BENCH-SCALE TESTING OF REMEDIAL TECHNOLOGIES FOR NAPLS CONTAINING PCBS AND CHLORINATED BENZENES

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ABSTRACT

Bench-scale tests of various potential remedial technologies were performed on samples of NAPLs and NAPL-saturated soils containing PCBs and chlorinated benzenes obtained from a CERCLA site in western Pennsylvania. Two destruction technologies (in-situ oxidation and a biological treatment process) were tested in a laboratory setting to determine if the technologies are capable of remediating the specific contaminants and concentrations found in site media. Solubility and viscosity tests using various solvents and at various temperatures were also performed to determine the viability of solvent washing and/or electrical resistivity heating in improving the effectiveness of NAPL recovery wells. The bench-scale oxidation tests indicate a full-scale efficiency of approximately 5 pounds hydrogen peroxide per pound of organic contaminant, depending on the silt content of the impacted soils. The biological treatment tests indicated destruction of up to 89 percent of the organic contaminants within two weeks. Solvent washing with isopropanol indicated a transfer of up to 88 percent of the organic contaminants from the impacted soil to the solvent. No hazardous intermediate or final degradation products were observed to have been formed during any of these tests.

SITE BACKGROUND

Both light and dense non-aqueous phase liquids (LNAPLs and DNAPLs) are present in the alluvial aquifer at the site, predominantly located in the vicinity of a former above- and below-ground storage tank farm. Based on available product measurements, the estimated volume of LNAPLs, consisting of PCBs and mineral oil, is approximately 60,000 gallons, at typical depths of 12 to 15 feet below ground surface. The estimated volume of DNAPLs, consisting of PCBs and trichlorobenzene, is approximately 900,000 gallons, at typical depths of 35 to 45 feet below ground surface. The alluvial aquifer is underlain by a relatively impermeable glacial till, which has retarded the further vertical migration of DNAPLs. Likewise, neither the LNAPL or DNAPL layers have shown significant horizontal migration.

As part of the Feasibility Study for the site, bench-scale tests were performed for several potential NAPL remedial technologies in October 1999.

IN-SITU OXIDATION

Geo-Cleanse International, Inc. was provided with two samples of DNAPL-saturated subsurface soils in order to conduct lab testing of their Geo-Cleanse® treatment process, in which organic contaminants are chemically oxidized using a mixture of hydrogen peroxide and ferrous iron (Fenton's reagent). The results of the testing (see Table 1) indicated that the Geo-Cleanse® process can effectively oxidize chlorinated benzenes, but the oxidation of PCBs was dependent on the soil grain size, with more efficient oxidation occurring in coarser-grained soils. Based on the lab results, a full-scale efficiency of approximately 4.6 pounds of 50 percent hydrogen peroxide per pound of organic contaminant was estimated. These findings are generally consistent with published findings from other studies of Fenton's reagent oxidation of these compounds. This process would be implemented in the field by injecting the hydrogen peroxide/ferrous iron solution directly into the NAPLs and associated groundwater.

Table 1 – Results of Oxidation Tests

	Sandy Soils	Silty Soils
Pre-Treatment Soil Contaminant Mass (g)	112.1	211.0
Post-Treatment Soil Contaminant Mass (g)	53.6	156.5
Percent of Contaminants Oxidized:		
Chlorinated Benzenes	53.7	82.2
PCBs	51.7	none

IN-SITU BIOREMEDIATION

Environmental Remediation Consultants, Inc. was provided with approximately two gallons of DNAPL and LNAPL-impacted groundwater in order to assess the degradative capabilities of their Bio-Integration™ process. After initial difficulties, the test media were eventually homogenized and diluted such that testing using biotic and abiotic co-treatments could proceed. Test results indicated that trichlorobenzene concentrations in the homogenized mixtures were reduced by 66 percent within seven days, and PCB concentrations were reduced by up to 89 percent within 14 days (see Table 2). This process would be implemented in the field by creating a homogenous mixture of NAPLs, groundwater, and amendments either within the aquifer or in above-ground reactors.

Table 2 – Results of Biological Treatment Tests

	1:100 Dilution of NAPLs		1:1000 Dilution of NAPLs	
Aroclor-1254 Conc. (μg/l)	Co-treatment only	Co-treatment + bacteria	Co-treatment only	Co-treatment + bacteria
At t = 0 days	1,650	NA	159	116
At t = 7 days	831	903	112	91
At t = 14 days	398	353	17	14
Percent Removal	76	NA	89	88

SOLUBILITY TESTING AND SOLVENT WASHING

Applied Hydrology Associates, Inc. was provided with approximately four gallons each of DNAPL and LNAPL in order to evaluate NAPL solubility in various solvents and viscosity at various temperatures. Based on the preliminary findings, additional testing was performed on DNAPL and LNAPL-impacted soils to evaluate the effects of washing the soil with a solvent (isopropanol) to remove NAPL constituents. The findings of the testing indicate that NAPL viscosity can be substantially reduced through electrical resistivity heating or by injecting isopropanol, or by both methods, thereby improving the efficiency of extraction methods such as pumping (see Table 3). Chemical analysis of impacted soil washed with isopropanol indicated that up to 88 percent of the contaminant mass was transferred from the soil to the solvent during washing tests (see Table 4). In a field implementation, this solvent/NAPL/water mixture would be pumped to the surface for subsequent treatment, potentially including phase separation and solvent recycling.

Table 3 – Results of Viscosity Tests

Viscosity in centistokes	**65 °F**	**100 °F**	**210 °F**
Avg. LNAPL Viscosity	23.7	10.8	2.9
LNAPL + IPA (50/50 mix)	5.4	3.0	1.5
Avg. DNAPL Viscosity	34.9	11.5	2.8
DNAPL + IPA (50/50 mix)	4.0	2.2	1.0

Table 4 – Results of Solvent Washing Tests

	1,2,4-TCB	**1,2,3-TCB**	**PCB-1254**
Pre-test Soil Contaminant Mass (g)	0.196	0.063	1.111
Post-test Soil Contaminant Mass (g)	0.039	0.015	0.122
Percent of Contaminant Removed	79	75	88

CONCLUSION

The results of the bench-scale tests were submitted to the state and federal agencies in November 1999, and the findings, along with "ballpark" full-scale implementation cost estimates, were incorporated into the Final Feasibility Study for NAPLs submitted in June 2000. Based on current estimates of NAPL volumes, a full-scale implementation of the Geo-Cleanse® process, without prior removal of NAPLs, would have an estimated net present worth of approximately $28 million. Full-scale implementation of either the Bio-Integration™ process or direct and solvent/heat-enhanced pumping of NAPLs would have an estimated net present worth of approximately $6 to 8 million. The success of the Geo-Cleanse® process would be dependent on the distribution of silty and sandy soils within the NAPL-impacted area. The success of either of the other two methods would be dependent on the ability draw significant volumes of NAPLs to the recovery wells. USEPA is expected to issue a Proposed Plan for a NAPL remedy in the spring of 2001.

REFERENCES

Applied Hydrology Associates, Inc., 1999, "Bench-Scale Testing of NAPL Removal Parameters," November.

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