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HARTCROWSER

Earth and Environmental Technologies

Treatability Study for PCE Impacted Soils Anchorage, Alaska

Prepared for
TERRASAT, INC.

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TABLES

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TREATABILITY STUDY FOR PCE IMPACTED SOILS
TERRASAT, INC.
ANCHORAGE, ALASKA

INTRODUCTION

In October 1992, Hart Crowser, Inc. was contacted by a representative of TERRASAT, INC. for information concerning the remediation of soil impacted by halogenated volatile organics (HVO) at a proprietary site in Anchorage, Alaska. Elevated concentrations of perchloroethlyene (PCE) and methylene chloride (MeCl) have been detected from soil samples collected during site investigation activities conducted by TERRASAT.

On May 5, 1993, representatives from Hart Crowser and TERRASAT collected four aseptic soil samples from a test pit at a predetermined location on the site. The samples were used for a treatability study to determine the appropriate remedial alternative.

This report presents the results of the treatability study suggested and applications of the data.

MICROBIAL ENUMERATION

The biological activity of the soil was measured using standard microbiological plating techniques (Hart Crowser, 1992). The microbial counts for the soil samples are reported in Table 1. Experimental results indicate moderate numbers of heterotrophic and methanotrophic HVO degrading bacteria, capable of growing at a temperature of 10°C, are present at the site. Low to moderate numbers of aerobic HVO degraders are present at the site. The total heterotrophic microbial population (TMP) counts from all soil samples ranged from 120,000 colony forming units per gram of soil (cfu/g) (S-4) to 510,000 cfu/g (S-1). The methanotrophic HVO degrading population (HDP) ranged from 64,000 cfu/g (S-4) to 580,000 cfu/g (S-3). The aerobic HVO degrading population (ADP) ranged from 7,600 cfu/g (S-2) to 48,000 cfu/g (S-3).

NUTRIENT ANALYSIS

Static microcosms were used to determine the optimum inorganic nutrient amendments for bioremediation at the site. Indigenous microorganisms collected from the soil samples were used in batch

experiments conducted under methanotrophic and aerobic conditions to determine the combination of inorganic nutrients which provided optimum growth for the organisms. The nitrogen sources tested included urea, ammonium nitrate, and ammonium sulfate. Phosphorous and potassium requirements were determined by using mono- and dibasic salts of sodium and potassium phosphate. In addition, the requirement for the micronutrients sodium carbonate, calcium chloride, magnesium, manganese, and iron were tested in combination with the above amendments to determine if these nutrients can be shown to be growth-limiting at this site. MeCl (500 mg/L) and PCE (100 mg/L) were added to each microcosm, with the exception of the positive control, as a possible carbon source or cometabolite for the organisms.

A total of 13 microcosms, one for each nutrient combination tested, were set up and incubated at a temperature of 10°C for two weeks. The optimum nutrient amendment, which promotes the best growth of the microorganisms, was chosen on the basis of the greatest increase in the turbidity of the nutrient solution.

Table 2 presents the results of the nutrient analysis. The indigenous population of methanotrophic and aerobic microorganisms exhibited the greatest growth response to Treatments E and F. The inorganic nutrients in Treatment E were ammonium nitrate, mono- and dibasic salts of potassium phosphate, and micronutrients. The inorganic nutrients in Treatment F were ammonium nitrate, mono- and dibasic salts of sodium phosphate, and micronutrients. The micronutrients were sodium carbonate, calcium chloride, magnesium sulfate, manganese sulfate, and iron sulfate.

Treatment F was chosen for use during the degradation testing because sodium phosphate salts are readily available and less expensive than potassium phosphate salts.

DEGRADATION STUDIES

Degradation and contaminant mobility studies were carried out in glass columns packed with soil from samples obtained from the test pit. Soil sample S-1 was used for the degradation experiments because of elevated concentrations of PCE, the contaminant of interest (Table 1). Soil-packed columns were used during this experiment to establish biodegradation rates, utilizing appropriate controls.

Soil obtained from the test pit was composited, split into fractions, and used to uniformly pack the columns to resemble soil conditions at the

site. A sample was sent to North Creek Analytical (NCA), Bothell, Washington, for analysis of HVO (EPA Method 8010) and HVO per the Toxic Characteristic Leaching Procedure (HVO-TCLP). These analyses were chosen to determine the levels of PCE present in the soil and its relative mobility prior to the start of the treatability study.

