APPENDIX B

ANAEROBIC BIODEGRADATION TREATABILITY STUDY REPORT

Draft

Anaerobic Biodegradation Treatability Study Report
Small Weapons Repair Shop, Parcel 66(7)

Fort McClellan
Calhoun County, Alabama

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Task Order CK10
Contract No. DACA21-96-D-0018
IT Project No. 774645

September 2002

Revision 1

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List of Acronyms and Abbreviations

bgs	below ground surface
CO_2	carbon dioxide
COPC	chemical(s) of potential concern
DCA	dichloroethane
DCE	dichloroethene
DO	dissolved oxygen
Fe^{+3}	ferric iron
Fe^{+2}	ferrous iron
foot/day	foot per day
FTMC	Fort McClellan
HRC	hydrogen release compound
IT	IT Corporation
MCL	maximum contaminant level
mg/L	milligrams per liter
mV	millivolt
NO_3	nitrate
O_2	oxygen
RI	remedial investigation
Shaw E & I	Shaw Environmental & Infrastructure, Inc.
SO_4^{-2}	sulfate
TCA	trichloroethane
TCE	trichloroethene
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
VC	vinyl chloride
VOC	volatile organic compound

1.0 Introduction

The U.S. Army has selected Fort McClellan (FTMC), located in Calhoun County, Alabama, for closure by the Base Realignment and Closure Commission. The Army is conducting environmental studies of the impact of suspected contaminants at FTMC under the management of the U.S. Army Corps of Engineers (USACE)-Mobile District. The USACE contracted IT Corporation (IT) to complete the remedial investigation (RI) of the Small Weapons Repair Shop, Parcel 66(7). The RI determined the nature and extent of contamination and concluded that the concentrations of chlorinated solvents detected in groundwater present an unacceptable risk to human health (IT, 2002). The streamlined human health risk assessment identified the following five chlorinated volatile organic compounds (VOC) as chemicals of potential concern (COPC) in groundwater at Parcel 66(7): 1,1-dichloroethene (DCE), 1,2-dichloroethane (DCA), cis-1,2-DCE, trichloroethene (TCE), and vinyl chloride (VC). Based on the results of the RI, further investigation of the groundwater contamination at Parcel 66(7) was recommended. In April 2002, contaminated site soil and groundwater were collected to conduct a laboratory treatability study to investigate the potential for intrinsic and enhanced biodegradation of chlorinated solvents in the residuum water-bearing zone at Parcel 66(7). The objective of this investigation was to evaluate the effectiveness of lactate for stimulating reductive dechlorination of the five COPCs by naturally occurring microbes. The rate of dechlorination by the indigenous microorganisms at the site was calculated and factors were identified that may affect performance of the technology during pilot or full-scale implementation. A feasibility study was initiated to screen remedial action technologies and process options for groundwater remedial alternatives. The results from this treatability study will be incorporated into the feasibility study report.

1.1 Site Description and History

Parcel 66(7) is located in the central portion of the Main Post at FTMC at the intersection of Waverly Road and Freemont Road. Buildings 335 and 336 are located within the site boundary. In the Small Weapons Repair Shop located in Building 335, weapons brought for repair were degreased with 1,1,1-trichloroethane (TCA) in a vapor degreaser and then stripped with a caustic solution (IT, 2002). An alternate description of weapons refinishing activities states that TCE was used for the initial step as a degreasing agent for small weapons parts (FTMC, 1985). According to this alternate description, a 110-gallon vat of heated TCE was used for a 10 to 15-minute period to degrease parts. Typically, the vat contents would be pumped into drums for disposal. However, the potential existed for the contents of the vat to discharge directly to the ground surface outside the building.

1.2 Summary of Geology and Hydrogeology

A complete description of the site-specific geology and hydrogeology is presented in the RI report (IT, 2002). In brief, the geologic data collected at Parcel 66(7) show that the upper portion of the residuum consists of brown to brownish gray to yellowish orange silty clay and clay, with occasional intervals of highly weathered shale. This sequence extends from the ground surface to a depth of around 10 to 13 feet below ground surface. Underlying this interval, and included as residuum, is a variable thickness of highly weathered, light gray to black shale that extends to a maximum depth of approximately 30 feet below ground surface. Underlying the residuum is bedrock consisting of moderately hard, slightly weathered, fractured, dark gray to black shale.

Groundwater flow across the area appears to be influenced by a topographic high located to the west of the site that has created a local groundwater divide in the vicinity of Parcel 66(7). In the residuum water-bearing zone, the axis of a groundwater divide is located just to the west of Building 335. Groundwater flow in the northern portion of the site is to the north, while groundwater flow in the southwestern part of the parcel is to the south. The groundwater flow in the bedrock water-bearing zone is similar to the groundwater flow regime in the residuum water-bearing zone (IT, 2002).

The horizontal hydraulic gradients of the residuum and bedrock water-bearing zones are low, indicating a relatively flat water table. The horizontal hydraulic gradients are approximately 0.01 feet per foot for both the residuum and the bedrock water-bearing zones. The geometric means of hydraulic conductivity values are 0.07 foot per day (foot/day) for the residuum and 0.09 foot/day for the bedrock. Using estimated porosities of 30 percent for the residuum and 15 percent for the bedrock, the groundwater flow velocities were calculated at approximately 0.0022 foot/day for the residuum and 0.0078 foot/day for the bedrock. These groundwater velocities will be used in calculating the degradation rates of the COPCs at Parcel 66(7).

2.0 Technology Description

Most naturally occurring and many anthropogenic chemicals can be biodegraded under either aerobic (with oxygen) or anaerobic (without oxygen) conditions. Chlorinated solvents, such as the COPCs identified at Parcel 66(7), are biodegradable under anaerobic conditions provided suitable conditions exist at a site, including an appropriate oxidation reduction potential and availability of a readily biodegradable carbon source to provide electrons for reductive dechlorination. The site conditions dictate the rate and completeness of the biodegradation reactions. Biodegradation may not occur at some sites due to toxicity associated with high concentrations of contaminants, competition with other biological reactions, or the lack of a suitably adapted indigenous microbial population. The biological reactions, conditions necessary to support biodegradation, and steps required to enhance in situ reductive dechlorination are discussed.

2.1 Anaerobic Biodegradation

In general, aerobic degradation of TCE does not occur under natural conditions because it is such a highly oxidized compound. Instead, TCE can be degraded under anaerobic conditions via pathways that result in the sequential dechlorination of TCE to DCE, to VC, and ultimately, to ethene or ethane. However, under less-than-ideal circumstances where geochemical conditions are unfavorable for complete reductive dechlorination, incomplete conversion of the parent compound can occur, resulting in an accumulation of the daughter products cis-1,2-DCE or VC. Biodegradation may continue to occur, however, because cis-1,2-DCE and VC can be mineralized to carbon dioxide and water under aerobic, nitrate-reducing, or iron-reducing conditions. Thus, by providing a sufficient supply of an electron donor (i.e., carbon source) and appropriate oxidation reduction potential conditions (i.e., rendering the environment more anaerobic), the microbial community can be stimulated to effect complete dechlorination of TCE to ethene.

Although not selected as a COPC, 1,1,1-TCA was detected in the residuum water-bearing zone at Parcel 66(7). Abiotic transformation of 1,1,1-TCA results in the formation of the COPC 1,1-DCE and acetic acid (Vogel and McCarty, 1987). Biotic transformation of 1,1,1-TCA under anaerobic conditions results in the formation of 1,1-DCA (detected but not a COPC), which can be further transformed into chloroethane. The COPC 1,2-DCA may be biologically transformed into chloroethane. Once chloroethane is formed, it rapidly degrades abiotically to ethanol. Figure 2-1 presents published pathways for the anaerobic degradation of chlorinated aliphatic compounds, including the five COPCs at Parcel 66(7).

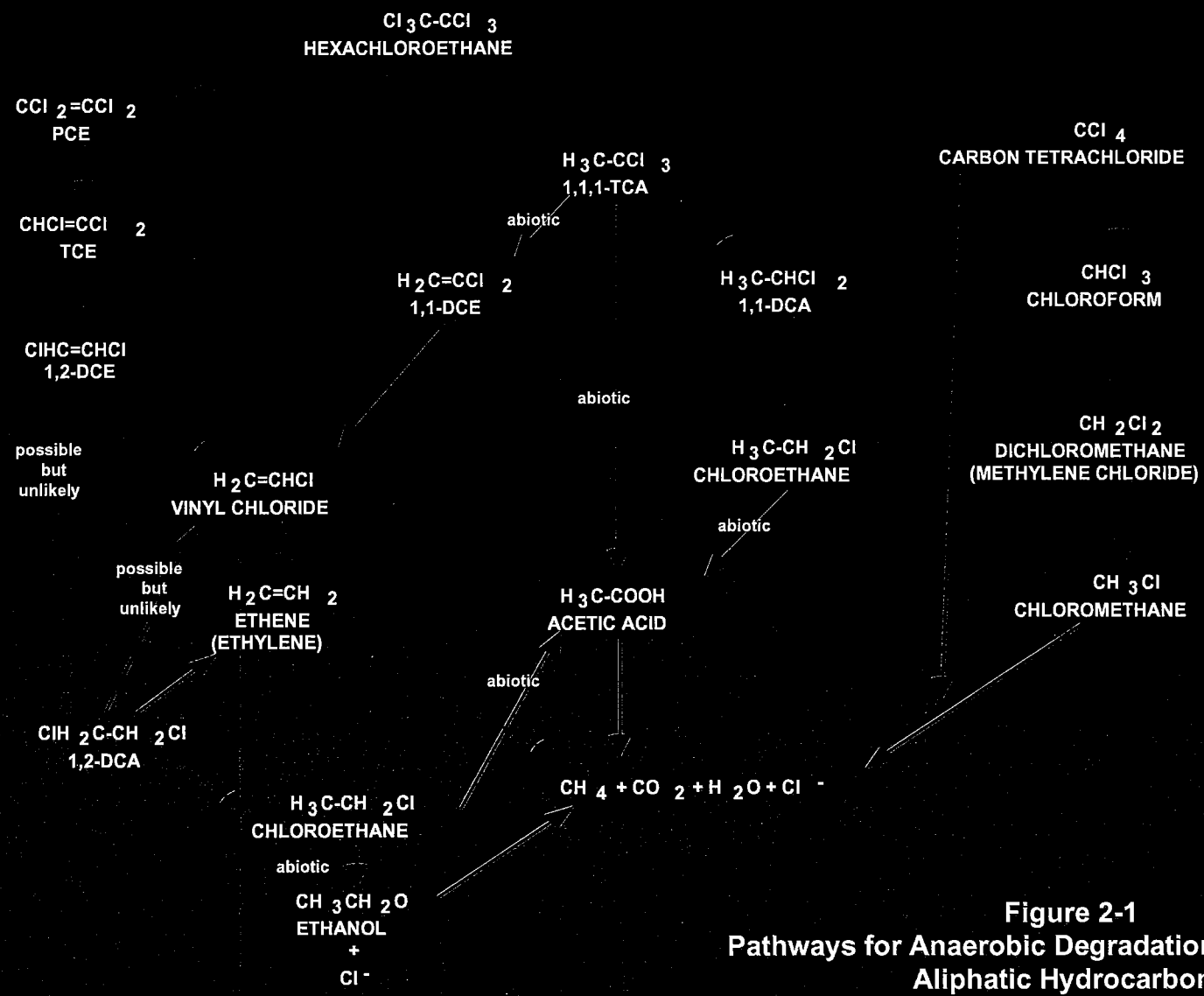


Figure 2-1
Pathways for Anaerobic Degradation of Chlorinated Aliphatic Hydrocarbons
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

