showed some increases in both total TCE and DNAPL TCE mass.

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Mass	Sampling Event	USU	MFGU	LSU	Total for Plot
Total TCE	**Pre-demo (kg)**	846	1,048	4,228	6,122
	Post-demo (kg)	23	233	844	1,100
	Extended Monitoring (kg)	82	160	1,172	1,415
DNAPL	**Pre-demo (kg)**	601	749	3,689	5,039
	Post-demo (kg)	10	163	637	810
	Extended Monitoring (kg)	57	126	1,036	1,219

Cost Analysis

The total invoiced cost for this technology demonstration was $994,057. The total cost incurred by the IT Group (IT) was $1,013,947. In other words, IT shared $19,890 of the total project costs. Other costs directly associated with the demonstration include $4,135 for waste disposal, $170 for electricity, and $2,060 for water. The project also supplied $32,000 in process analysis support through a mobile laboratory. The preliminary design cost of $76,000 should also be included in the total. Therefore, the total cost for the permanganate oxidation demonstration at LC34 amounts to $1,128,312.

On the basis of the first post-demonstration characterization, the permanganate oxidation technology was able to remove or destroy 82% of the TCE present in the test cell. The total amount of TCE treated was 11,044 lbs. Therefore, the unit cost for the demonstration was $102 per lb of TCE removed or destroyed. The unit cost for remediating the soil volume of the test cell was $180.53 per cubic yard.

Six Phase Soil Heating

Operations

Six-Phase Heating ^{TM} (SPH^{TM}) operations were initiated on August 30, 1999 and continued intermittently for six weeks. Rainfall damaged a transformer and raised the water table, rendering the vapor extraction system inoperative. Current Environmental Solutions (CES) replaced the damaged transformer and installed a surface plenum and horizontal vapor extraction wells to ensure TCE capture. The rising water table also flooded an adjacent drainage ditch. Subsequent sampling of the drainage ditch revealed elevated concentrations of TCE. The 45th Space Wing Regulatory Partnering Team reviewed the site conditions after the presence of TCE in the drainage ditch was discovered. Based on Partnering Team review, CES installed additional pressure, temperature, and vacuum monitoring points in and around the SPH treatment cell. Operations were restarted on December 15, 1999 and power input over the next 80 days averaged approximately 6800kW hours per day. However, electrode inefficiencies did not allow for continuous operation of the system and some portions of the treatment cell did not achieve design temperatures. At the end of February, replacement electrodes were installed to increase power input. Over the period from March 3rd to March 24th, 2000, the power input to the cell averaged over 12,200 kW hours per day. Operations were again suspended for a transformer replacement and resumed May 11, 2000. Heating continued until July 12, 2000 and the vapor extraction system operated until August 25, 2000. Power input over the final two months of heating averaged 11,087 kW hours per day.

Product Recovery
TCE recovery increased slowly during December and January and then increased more rapidly during February. Steam production also increased during the same period with a sharp rise after the electrode replacement in late February. However, TCE recovery peaked at approximately the same time as the electrode replacement and fell significantly during March. TCE recoveries during the final two months of heating were modest. Total TCE recovery through the SPH™ system was approximately 1,952 kg, which represents only 17% of the initial mass estimate.

Performance
Battelle performed post-demonstration coring in October and November of 2000. The results showed that approximately 90% of the total TCE and 97% of the DNAPL TCE had been removed or destroyed. Substantial uncertainty exists regarding the fate of approximately 8,000 kg of TCE that was not recovered. It is possible that some amount of TCE was mobilized out of the test cell during heating. CES has estimated that up to 832 kg could have been lost in this manner. However, coring and water sampling outside the test cell has not shown any clear evidence of TCE mobilization. It is also possible that in-situ degradation could account for some of the missing TCE. Limited sampling shows an order-of-magnitude increase in chloride concentrations in the Lower Sand Unit of the test cell. If these concentrations are representative, the increased chloride could have resulted from the degradation of approximately 4000 kg TCE.

Cost Analysis
The contract costs to CES for preliminary and final design, mobilization, operations, demobilization, and reporting totaled $530,902. Total electricity usage was 1,725,801 kW hours @ $0.042 per kW hour for a total electricity cost of $72,484. Waste disposal for the project totaled $39,713. Therefore the total cost for the SPH™ demonstration was $643,099. The amount of TCE removed or destroyed from the test cell was 10,212 kg or 22,513 lbs. The cost per pound of TCE removed or destroyed was $28.57 and the unit cost for remediating the soil volume in the test cell was $102.90 per cubic yard.

Influence of Demonstrations Outside the Test Cells

Both the permanganate oxidation and SPH™ demonstrations had significant impacts outside the test cell boundaries. The injection of permanganate solution generated a strong radial gradient outward from the oxidation plot. Elevated levels of potassium permanganate have been found outside the test cell boundaries. Hot water at shallow depths was released from the SPH™ test cell. The increased flow of groundwater from the permanganate test cell likely exacerbated the release of heated shallow groundwater from the SPH™ cell.