Sterile nutrient solution or a microbial inoculum, where appropriate, was added to the soil at the top of the column and allowed to percolate through the soils in the column. Air, methane enriched air, or ammonia enriched air was passed through the column, singly or in combination, to adequately ventilate the soil in the column (rate corresponds to field application of approximately 100 scfm). The experiment was run for a period of four weeks in a temperature controlled room at 10°C. After completion of the experiment, the columns were dismantled and soil samples were submitted to NCA for HVO and HVO-TCLP analyses.

A total of twelve columns were used to examine both *in situ* and *ex situ* treatment alternatives. Eight *in situ* and four *ex situ* treatments were investigated.

In Situ Testing

Eight separate treatments were tested during the *in situ* degradation experiment: Treatment 1 - methane enriched air (2.5% methane); Treatment 2 - ammonia enriched air (35 ppm ammonia); Treatment 3 - methane and ammonia enriched air; Treatment 4 - methane enriched air and nutrient addition; Treatment 5 - soil venting; Treatment 6 - soil venting and nutrient addition; Treatment 7 - nutrient addition, no soil venting; Treatment 8 - no treatment.

The results of the *in situ* degradation experiment are shown in Table 3. Laboratory data are provided in Appendix A. Laboratory analyses of the soils used for the degradation experiment revealed the initial PCE concentration in the soils was 5.6 mg/Kg (samples PRE 1 and 2 Composite). Post-treatment samples are identified in the laboratory report by treatment number.

The greatest reduction in PCE concentration during the *in situ* testing was produced by Treatments 1 (methane enriched air) and 3 (methane and ammonia enriched air) which reduced the PCE concentration in the soil to 1.4 mg/Kg, a 75 percent reduction. A similar reduction was noted for Treatment 2 (ammonia enriched air) where the PCE concentration in the soil was reduced to 1.7 mg/Kg, a 70 percent reduction. Treatment 5 (soil venting) reduced the PCE concentration to

1.9 mg/Kg, a 66 percent reduction. Treatment 4 (methane enriched air and nutrient addition) reduced the PCE concentration in the soil by 12 percent to 4.9 mg/Kg, and was the only other treatment to produce a reduction in the PCE concentration in the soil during the test.

The TCLP analysis for Treatments 1, 2, 3, and 5 indicate similar reductions in the concentration of TCLP-PCE in the soils. A reduction of 71 to 76 percent was observed for these treatments. The TCLP analysis for Treatments 4 and 6 produced a TCLP-PCE reduction of 39 and 28 percent, respectively.

The results of the microbial enumeration for the *in situ* degradation studies are shown in Table 4. The average TMP density present in the soil prior to the additional degradation experiments was 510,000 cfu/g. The enumeration of the columns sampled after one month showed a 1.3 to 2.8 fold decrease in the TMP. During the same period, the HDP remained constant or showed an increase of approximately 2.2 fold from an average density of 450,000 cfu/g.

Ex Situ Testing

Four separate treatments were tested during the *in situ* degradation experiment: Treatment 9 - methane enriched air and microbial inoculum; Treatment 10 - ammonia enriched air and microbial inoculum; Treatment 11 - only microbial inoculum; Treatment 12 - microbial inoculum and soil venting.

The results of the *ex situ* degradation experiment are shown in Table 5. Laboratory data are provided in Appendix A. Laboratory analyses of the soils used for the degradation experiment revealed that the initial PCE concentration in the soils was 5.6 mg/Kg (samples PRE 1 and 2 Composite). Post-treatment samples are identified in the laboratory report by treatment number.

The greatest reduction in PCE concentration during the *ex situ* testing was produced by Treatment 12 (microorganisms and soil venting) where the PCE concentration in the soil was reduced to 2.4 mg/Kg, a 57 percent reduction. Treatment 10 (microorganisms and ammonia enriched air) resulted in a reduction of the PCE concentration to 3.3 mg/Kg, a 41 percent reduction. Treatment 9 (microorganisms and methane enriched air) reduced the PCE concentration in the soil to 5.0 mg/Kg, a reduction of 11 percent. The 34 percent increase in PCE concentration noted for Treatment 11 may be due to sampling heterogeneity.

The results of the microbial enumeration for the *ex situ* degradation studies are shown in Table 6. The average TMP density present in the soil prior to the *ex situ* degradation experiments was 510,000 cfu/g. The enumeration of the columns sampled after one month showed a 1.2 to 2.6 fold decrease in the TMP. During the same period, the HDP increased 1.2 to 2.7 fold from an average density of 450,000 cfu/g.