KN2/4040/P66/TSR/Fig 2-1.ppt/10/24/02 10:11 AM

Reductive dechlorination requires the presence of a biodegradable organic substrate, since the chlorinated hydrocarbons are not used as a carbon and energy (food) source by the anaerobic microbes responsible for reductive dechlorination. Instead, the chlorinated ethenes and ethanes are used as respiratory substrates, or electron acceptors, during metabolism. Because it depends on an organic carbon source, reductive dechlorination does not occur in groundwater lacking a natural or anthropogenic source of biodegradable organic carbon.

Reductive dechlorination may occur by either of two distinct processes. Co-metabolic reductive dechlorination is a relatively slow process whereby chlorinated ethenes and ethanes are gratuitously degraded during the anaerobic biodegradation of other organic compounds under sulfate-reducing or methanogenic conditions. Halorespiration is a much more rapid form of reductive dechlorination in which the organic carbon is biodegraded to yield hydrogen. The hydrogen is then used by a halo-respiring microorganism that converts hydrogen and carbon dioxide to biomass using the chlorinated ethenes and ethanes as the electron acceptors (respiratory substrates) in the process.

Supplying a biodegradable organic compound to the groundwater can often stimulate reductive dechlorination. Lactate, molasses, hydrogen release compound (HRC), and a variety of other readily degradable materials can be used as a carbon source to stimulate reductive dechlorination. The application of a carbon source requires the direct injection of a dilute aqueous solution (usually one to two percent by weight) of the carbon source into the aquifer or injection of concentrated materials (e.g., HRC). This may be accomplished using a batch delivery system or by continuous injection. Extraction wells are often used to facilitate the movement of soluble carbon sources. Poorly soluble or concentrated materials such as HRC are typically injected directly into the aquifer and allowed to diffuse into the groundwater. This passive distribution method requires much closer spacing of the injection points than injection/extraction systems, but water treatment is eliminated and there is no operation and maintenance associated with the application, other than monitoring and perhaps additional periodic deliveries of the material. Inorganic nutrients such as ammonia and phosphate may also be required in a nutrient-deficient aquifer. These can be added as soluble salts mixed with the organic carbon substrate.

2.2 Technology Application

This treatability study was designed to evaluate the potential for successfully stimulating the anaerobic reductive dechlorination of TCE, 1,1-DCE, cis-1,2-DCE, and VC. Lactate and HRC were tested for their ability to support reductive dechlorination. These products were chosen

3.0 Methods

A laboratory investigation was conducted to evaluate the biological dechlorination potential of the indigenous microbes at the site. Soil and groundwater samples were collected from the impacted portion of the residuum water-bearing zone at Parcel 66(7) and were used to establish the microcosms for the treatability study. The investigation was designed to determine the biodegradability of the five COPCs (TCE, 1,1-DCE, cis-1,2-DCE, 1,2-DCA, and VC) by naturally occurring bacteria, to measure the rate of biodegradation and the persistence of biodegradation products, and to evaluate the effect of adding an easy-to-degrade carbon source to the impacted medium.

3.1 Microcosm Preparation

Anaerobic biodegradation of the chlorinated solvents was evaluated in 40-milliliter capacity volatile organic analysis glass vials. Approximately 3 gallons of groundwater from monitoring well PPMP-66-MW06 and 2 kilograms of soil from a soil boring near PPMP-66-MW06 were collected for the treatability study. The groundwater and soil samples were composited separately to achieve a homogeneous mixture for each. Ten-gram aliquots of composited soil and approximately 30 milliliters of groundwater were placed in each vial (filled to capacity, leaving no remaining headspace). The groundwater sample used to establish the microcosms contained adequate concentrations of TCE, cis-1,2-DCE, 1,1,-DCE, and 1,2-DCA to enable the tracking of the contaminants throughout the study; therefore, the vials were not spiked with the parent compound TCE. The vials were incubated upside-down at room temperature in an anaerobic glove box. Five treatments were established to allow for triplicate analysis over five time points. A total of 75 individual vials were prepared for the treatability study. The time points for analysis were selected to track the activity in the microcosms and determine if biodegradation was reducing the contaminant levels. The following time points were selected: baseline, 2 weeks, 4 weeks, 8 weeks, and 12 weeks. This experimental design eliminated the error associated with trying to reproducibly sample the same container over time, which is problematic with volatile compounds.

As shown in Table 3-1, an abiotic control, an untreated control, an HRC-amended treatment, and two lactate-amended treatments were established. The abiotic control was established by storing the vials in a refrigerator at 4 degrees Celsius to inhibit microbial activity. Any changes in VOC concentrations in this treatment were attributed to experimental error and physical loss. The untreated control simulates the occurrence of natural biodegradation in the absence of any amendment or stimulation. The HRC treatment vials were amended with 1,100 milligrams per

Table 3-1

Summary of Treatment Conditions
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

Treatment	Conditions
Inhibited Control	Soil and groundwater slurry, stored at 4°C
Unamended Control	Soil and groundwater slurry
500 mg/L Lactate Amended	Soil and groundwater slurry amended with 500 mg/L total carbon as Lactate, and 250 mg/L Restore 375
2,000 mg/L Amended	Soil and groundwater slurry amended with 2,000 mg/L total carbon as Lactate, and 500 mg/L Restore 375
HRC Amended	Soil and groundwater slurry amended with 1,100 mg/L Lactate as HRC, and 580 mg/L Restore 735

°C - Degrees Celsius.
mg/L - Milligrams per liter.
HRC - Hydrogen release compound.

liter (mg/L) organic carbon as HRC and 500 mg/L RESTORE 375®, a microbial nutrient formulation designed for application in groundwater. One of the lactate treatments was amended with 2,000 mg/L organic carbon as sodium lactate and 1,000 mg/L RESTORE 375. The other lactate treatment was amended with 500 mg/L organic carbon as sodium lactate and 250 mg/L RESTORE 375. Two lactate treatments were established to evaluate the effect of varying the lactate concentration on the biodegradation of TCE.

RESTORE 375 contains ammonium chloride and sodium phosphate salts pH buffered to pH 7.0. In addition to supplying inorganic nutrients, RESTORE 375 also buffers the pH of the groundwater and soil. This is a potentially valuable benefit, since biodegradation can be inhibited if the pH of the groundwater is not in the range of 5 to 9. The optimal pH range for biodegradation is 6 to 8. During the biodegradation of organic carbon, volatile fatty acids are produced that can reduce the pH of the groundwater to a level that may reduce degradation rates or even prevent biodegradation; thus, the buffering capacity of the RESTORE 375 solution is highly beneficial for biodegradative processes.

Each treatment and the two controls were analyzed for TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, 1,2-DCA, VC, methane, ethane, ethene, total organic carbon (TOC), ortho-phosphate, ammonia, pH, nitrate, nitrite, sulfate, chloride, and DO. The analyses were conducted at the beginning of the treatability study and after 2, 4, 8, and 12 weeks of incubation. All analyses, with the exception of pH, ammonia, ortho-phosphate, and DO, were conducted in triplicate.

3.2 Analytical Methods

All analyses were conducted at the Shaw Environmental Technology Development Laboratory. The analytical methods used for the investigation are summarized in Table 3-2 and are described as follows:

- ***Chlorinated Solvent Analysis.*** Chlorinated ethenes were detected by gas chromatography equipped with a flame ionization detector using a modification of SW846 Method 8015B.

- ***Methane, Ethene, and Ethane Analysis.*** Methane, ethene, and ethane were analyzed by gas chromatography with a flame ionization detector. Methane is a metabolic by-product of anaerobic microbial respiration; detection of methane indicates that conditions are suitable for the reductive dechlorination of TCE and its intermediates. Ethene is the product of the complete dechlorination of TCE. Ethane is the biological breakdown product of ethene.

Table 3-2

Laboratory Analytical Methods
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

Lab Parameter	Method	Application
Chlorinated Ethenes (Volatile Organic Compounds)	SW-846 Method 8260	Used to quantify TCE and intermediates and provide evidence for biodegradation.
Methane, Ethane, Ethene	RSK 175, EPA Draft Method	Increased concentrations of methane indicate the occurrence of methanogenesis, a form a microbial respiration that will support the reductive dechlorination of TCE.
pH	*Standard Methods for Analysis of Water and Wastewater*, 18th Ed 4500-H+ or EPA Method 150.1	The preferred pH for biodegradation ranges from pH 6 to 8. Biological activity will generally continue between a range of 5 to 9 but outside this range, activity may be inhibited.
TOC	*Standard Methods for the Analysis of Water and Wastewater*, 18th Ed. 5310 B	Provides carbon and energy to sustain microbial activity. TOC is especially important for the biodegradation of compounds that are not directly used as a carbon and energy source for microbial growth, such as TCE.
Ammonia	*Standard Methods for the Analysis of Water and Wastewater*, 18th Ed. 4500-NH_3 F	Used to indicate nutrient deficiencies, and the disappearance of nutrients added to selected microcosms.
Phosphate	*Standard Methods for Analysis of Water and Wastewater*, 18th Ed 4500-P E or EPA Method 300	Used to indicate electron acceptor presence, and the disappearance of nutrients added to selected microcosms.
Nitrate, Nitrite, Sulfate, Chloride	SW-846, Method 9056, SW-846 Method 300	Used to indicate electron acceptor presence required for microbial activity. Chloride levels are used to measure an increase in chloride concentrations as evidence of reductive dechlorination.
Dissolved Oxygen	*Standard Methods for Analysis of Water and Wastewater*, 18th Ed 4500-O G	Determines whether a microcosm is aerobic or anaerobic.