CONCLUSIONS

An exhaustive, statistically verifiable, quantitative analysis of the data is beyond the scope of this project, but trends in the data are apparent. Similar results and degradation half-lives were received from four of the treatment scenarios tested during this treatability study (Treatments 1, 2, 3, and 5), and these remarks will concentrate on those treatments. The degradation half-life is defined as the amount of time required to reduce the concentration of a contaminant to one-half of its original value.

The predominant mechanism for removal of PCE from the soil appears to be volatilization, as evidenced by the 66 percent reduction noted for Treatment 5 (soil venting). Volatilization is thought to account for this reduction because no reports of aerobic PCE biodegradation can be found in the scientific literature. The calculated volatilization half-life of 13.2 days is in the range of those reported by Kempton, Davis and Olsen (1992).

Vogel and McCarty (1985) report the biotransformation of PCE by reductive dechlorination under methanogenic conditions. Biotransformation of chlorinated aliphatics by aerobic, methanotrophic, and ammonia-oxidizing bacteria is reported in the literature (Wilson and Wilson, 1985; Speitel and Alley, 1991; Vannelli et. al., 1990). However, biodegradation of PCE has not been successful under these conditions, although, it is theoretically possible.

There appears to be a sufficient microbial population for bioremediation to be successful at this site. It also appears that biodegradation may enhance the rate of PCE removal from the soil tested during the treatability study. The calculated half-life for the methane enriched and methane and ammonia enriched soil (Treatments 1 and 3) is 9.7 days. The calculated half-life for the ammonia enriched soil (Treatment 2) is 11.7 days.

The degree of soil saturation (Table 3) also appears to affect the removal of PCE from the soil under the conditions tested. Evidence of

this effect is noted for Treatments 1 and 4 as well as Treatments 5 and 6. For each case, the most significant reduction in PCE concentration in the soil was noted for the least saturated soil. This effect could be caused by a lack of uniform air flow as is frequently noted in saturated soils.

APPLICATION

The results of the treatability study indicate a positive prospect for the remediation of PCE-impacted soil at TERRASAT's site. The data suggest the most effective means of remediation is bioremediation via methane enriched air injection.

While bioremediation appears to be the most efficient technique, it may not be the most economical remedial action. Volatilization through soil vapor extraction appeared to be only a slightly less efficient process for removing PCE from the soil. It is, however, a considerably less expensive remedial alternative and may warrant further consideration.

LIMITATIONS

The work of this project was performed and this report was prepared in accordance with generally accepted professional practices for the nature of the work completed in the same or similar localities at the time the work was performed. It is intended for the exclusive use of TERRASAT, INC. for specific application to the project site. This report is not meant to represent a legal opinion, and no other warranty, express or implied, is made.

Any questions regarding the field work or report, the presentation of the information, or the interpretation of the data are welcome and can be addressed to Hal Marlow at 276-7475.

Sincerely,

HART CROWSER, INC.

Harold J. Marlow
Project Environmental Scientist

James D. Gill, P.E.
Alaska Manager

HJM/kgd

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REFERENCES

Hart Crowser, 1992. Proposal for Biotreatability Testing, TERRASAT, INC., Anchorage, Alaska, 5 pp.

Kempton, H., A. Davis and R. Olsen, 1992. Remediation of Solvent-Contaminated Soils by Aeration. J. Environ. Qual. 21:121-128.

Vogel, T.M. and P.L. McCarty, 1985. Biotransformation of Tetrachloroethylene to Trichloroethylene, Dichloroethylene, Vinyl Chloride and Carbon Dioxide Under Methanogenic Conditions. Applied and Environmental Microbiology, 49(5), 1080-1083.

Wilson, J.T. and B.H. Wilson, 1985. Biotransformation of Trichloroethylene in Soil. Applied and Environmental Microbiology, 49(1), 242-243.

Speitel, G.E. and E.R. Alley, 1991. Bioremediation of Unsaturated Soils Contaminated with Chlorinated Solvents. Proceedings of the Third Annual Gulf Coast Hazardous Substance Research Center Symposium. Lamar University, Beaumont, Texas.

Vannelli, T. M. Logan, D. Arciero, and A. Hooper, 1990. Degradation of Halogenated Aliphatic Compounds by the Ammonia-Oxidizing Bacterium Nitrosomonas europaea. Applied and Environmental Microbiology 56(4), 1169-1170.

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TABLE 1: BIOTREATABILITY STUDY
SOIL MICROBIAL ENUMERATION
TERRASAT, INC.
ANCHORAGE, ALASKA

SAMPLE NUMBER	SENSIDYNE READING PCE tube (ppm)	SOIL TYPE	TOTAL HETEROTROPHIC (cfu/g)*	METHANE ENRICHED HVO DEGRADERS (cfu/g)	AEROBIC HVO DEGRADERS (cfu/g)
S-1	12	Sand with Gravel and Silt	510,000 [87,000]	450,000 [99,000]	39,000 (a)
S-2	6	Sand with Gravel and Silt	140,000 [110,000]	100,000 [9,200]	7,600 (a)
S-3	4	Sand with Gravel and Silt	490,000 [98,000]	580,000 [70,000]	48,000 (a)
S-4	0	Sand with Gravel and Silt	120,000 [7,600]	64,000 [6,600]	(b)

(cfu/g) – Colony forming units/gram of soil
* – Results are the mean of three plate counts [standard deviation]
(a) – Duplicate sample, average of 2 plates reported
(b) – Sample not plated

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TABLE 2: BIOTREATABILITY STUDY
NUTRIENT ANALYSIS
TERRASAT, INC.
ANCHORAGE, ALASKA

TREATMENT	NUTRIENTS ADDED*	METHANE ENRICHED CULTURE #	AEROBIC CULTURE #
A	U, 1, S	++	0
B	U, 2, S	++	0
C	U, 1, N	0	0
D	U, 2, N	0	0
E	AN, 1, S	++++	+++
F	AN, 2, S	++++	+++
G	AN, 1, N	0	0
H	AN, 2, N	0	0
I	AS, 1, S	+++	++
J	AS, 2, S	+++	++
K	AS, 1, N	+	0
L	AS, 2, N	0	0
M(a)	AN, 2, S	0	0
N(b)	AN, 2, S	0	0

* – Nutrients Added:
U–Urea
AN–Ammonium nitrate
AS–Ammonium sulfate
1–Mono– and dibasic salts of potassium phosphate
2–Mono– and dibasic salts of sodium phosphate
S–Trace metals
N–No trace metals

(a) – Positive control (no carbon source)
(b) – Negative control (no microorganisms added)

– Quantitative growth assessment:
0 – No turbidity
+ – Slight turbidity
++ – Minimal tubidity
+++ – Moderate turbidity
++++ – Significant tubidity

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TABLE 3: BIOTREATABILITY STUDY
IN SITU DEGRADATION TESTING
DEGRADATION RESULTS
TERRASAT, INC.
ANCHORAGE, ALASKA

TREATMENT*	SAMPLE I.D.	PCE (mg/Kg)	PERCENT PCE REDUCTION	TCLP-PCE (mg/l)	SOIL MOISTURE
INITIAL	PRE-1&2 COMP	5.6	INITIAL	0.18	6.0%
Methane enriched	#1	1.4	75%	0.046	5.0%
Ammonia enriched	#2	1.7	70%	0.040	5.0%
Methane and ammonia	#3	1.4	75%	0.038	5.0%
Methane and nutrients	#4	4.9	12%	0.13	8.0%
Soil venting	#5	1.9	66%	0.048	5.0%
Soil venting and nutrients	#6	5.7	-2%	0.11	9.0%
Nutrients, no soil venting	#7	5.6	0%	NA	8.0%
No nurtients, no soil venting	#8	5.6	0%	NA	5.0%

NA - Not Analyzed

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TABLE 4: BIOTREATABILITY STUDY
IN SITU DEGRADATION TESTING
POST TREATMENT – SOIL MICROBIAL ENUMERATION
TERRASAT, INC.
ANCHORAGE, ALASKA

TREATMENT*	SAMPLE I.D.	TOTAL HETEROTROPHIC (cfu/g)**	METHANE ENRICHED HVO DEGRADERS (cfu/g)
INITIAL	PRE-1&2 COMPOSITE	510,000 [87,000]	450,000 [99,000]
1	#1	140,000 [140,000]	930,000 [71,000]
2	#2	360,000 (a)	600,000 [38,000]
3	#3	280,000 (a)	730,000 [11,000]
4	#4	400,000 (a)	1,000,000 [95,000]
5	#5	220,000 (a)	790,000 [72,000]
6	#6	180,000 [140,000]	580,000 [40,000]
7	#7	200,000 [50,000]	430,000 [110,000]
8	#8	380,000 (a)	460,000 [130,000]

* – TREATMENT:
1 – Methane enriched
2 – Ammonia enriched
3 – Methane and ammonia enriched
4 – Methane and nutrient addition
5 – Soil venting
6 – Soil venting and nutrient addition
7 – Nutrient addition, no soil venting
8 – No addition, no soil venting

** – Results are the mean of three plate counts [standard deviation]

(a) – Duplicate sample

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TABLE 5: BIOTREATABILITY STUDY
EX SITU DEGRADATION TESTING
DEGRADATION RESULTS
TERRASAT, INC.
ANCHORAGE, ALASKA