EPA - U.S. Environmental Protection Agency.
TCE - Trichloroethene.
TOC - Total organic carbon.

- ***DO.*** DO was tested in the treatment vessels using a galvanic detector. Very low DO concentrations were expected in the treatment vessels undergoing reductive dechlorination. For each set of triplicates, the DO of one sample was measured at each time point.

- ***Anions (Nitrate, Nitrite, Sulfate, Chloride).*** Nitrate, nitrite, and sulfate are used to indicate the presence of electron acceptors. Chloride levels are used to measure the increase in chloride concentrations as evidence of reductive dechlorination.

- ***pH Analysis.*** For each set of triplicates, the pH of one sample was measured at each time point.

- ***Total Organic Carbon.*** TOC was analyzed by the combustion-infrared detection method (Standard Methods for the Analysis of Water and Wastewater, Method 5310B).

- ***Ortho-Phosphate.*** Ortho-phosphate was supplied to the microcosms with lactate and HRC using the microbial nutrient blend RESTORE 375. The concentration of phosphate was quantified using Standard Method 4500-P E.

- ***Ammonia.*** Ammonia was supplied to the microcosms amended with lactate and HRC using the microbial nutrient blend RESTORE 375. Ammonia was measured using Standard Method 4500-NH_3F.

In addition to the analytical methods described above, two soil samples from the composited soil were evaluated for the competence of the indigenous microbial population to complete the reductive dechlorination of TCE. The soil samples were screened for the presence of Dehalococcoides Ethenogenes using a targeted gene detection approach. Dehalococcoides Ethenogenes is the only microbe that has been cultured as a pure strain with the capability to completely dechlorinate TCE. While it is probably not the only organism capable of this reaction, it is the only one identified and cultured to date. The analyses was conducted by Microbial Insights, Inc. Primers specific for 16S ribosomal DNA were used to selectively enrich for DNA sequences unique to Dehalococcoides Ethenogenes. This DNA testing is an innovative approach used to substantiate the results of the treatability test. The DNA testing is currently not accepted as an alternate to treatability testing.

3.3 Degradation Rate Constants

The data produced from the various microcosms were evaluated for trends that indicate intrinsic bioremediation via reductive dechlorination. Biodegradation rate constants were determined assuming first-order kinetics and using an equation of the form:

$$C_0 = C_i e^{-kt}$$

where:

C_0 = The final measured concentration of a given contaminant in mg/L
C_i = The initial measured concentration in mg/L
t = Time between initial and final measurement (weeks)
k = Degradation rate constant (per week).

From the biodegradation rate constant, the half-life of a contaminant was calculated using the following equation:

$$t_{1/2} = (\ln 2)/k$$

where:

$t_{1/2}$ = Contaminant half-life, the time required for the concentration of the contaminant to decrease by one-half.

4.0 Results

The treatability study failed to demonstrate that naturally occurring bacteria from the site could biodegrade the chlorinated solvents detected in the residuum water-bearing zone under field conditions. Amending the soil and groundwater microcosms with lactate and nutrients did not result in the degradation of the chlorinated solvents. The addition of HRC as the carbon source promoted limited reductive dechlorination of TCE to the desirable end product, ethene; however, the bulk of the degraded TCE accumulated as cis-1,2-DCE. The rate at which TCE could be biodegraded to cis-1,2-DCE in site soil with the addition of HRC was calculated. The following sections present the results of the enhanced anaerobic biodegradation treatability study.

4.1 Inhibited Control Microcosms

The inhibited control microcosms were set up to measure the loss of chlorinated solvents due to physical processes and experimental error. Table 4-1 and Figure 4-1 present the results of the inhibited control microcosms. The concentrations of TCE in the inhibited microcosms decreased from 1.29 mg/L to 0.732 mg/L over the duration of the 12-week study. This indicates that physical losses of TCE through experimental error were not well controlled during the study. The relatively constant levels of DCE (slight decrease) and the absence of any VC, ethane, or ethane demonstrate that reductive dechlorination was not occurring in the inhibited microcosms. In addition, the low levels of methane and the constant levels of sulfate and chloride over the course of the 12-week study indicate that the temperature-inhibited microcosms effectively suppressed microbial activity. The inhibited microcosms provided a baseline against which the remaining microcosms were compared. Observed differences between the inhibited microcosms and the remainder of the microcosms were attributed to biological activity.

4.2 Unamended Control Treatment

The unamended soil and groundwater microcosms were used to evaluate the reductive dechlorination of chlorinated solvents that could occur in situ under current field conditions. Table 4-2 and Figure 4-2 present the results of the unamended microcosms. The results indicate that the concentration of TCE decreased from 1.23 mg/L to 0.631 mg/L, a level of decrease that is similar to the change in TCE concentrations observed in the inhibited control. The concentrations of DCE remained relatively unchanged (slight decrease), which is evidence that TCE did not degrade to cis-1,2-DCE in the unamended microcosms. The lack of VC production and the constant concentrations of methane, sulfate, and chloride throughout the 12-week study are further evidence of the lack of reductive dechlorination. The results obtained from the unamended microcosms mirrored the results obtained from the inhibited microcosms.

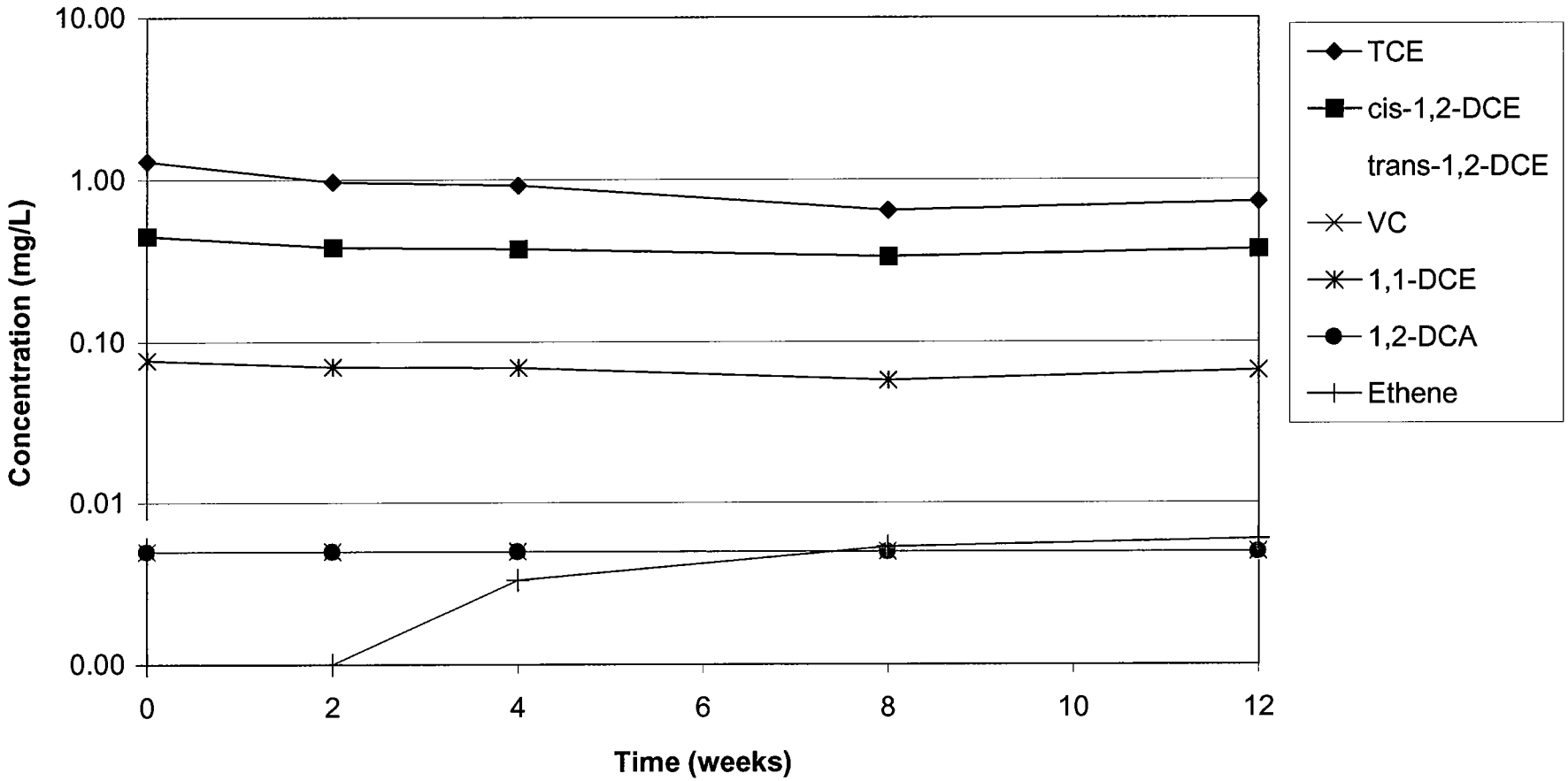
Table 4-1

Inhibited Control Microcosm Results
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

Analyte	Sampling Points									
	Initial		Week 2		Week 4		Week 8		Week 12	
TCE (mg/L)	1.29		0.970		0.924		0.648		0.732	
cis-1,2- DCE (mg/L)	0.453		0.384		0.375		0.337		0.376	
trans-1,2-DCE (mg/L)	0.007		0.006		0.006		0.004	J	0.005	U
VC (mg/L)	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U
1,1-DCE (mg/L)	0.077		0.070		0.069		0.057		0.067	
1,2-DCA (mg/L)	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U
Methane (mg/L)	0.043		0.054		0.107		0.095		0.046	
Ethene (mg/L)	0.001	U	0.001		0.003		0.005		0.006	
Ethane (mg/L)	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U
TOC (mg/L)	1.0	U	1.3		12		1.4		3.3	
pH (S.U.)	8.0		8.4		8.4		8.3		8.4	
Ortho-phosphate (mg/L)	0.5	U	0.5	U	0.5		0.5	U	0.5	U
Ammonia (mg/L)	1.0	U	1.0	U	1.0	U	1.0	U	1.0	U
DO (mg/L)	3		3		NA		NA		NA	
Nitrate (mg/L)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Nitrite (mg/L)	0.5	U	0.5	U	0.53		0.5	U	0.5	U
Sulfate (mg/L)	180		190		150		210		170	
Chloride (mg/L)	8.5		8.6		8.1		8.6		8.0	

DCA - Dichloroethane.
DCE - Dichloroethene.
DO - Dissolved oxygen.
mg/L - Milligrams per liter.
S.U. - Standard unit.
TCE - Trichloroethene.
TOC - Total organic carbon.
VC - Vinyl chloride.
U - Analyte not detected or below method detection limits.
J - Estimated value, average below method detection limits.