TREATMENT*	SAMPLE I.D.	PCE** 1311/8010 (mg/Kg)	PERCENT PCE REDUCTION
INITIAL	PRE–1&2 COMP	5.6	INITIAL
9	#9	5.0	11%
10	#10	3.3	41%
11	#11	7.5	–34%
12	#12	2.4	57%

* – TREATMENT:
9 – Methane and microorganisms
10 – Ammonia and microorganisms
11 – Microorganisms only
12 – Microorganisms and soil venting

** – NOTE: Results reported on a "Dry Weight" basis

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TABLE 6: BIOTREATABILITY STUDY
EX SITU DEGRADATION TESTING
POST TREATMENT – SOIL MICROBIAL ENUMERATION
TERRASAT, INC.
ANCHORAGE, ALASKA

TREATMENT*	SAMPLE I.D.	TOTAL HETEROTROPHIC (cfu/g)**	METHANE ENRICHED HVO DEGRADERS (cfu/g)
INITIAL	PRE-1&2 COMPOSITE	510,000 [87,000]	450,000 [99,000]
9	#9	280,000 (a)	1,200,000 [170,000]
10	#10	360,000 (a)	710,000 [82,000]
11	#11	200,000 (a)	590,000 [32,000]
12	#12	410,000 [44,000]	540,000 [67,000]

* – TREATMENT:
9 – Methane and microorganisms
10 – Ammonia and microorganisms
11 – Microorganisms only
12 – Microorganisms and soil venting
(cfu/g) – Colony forming units/gram of soil
** – Results are the mean of three plate counts [standard deviation]
(a) – Duplicate sample

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TABLE 7: BIOTREATABILITY STUDY
PCE DEGRADATION RESULTS AND DETECTION LIMITS
TERRASAT, INC.
ANCHORAGE, ALASKA

TREATMENT*	SAMPLE I.D.	PCE (mg/Kg)	PCE DETECTION LIMIT (mg/Kg)	TCLP-PCE (mg/Kg)	TCLP-PCE DETECTION LIMIT (mg/Kg)
INITIAL	PRE-1&2	5.6	0.050	0.18	0.0010
IN SITU					
Methane enriched	#1	1.4	0.050	0.046	0.0010
Ammonia enriched	#2	1.7	0.050	0.040	0.0010
Methane and ammonia	#3	1.4	0.050	0.038	0.0010
Methane and nutrients	#4	4.9	0.050	0.13	0.0010
Soil venting	#5	1.9	0.050	0.048	0.0010
Soil venting and nutrients	#6	5.7	0.050	0.11	0.0010
Nutrients, no soil venting	#7	5.6	0.050	NA	NA
No nurtients, no soil venting	#8	5.6	0.050	NA	NA
EX SITU					
Methane and microorganisms	#9	5.0	0.050	NA	NA
Ammonia and microorganisms	#10	3.3	0.050	NA	NA
Microorganisms only	#11	7.5	0.050	NA	NA
Microorgamisms and soil venting	#12	2.4	0.050	NA	NA

NA - Not Analyzed

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TABLE 8: BIOTREATABILITY STUDY
MECL DEGRADATION RESULTS AND DETECTION LIMITS
TERRASAT, INC.
ANCHORAGE, ALASKA

TREATMENT*	SAMPLE I.D.	MECL (mg/Kg)	MECL DETECTION LIMIT (mg/Kg)	TCLP-MECL (mg/Kg)	TCLP-MECL DETECTION LIMIT (mg/Kg)
INITIAL	PRE-1&2	ND	0.25	ND	0.0050
IN SITU					
Methane enriched	#1	ND	0.25	ND	0.0010
Ammonia enriched	#2	ND	0.25	ND	0.0010
Methane and ammonia	#3	ND	0.25	ND	0.0010
Methane and nutrients	#4	ND	0.25	ND	0.0010
Soil venting	#5	ND	0.25	ND	0.0010
Soil venting and nutrients	#6	ND	0.25	ND	0.0010
Nutrients, no soil venting	#7	ND	0.25	NA	NA
No nurtients, no soil venting	#8	ND	0.25	NA	NA
EX SITU					
Methane and microorganisms	#9	ND	0.25	NA	NA
Ammonia and microorganisms	#10	ND	0.25	NA	NA
Microorganisms only	#11	3.2	0.25	NA	NA
Microorgamisms and soil venting	#12	ND	0.25	NA	NA

ND - Not Detected
NA - Not Analyzed