Figure 4-1
Inhibited Control Data Graph
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama



mg/L - Milligrams per liter.

Table 4-2

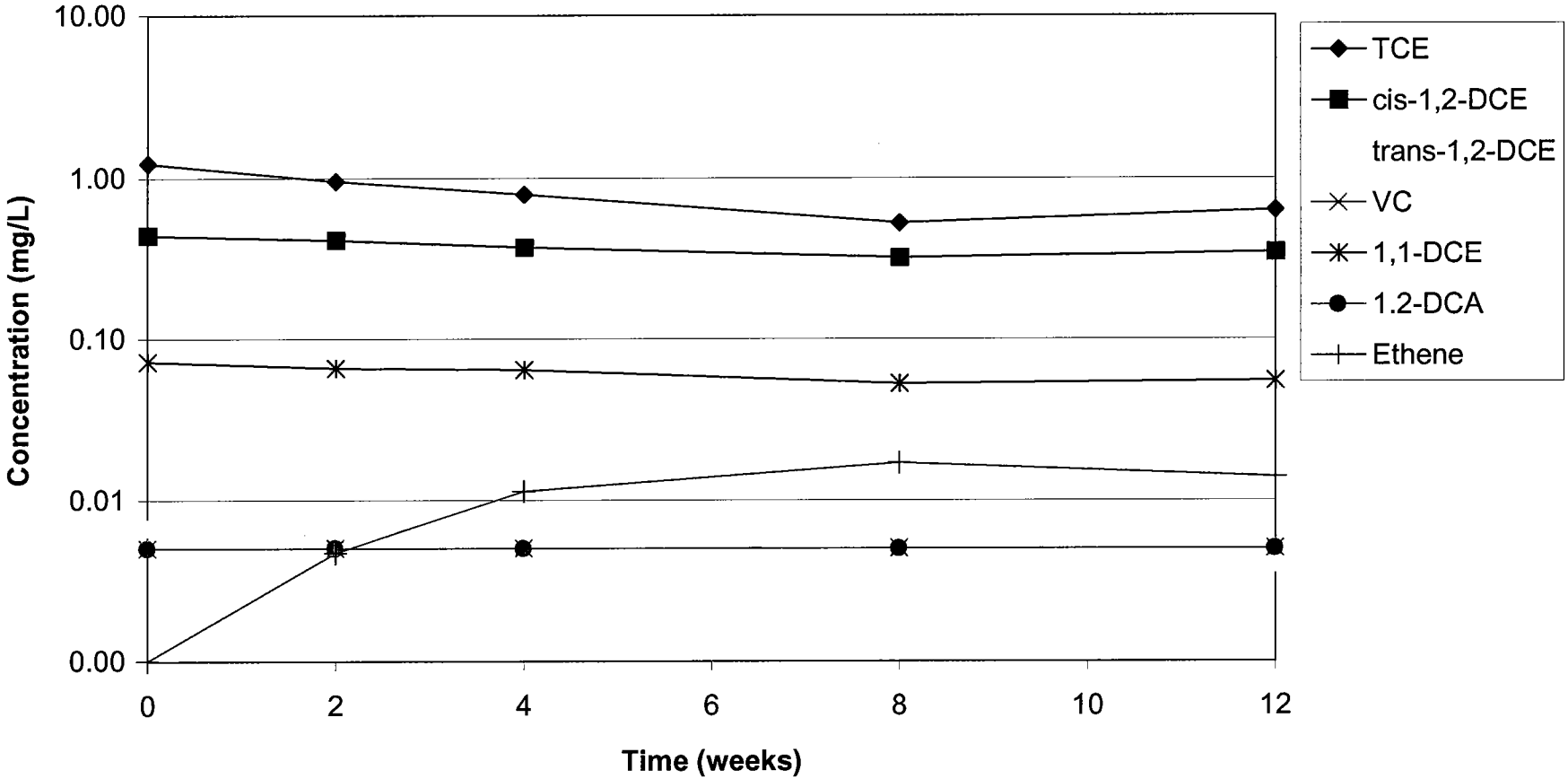
Unamended Control Treatment Results
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

Analyte	Sampling Points									
	Initial		Week 2		Week 4		Week 8		Week 12	
TCE (mg/L)	1.23		0.956		0.790		0.526		0.631	
cis-1,2- DCE (mg/L)	0.440		0.412		0.370		0.319		0.346	
trans-1,2-DCE (mg/L)	0.007		0.006		0.008		0.004	J	0.004	J
VC (mg/L)	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U
1,1-DCE (mg/L)	0.073		0.066		0.065		0.053		0.055	
1,2-DCA (mg/L)	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U
Methane (mg/L)	0.031		0.069		0.087		0.068		0.042	
Ethene (mg/L)	0.001	U	0.005		0.011		0.017		0.014	
Ethane (mg/L)	0.001	U	0.001	U	0.001	U	0.004		0.001	
TOC (mg/L)	1.0	U	1.0	U	2.4		28		2.6	
pH (S.U.)	8.6		8.6		8.5		8.3		8.3	
Ortho-phosphate (mg/L)	0.5	U	0.5	U	0.6		0.5	U	0.5	U
Ammonia (mg/L)	1.0	U	1.0	U	1.0	U	1.0	U	1.0	U
DO (mg/L)	2		1		NA		NA		NA	
Nitrate (mg/L)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Nitrite (mg/L)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Sulfate (mg/L)	180		190		220		200		190	
Chloride (mg/L)	8.6		8.8		8.4		8.8		8.2	

Notes:

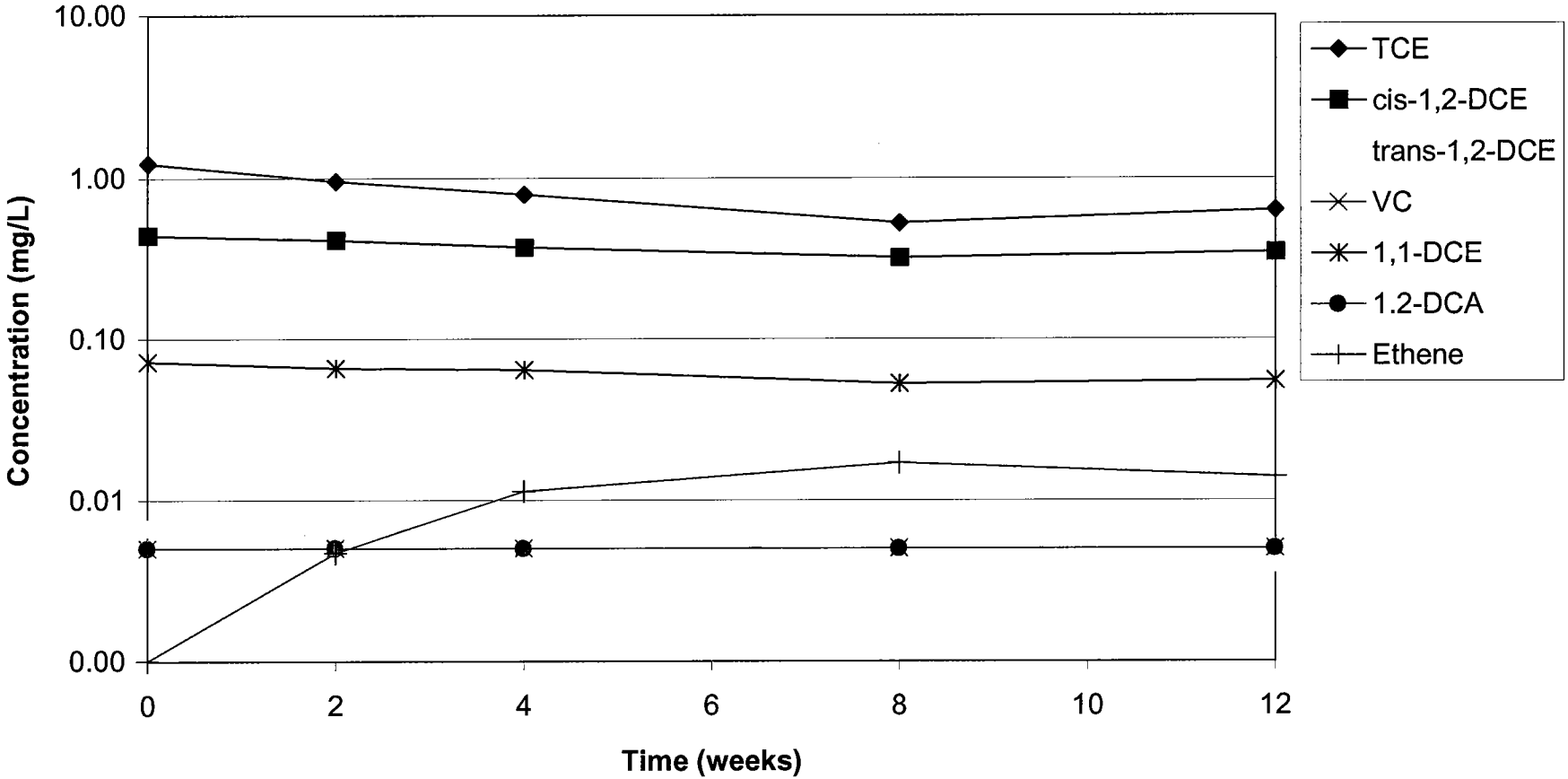
DCA - Dichloroethane.
DCE - Dichloroethene.
DO - Dissolved oxygen.
mg/L - Milligrams per liter.
S.U. - Standard unit.
TCE - Trichloroethene.
TOC - Total organic carbon.
VC - Vinyl chloride.
U - Analyte not detected or below method detection limits.
J - Estimated value, average below method detection limits.

Figure 4-2
Unamended Control Data Graph
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama



mg/L - Milligrams per liter.

Figure 4-2
Unamended Control Data Graph
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama



mg/L - Milligrams per liter.

Regardless of the electron acceptor used, organic carbon is a required source of reduced carbon and energy to sustain microbial activity. TOC concentrations greater than 20 mg/L are considered adequate to support microbial activity. The lack of reductive dechlorination in the unamended microcosms can be attributed to insufficient TOC levels and elevated sulfate concentrations. The system also appears to be nutrient limited, as indicated by the nondetect levels of ortho-phosphate and ammonia. The results obtained from the unamended microcosms indicate that conditions are not favorable for reductive dechlorination to occur under current field conditions at Parcel 66(7).

4.3 500 mg/L Lactate-Amended Treatment

The addition of 500 mg/L carbon to the microcosms in the form of sodium lactate did not induce the anaerobic biodegradation of chlorinated solvents. Table 4-3 and Figure 4-3 present the results of the 500 mg/L lactate treatment. TCE decreased from an initial level of 1.06 mg/L to 0.530 mg/L following 12 weeks of incubation. The level of decrease in TCE concentrations was similar to that observed in the inhibited and unamended controls. The concentrations of cis-1,2-DCE remained unchanged throughout the duration of the treatability study, which indicates that the decrease in TCE concentrations was not the result of reductive dechlorination. Similarly, the levels of 1,1-DCE remained unchanged over the 12 weeks of treatment. The lack of VC production was further evidence that reductive dechlorination did not occur in the 500 mg/L lactate-amended treatments.

TOC, supplemented by lactate, was present at high levels throughout the treatment period and contained enough biodegradable carbon to support microbial activity. Ammonia and phosphate were present at high levels, and the pH remained near neutral throughout the treatment period. Therefore, sufficient nutrients were available and the pH was within the optimal range for microbial activity. The DO concentration decreased from 6 mg/L to nondetect levels within the first four weeks of incubation. The concentration of sulfate decreased from 140 mg/L to 6.3 mg/L by week 12, with the bulk of the sulfate being reduced within the first two weeks of incubation. The sharp drop in sulfate concentrations indicates that sulfate-reducing conditions were rapidly established in the microcosms. Following the consumption of sulfate, only limited methane production was observed (maximum 0.089 mg/L by 4 weeks), indicating that conditions were not favorable for anaerobic microbial processes. Reductive dechlorination results in the release of chloride ion. Chloride concentrations remained unchanged throughout the treatment, indicating that reductive dechlorination did not occur in the microcosms. The results obtained from the 500 mg/L lactate-amended treatment were not favorable for the application of lactate in situ at Parcel 66(7).

Table 4-3

500 mg/L Lactate-Amended Treatment Results
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

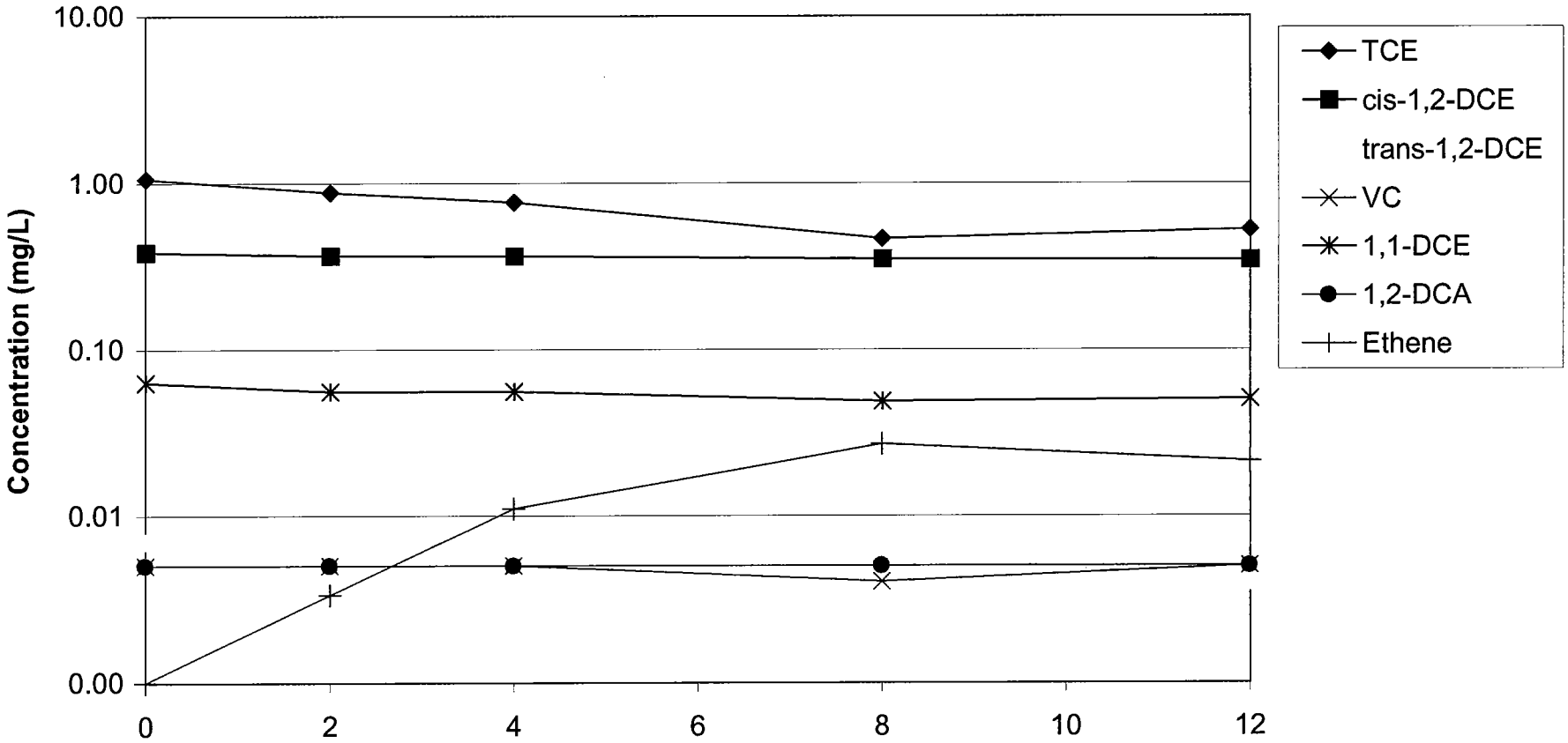
Analyte	Sampling Points									
	Initial		Week 2		Week 4		Week 8		Week 12	
TCE (mg/L)	1.06		0.880		0.770		0.465		0.530	
cis-1,2- DCE (mg/L)	0.384		0.365		0.365		0.348		0.346	
trans-1,2-DCE (mg/L)	0.007		0.006		0.007		0.006		0.004	J
VC (mg/L)	0.005	U	0.005	U	0.005	U	0.004	J	0.005	J
1,1-DCE (mg/L)	0.063		0.056		0.056		0.049		0.051	
1,2-DCA (mg/L)	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U
Methane (mg/L)	0.027		0.055		0.089		0.057		0.035	
Ethene (mg/L)	0.001	U	0.003		0.011		0.027		0.021	
Ethane (mg/L)	0.001	U	0.001	U	0.001	U	0.001		0.001	U
TOC (mg/L)	190		130		110		130		160	
pH (S.U.)	7.8		7.8		8.3		8.0		8.2	
Ortho-phosphate (mg/L)	0.8		5.5		4.8		1.8		1.7	
Ammonia (mg/L)	16		1.0	U	4.5		3.3		20	
DO (mg/L)	6		3		NA		NA		NA	
Nitrate (mg/L)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Nitrite (mg/L)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Sulfate (mg/L)	140		0.65		14		9.6		6.30	
Chloride (mg/L)	44		43		42		46		43	

Notes:

DCA - Dichloroethane.
DCE - Dichloroethene.
DO - Dissolved oxygen.
mg/L - Milligrams per liter.
S.U. - Standard unit.
TCE - Trichloroethene.
TOC - Total organic carbon.
VC - Vinyl chloride.
U - Analyte not detected or below method detection limits.
J - Estimated value, average below method detection limits.

Figure 4-3

500 mg/L Lacate-Amended Data Graph
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama



mg/L - Milligrams per liter.

4.4 2,000 mg/L Lactate-Amended Treatment

The addition of 2,000 mg/L carbon in the form of sodium lactate did not induce the anaerobic biodegradation of chlorinated solvents. Table 4-4 and Figure 4-4 present the results of this treatment. TCE decreased from an initial concentration of 0.976 mg/L to 0.606 mg/L following 12 weeks of incubation. The level of decrease in TCE was similar to that observed in the inhibited, unamended, and 500 mg/L lactate treatments. The concentrations of cis-1,2-DCE remained unchanged throughout the duration of the treatability study, which indicates that the decrease in TCE concentrations was not the result of reductive dechlorination. Similarly, the levels of 1,1-DCE remained unchanged over the 12 weeks of treatment. The lack of VC production was further evidence that reductive dechlorination did not occur in the 2,000 mg/L lactate-amended treatments.

TOC, supplemented by lactate, was present at high levels throughout the treatment period and contained enough biodegradable carbon to support microbial activity. Ammonia and phosphate were present at high levels, and the pH remained near neutral throughout the treatment period. Therefore, sufficient nutrients were available and the pH was within the optimal range for microbial activity. The DO concentration decreased from 4 mg/L to nondetect levels within the first four weeks of incubation. The concentration of sulfate decreased from 160 mg/L to 2.7 mg/L by week 12, with the bulk of the sulfate being reduced within the first two weeks of incubation. The sharp drop in sulfate concentrations indicates that sulfate-reducing conditions were rapidly established in the microcosms. Following the consumption of sulfate, only limited methane production was observed (maximum 0.084 mg/L by 4 weeks), indicating conditions were not favorable for anaerobic microbial processes. Chloride concentrations remained unchanged throughout the treatment, indicating that reductive dechlorination did not occur in the microcosms. The results obtained from the 2,000 mg/L lactate-amended treatment were not favorable for the application of lactate in situ at Parcel 66(7).

4.5 HRC-Amended Treatment

The addition of 1,100 mg/L carbon in the form of HRC resulted in limited anaerobic biodegradation via reductive dechlorination of chlorinated solvents. Table 4-5 and Figure 4-5 present the results of this treatment. TCE decreased from an initial concentration of 1.33 mg/L to 0.186 mg/L following 12 weeks of incubation. The level of decrease in TCE concentrations was greater than the decrease observed in the inhibited, unamended, and lactate amended treatments. In addition, cis-1,2-DCE increased from an initial concentration of 0.444 mg/L to 0.817 mg/L by the end of the 12-week incubation. The increase in cis-1,2-DCE concentrations, coupled with the decrease in TCE concentrations, is direct evidence that reductive dechlorination

Table 4-4

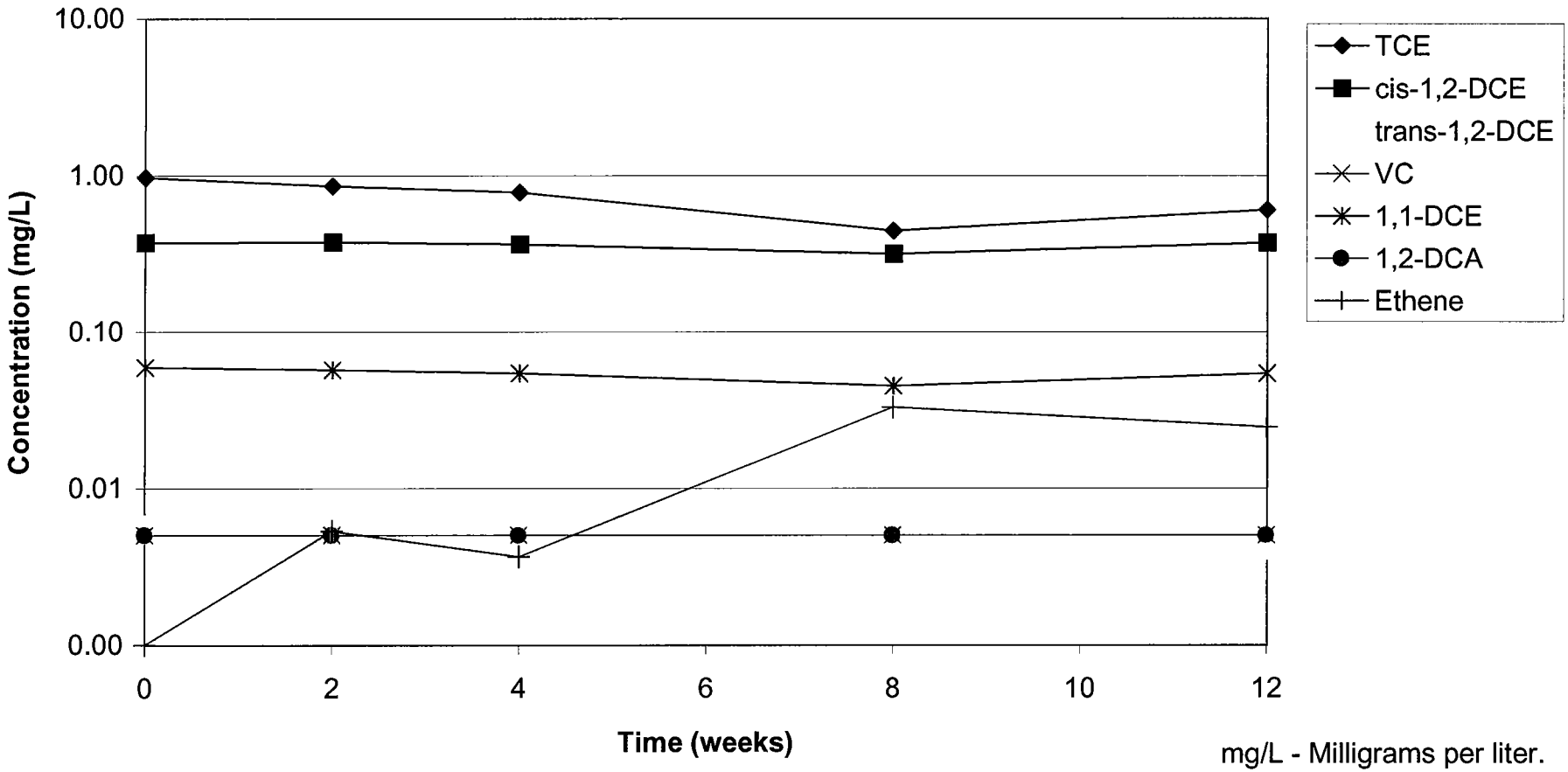
2,000 mg/L Lactate-Amended Treatment Results
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

Analyte	Sampling Points									
	Initial		Week 2		Week 4		Week 8		Week 12	
TCE (mg/L)	0.976		0.863		0.782		0.445		0.606	
cis-1,2- DCE (mg/L)	0.374		0.376		0.364		0.317		0.374	
trans-1,2-DCE (mg/L)	0.006		0.006		0.007		0.006		0.004	J
VC (mg/L)	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U
1,1-DCE (mg/L)	0.059		0.057		0.054		0.045		0.054	
1,2-DCA (mg/L)	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U
Methane (mg/L)	0.048		0.078		0.084		0.067		0.044	
Ethene (mg/L)	0.001	U	0.005		0.004		0.033		0.025	
Ethane (mg/L)	0.001	U	0.001	U	0.001	U	0.002		0.001	
TOC (mg/L)	740		640		570		60		700	
pH (S.U.)	7.8		7.5		8.5		7.6		7.8	
Ortho-phosphate (mg/L)	0.8		5.5		4.8		1.8		1.7	
Ammonia (mg/L)	26		20		23		27		21	
DO (mg/L)	4		1		NA		NA		NA	
Nitrate (mg/L)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Nitrite (mg/L)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Sulfate (mg/L)	160		0.45		0.5	U	3.5		2.7	
Chloride (mg/L)	150		140		120		130		140	

Notes:

DCA - Dichloroethane.
DCE - Dichloroethene.
DO - Dissolved oxygen.
mg/L - Milligrams per liter.
S.U. - Standard unit.
TCE - Trichloroethene.
TOC - Total organic carbon.
VC - Vinyl chloride.
U - Analyte not detected or below method detection limits.
J - Estimated value, average below method detection limits.

Figure 4-4
2,000 mg/L Lacate-Amended Data Graph
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama



mg/L - Milligrams per liter.

Table 4-5

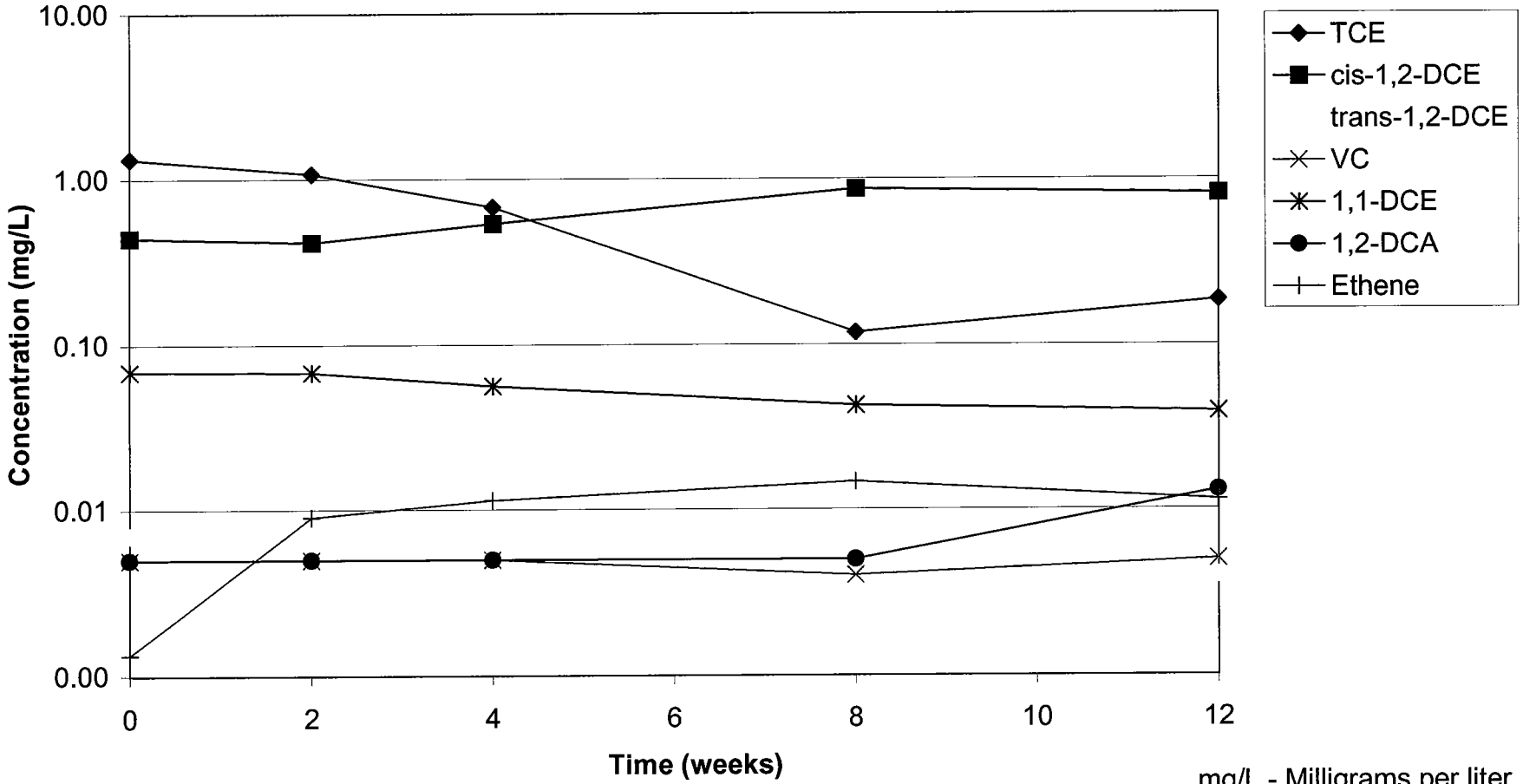
HRC-Amended Treatment Results
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

Analyte	Sampling Points									
	Initial		Week 2		Week 4		Week 8		Week 12	
TCE (mg/L)	1.33		1.08		0.677		0.118		0.186	
cis-1,2- DCE (mg/L)	0.444		0.416		0.542		0.872		0.817	
trans-1,2-DCE (mg/L)	0.007		0.007		0.007		0.005	U	0.004	J
VC (mg/L)	0.005	U	0.005	U	0.005	U	0.004	J	0.005	J
1,1-DCE (mg/L)	0.069		0.068		0.056		0.043		0.039	
1,2-DCA (mg/L)	0.005	U	0.005	U	0.005	U	0.005	U	0.013	
Methane (mg/L)	0.029		0.070		0.126		6.29		3.08	
Ethene (mg/L)	0.001	U	0.009		0.011		0.015		0.011	
Ethane (mg/L)	0.001	U	0.001		0.001		0.003		0.002	
TOC (mg/L)	730		950		1000		1000		1400	
pH (S.U.)	6.2		6.9		6.4		6.2		6.0	
Ortho-phosphate (mg/L)	0.5	U	25		10		6.4		7.6	
Ammonia (mg/L)	32		4.0		5.0		8.0		3.3	
DO (mg/L)	3		1		NA		NA		NA	
Nitrate (mg/L)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Nitrite (mg/L)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Sulfate (mg/L)	190		1.4		2.2		0.5	U	0.46	
Chloride (mg/L)	79		84		79		170		80	

Notes:

DCA - Dichloroethane.
DCE - Dichloroethene.
DO - Dissolved oxygen.
HRC - Hydrogen reduction compound.
mg/L - Milligrams per liter.
S.U. - Standard unit.
TCE - Trichloroethene.
TOC - Total organic carbon.
VC - Vinyl chloride.
U - Analyte not detected or below method detection limits.
J - Estimated value, average below method detection limits.

Figure 4-5
HRC-Amended Treatment Data Graph
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama



mg/L - Milligrams per liter.

occurred in the HRC-amended treatments. Similarly, the level of 1,1-DCE decreased from an initial concentration of 0.069 mg/L to 0.039 mg/L by the end of the treatment. Limited production of VC and ethene was observed in the microcosms following 8 weeks of incubation, indicating that reductive dechlorination had gone to completion. Although VC and ethene were produced in the HRC-amended treatments, the bulk of the degraded TCE accumulated as cis-1,2-DCE.

The TOC concentration supplemented by HRC increased steadily as the treatment proceeded, which was expected since HRC is a slow-release substrate. TOC was present at high levels throughout the treatment period and contained enough biodegradable carbon to support microbial activity. Ammonia and phosphate were present at high levels, and the pH remained near neutral throughout the treatment period. Therefore, sufficient nutrients were available and the pH was within the optimal range for microbial activity. The DO concentration decreased from 3 mg/L to nondetect levels within the first four weeks of incubation. The concentration of sulfate decreased from 190 mg/L to 0.46 mg/L by week 12, with the bulk of the sulfate being reduced within the first two weeks of incubation. The sharp drop in sulfate concentrations indicates that sulfate-reducing conditions were rapidly established in the microcosms. Following the consumption of sulfate, significant methane production was observed. Methane production peaked in week 8 with a concentration of 6.29 mg/L, indicating conditions were favorable for anaerobic microbial processes. The peak in methane production coincided with the lowest TCE concentration (0.118 mg/L) and highest chloride concentration (170 mg/L) detected throughout the treatment.

The results from this treatment indicate that reductive dechlorination can be induced through the application of HRC and nutrients. However, the accumulation of cis-1,2-DCE and the limited production of VC and ethene indicate that complete reductive dechlorination of the target contaminants may not proceed in a reasonable time frame. Furthermore, HRC is a viscous material that is injected directly into the subsurface through direct-push points or boreholes. The effectiveness of HRC in stimulating reductive dechlorination in situ greatly depends on the distribution of the hydrolyzed product through advective and diffusive processes. The RI at Parcel 66(7) concluded that the groundwater flow velocity in the residuum water-bearing zone is very slow (approximately 0.0022 ft/day) due to a groundwater divide and low hydraulic conductivities associated with weathered shale (IT, 2002). The application of HRC at Parcel 66(7) would require numerous injection points and an extended period of time to distribute the hydrolyzed HRC metabolites throughout the treatment zone.

4.6 Degradation Rate Constants

The degradation rate constant of TCE was calculated for each treatment assuming first order kinetics as presented in Section 3.3. Table 4-6 summarizes the degradation rate constants and the half-life of TCE degradation in each of the five treatments. The results indicate similar degradation rate constants in the inhibited control, unamended control, 500 mg/L lactate-amended treatment, and the 2,000 mg/L lactate-amended treatment. The decrease in TCE concentrations in those treatments was attributed to physical losses and not to reductive dechlorination. The degradation rate constants for the four treatments averaged 0.057 per week, which corresponds to an average half-life of 12 weeks. The HRC-amended treatment exhibited TCE degradation that was attributed to reductive dechlorination. The TCE biodegradation rate constant in the HRC-amended treatment was calculated at 0.201 per week, which corresponds to a half-life of 3.4 weeks. Correcting for the physical losses of TCE quantified in the inhibited control, the adjusted TCE biodegradation rate constant in the HRC-amended treatment equals 0.144 per week, which corresponds to a half-life of 4.8 weeks. The half-life of 4.8 weeks represents the time required for the concentration of TCE to decrease by one-half, resulting in the accumulation of cis-1,2-DCE. A degradation rate constant could not be calculated for cis-1,2-DCE because the compound accumulated in the HRC-amended treatment with no significant further dechlorination to VC.

4.7 Microbial Analysis

In addition to the analytical methods described above, two soil samples from the composited soil were evaluated for the competence of the indigenous microbial population to complete the reductive dechlorination of TCE. The soil samples were screened for the presence of Dehalococcoides Ethenogenes using a targeted gene detection approach. Dehalococcoides Ethenogenes is the only microbe that has been cultured as a pure strain with the capability to completely dechlorinate TCE. While it is probably not the only organism capable of this reaction, it is the only one identified and cultured to date. The analyses was conducted by Microbial Insights, Inc. Primers specific for 16S ribosomal DNA were used to selectively enrich for DNA sequences unique to Dehalococcoides Ethenogenes. This DNA testing is an innovative approach used to substantiate the results of the treatability test. The DNA testing is currently not accepted as an alternate to treatability testing. The DNA testing did not detect Dehalococcoides Ethenogenes in the Parcel 66(7) soil samples. The analysis report is presented in Attachment 1. The absence of Dehalococcoides Ethenogenes is further evidence that conditions at Parcel 66(7) are not suitable for the complete reductive dechlorination of TCE to ethene.

Table 4-6

TCE Degradation Rate Constants
Anaerobic Biodegradation Treatability Study
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

Treatment	TCE Biodegradation Rate Constant (per week)	TCE Half-life (weeks)	TCE Half-life (years)
Untreated Control	0.060	12	0.22
Inhibited Control	0.048	14	0.28
HRC Amended	0.201	3.4	0.07
500 mg/L Lactate Amended	0.065	11	0.20
2,000 mg/L Lactate Amended	0.052	13	0.26

Notes:
HRC - Hydrogen release compound.
mg/L - Milligrams per liter.
TCE - Trichloroethene.

5.0 Conclusions and Recommendations

The laboratory evaluation provided evidence that native microbes in the residuum water-bearing zone are not capable of reductively dechlorinating TCE at Parcel 66(7) significantly beyond cis-1,2-DCE under enhanced conditions. Specific conclusions from the evaluation are summarized:

- Biodegradation of chlorinated ethenes was not observed in the unamended treatment, indicating that current field conditions are not suitable for reductive dechlorination. The lack of reductive dechlorination was attributed to nondetect TOC concentrations, elevated sulfate concentrations, and the lack of nutrients.

- The addition of lactate at concentrations of 500 mg/L and 2,000 mg/L did not induce reductive dechlorination of TCE. Sulfate reduction occurred rapidly, while methanogenesis was very limited.

- The addition of HRC induced limited reductive dechlorination of TCE, resulting in the accumulation of cis-1,2-DCE with no significant further dechlorination to VC.

- The half-life for TCE dechlorination to cis-1,2-DCE in the HRC amended treatment was about 4.8 weeks (corrected for physical losses of TCE quantified in the inhibited control).

- Nutrient limitations and pH excursions were not observed in any of the amended treatments.

- Dehalococcoides ethenogenes was not detected in the soil samples used for the treatability study. The absence of Dehalococcoides ethenogenes is further evidence that conditions are not suitable for reductive dechlorination.

Enhanced anaerobic biodegradation through lactate or HRC addition is not recommended for this site. Lactate and nutrient addition at concentrations of 500 mg/L and 2,000 mg/L lactate did not induce reductive dechlorination of the chlorinated ethenes. Addition of HRC induced limited reductive dechlorination of TCE; however, the accumulation of cis-1,2-DCE was observed in the HRC-amended treatments. Only limited concentrations of VC and ethene were detected in the HRC-amended treatments. The accumulation of cis-1,2-DCE and the presence of limited concentrations of VC and ethene are evidence of the absence of significant reductive dechlorination beyond cis-1,2-DCE under amended conditions. A hypothesis for the lack of significant reductive dechlorination proposes that halorespiring microorganisms are not present at the site. This hypothesis was confirmed by microbial testing of two soil samples for the halorespiring microorganism Dehalococcoides ethenogenes. The absence of Dehalococcoides ethenogenes is further evidence that conditions are not suitable for reductive dechlorination.

Therefore, enhanced anaerobic biodegradation is not recommended as a treatment technology for the residuum water-bearing zone at Parcel 66(7).

6.0 References

Fort McClellan (FTMC), 1985, Letter from LTC Robert Cooper to LTC George Pincince (Director of Engineering and Housing, Fort McClellan, Alabama), "Possible Water Pollution at Weapons Branch, Building 335," December 18.

IT Corporation (IT), 2002, ***Draft Remedial Investigation Report, Small Weapons Repair Shop, Parcel 66(7), Fort McClellan, Calhoun County, Alabama***, May.

Vogel, T. M., and P. L. McCarty, 1987, "Abiotic and Biotic Transformations of 1,1,1-Trichloroethane under Methanogenic Conditions," ***Environmental Science and Technology***, 21(12), pp. 1208-1213.

ATTACHMENT 1

MICROBIAL ANALYSIS REPORT

microbial insights

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Microbial Analysis Report

Client: Amy Van Hout
Shaw Env. And Infrastructure
312 Directors Drive
Knoxville TN 37923-4799

Phone: (865) 690-3211

Fax: (865) 690-3626

MI Identifier: 2shw **Date Rec.:** 8/9/02 **Report Date:** 8/15/02

Analysis Requested: TGD: *Dehalococcoides ethenogenes*

Project: McClellon

Comments:

All samples within this data package were analyzed under U.S. EPA Good Laboratory Practice Standards: Toxic Substances Control Act (40 CFR part 790). All samples were processed according to standard operating procedures. Test results submitted in this data package meet the quality assurance requirements established by Microbial Insights, Inc.

Reported by:

(Data Analyst)

Reviewed by:

(Director)

NOTICE: This report is intended only for the addressee shown above and may contain confidential or privileged information. If the recipient of this material is not the intended recipient or if you have received this in error, please notify Microbial Insights, Inc. immediately. The data and other information in this report represent only the sample(s) analyzed and are rendered upon condition that it is not to be reproduced without approval from Microbial Insights, Inc. Thank you for your cooperation.

microbial insights

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Microbial Analysis Report

Executive Summary

The microbial communities from samples FMP66-HRC and FMP66-UC were screened for the presence of *Dehalococcoides ethenogenes* by a targeted gene detection approach. Results from this analysis were unable to confirm the presence of *Dehalococcoides ethenogenes* in either sample.

Overview of Targeted Gene Detection Approach

The recovery of DNA and its subsequent analysis provides a powerful tool for characterizing bacterial community structure. All cells (animals, plants, fungi, and bacteria) contain DNA that allows for their identification. These cells also contain ribosomes, which are required for normal cell functions. The favored target in DNA identification for bacteria is the small sub-unit ribosomal RNA gene, generally referred to as "16S rDNA" in prokaryotes). This target is favored because during the course of evolution, different regions of the ribosome have mutated (or changed) at different rates, with the overall result that some regions of this gene are virtually the same between all organisms (conserved), while other regions differ among even closely related species.

(*Variable and Conserved Regions*)

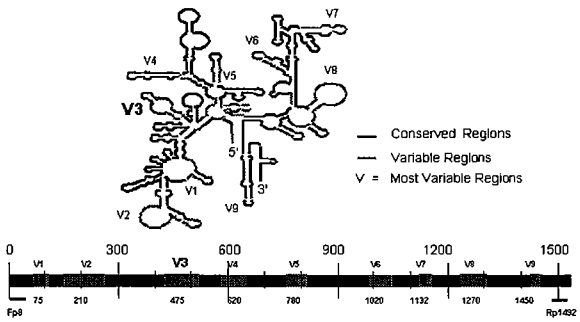


Figure 1. Diagramatic representation detailing the variable and conserved regions of the 16S rRNA gene. This figure was taken from ITRC Internet Training on Natural Attenuation of Chlorinated Solvents in Groundwater: Principles and Practices, Apr 00.

Specific primers directed to a variable region of the 16S rRNA gene of *Dehalococcoides ethenogenes* was used to determine its presence. Based upon Loffler et. al. the sensitivity of these primers is ~10^3 cells/mL or g of sample.

Table 1. Results from the DNA amplification using primers specific for *Dehalococcoides ethenogenes.* QA/QC samples are listed in blue. Extraction blank was used to account for any contamination during the DNA extraction procedure. Two amplification samples were used to unsure a negative response for E-coli and a positive response for *D. ethenogenes.*

Sample	Presence of Dehalococcoides ethenogenes
FMP66-HRC	-
FMP66-UC	-
Extraction Blank	-
Negative Control: E-Coli	-
Positive Control: *Dehalococcoides ethenogenes*	+++

Quality Assurance Section

Sample Arrival and Holding Times:

Two samples were received on 8/9/02, accompanied by a chain of custody form. All arrival conditions and required holding times were acceptable according to SOP #SREC.

Sample Analysis and QA/QC Parameters:

Samples were analyzed under the U.S. EPA Good Laboratory Practice Standards: Toxic Substances Control Act (40 CFR part 790). All samples were processed according to standard operating procedures.

Notes: No QC or analytical problems were encountered

Calibrations and Solvent Checks:

All laboratory equipment and instruments utilized throughout the analyses were calibrated and operating within acceptable ranges. The instruments were calibrated according to Standard Operating Procedures (EQ4). All solvents used in these analyses were validated for purity.

Data Validation:

All data analyses were performed correctly. All calculations and transcriptions of raw and final data were verified.

APPENDIX C

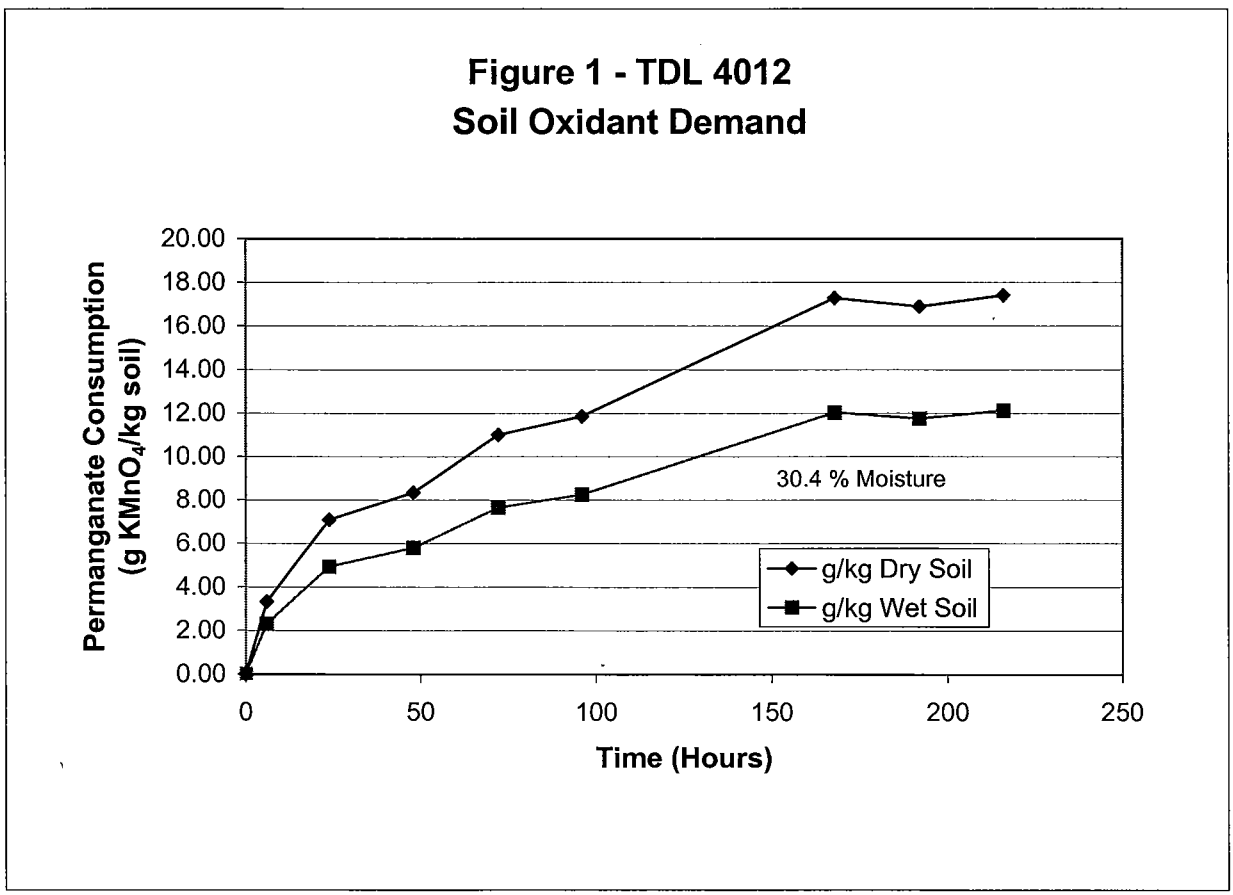
BACKUP CALCULATIONS AND COST INFORMATION FOR ALTERNATIVE 3

CALCULATION OF POTASSIUM PERMANGANATE DEMAND AND REQUIRED MASS

Project Name:	Ft. McClellan	Date Started:	7/12/02
Project Number:	774645.15050300	Analyst Initials:	AR

Client Sample No. (Soil):	Parcel 66 composite	Client Sample No. (Water):	GW-01
Description:	dark brn/blk silty clay	Description:	Ground Water
TAL Sample No.:	4012	TAL Sample No.:	4011
Solids (%):	69.6%	Volume Used (mL):	400
Fraction -4 mm particle size :	0		
Weight Used (g):	200	Initial Weight $KMnO_4$ (g):	4.000
		Initial Conc. $KMnO_4$ (mg/L):	8,700

Time (Hours)	$KMnO_4$ Conc. (mg/L)	$KMnO_4$ Addition (g)	Total $KMnO_4$ Added (g)	Time (Hours)	$KMnO_4$ Consumed (g/kg Dry Solid)	$KMnO_4$ Consumed (g/kg Wet Solid)
0	0	0	0.00	0	0.00	0.00
6	7680	4	4.00	6	3.31	2.31
24	6540	0	4.00	24	7.09	4.93
48	6160	0	4.00	48	8.34	5.81
72	5360	0	4.00	72	10.99	7.65
96	5100	0	4.00	96	11.85	8.25
168	3460	0	4.00	168	17.28	12.03
192	3580	0	4.00	192	16.88	11.75
216	3420	0	4.00	216	17.41	12.12



Shaw™ Shaw Environmental & Infrastructure, Inc.

By TL Date 9/17/02 Subject Parcel 66(7) $KMnO_4$ Calculations Sheet No. 1 of

Chkd. By DJ Date 9/17/02 Feasibility Study Proj. No.

.25 in. X .25 in.

Purpose: Calculate the $KMnO_4$ demand required to oxidize the contaminants and the soil oxidant demand (SOD) over an area of 8,200 ft^2 and a depth of 10 to 30 ft bgs, at Parcel 66(7), Fort McClellan.

Area = 8,200 ft^2 (area w/n 1 mg/L total VOCs contour)

Thickness = 20 ft (10 to 30 ft bgs)

$n = 0.3$

Volume = 8,200 x 20 = 164,000 ft^3

ρ_{soil} = 110 Ib / ft^3

Mass = 164,000 ft^3 x $\frac{110 \text{ Ib}}{ft^3}$ = 18,040,000 Ib

SAFETY FACTOR FOR FRACTURED MEDIA 25%

SOD = 0.25 x 12 $\frac{g\ KMnO_4}{kg\ soil}$ = 3 g $KMnO_4$/kg soil

Soil Mass in Kg = 18,040,000 Ib x $\frac{0.454 \text{ kg}}{\text{Ib}}$ = 8,190,160 kg

$KMnO_4$ demand = $\frac{3 \text{ g } KMnO_4}{\text{kg of soil}}$ x 8,190,160 kg of soil = 24,570.5 kg of $KMnO_4$

Ib of $KMnO_4$ = 24,570.5 kg x $\frac{1 \text{ Ib}}{0.454 \text{ kg}}$ = **54,120 Ibs of $KMnO_4$**

Check print
[signature]
9/17/2002

108A-05-02

VENDOR COSTS FOR POTASSIUM PERMANGANATE AND PERMANGANATE INJECTION (INCLUDING PNEUMATIC FRACTURING)

ARS TECHNOLOGIES, INC.

BREAKING NEW GROUND IN ENVIRONMENTAL TECHNOLOGY

October 10, 2002

Mr. Tarek Ladaa
Shaw Environmental & Infrastructure
312 Directors Drive
Knoxville, TN 37923

RE: Revised Cost Estimate
Potassium Permanganate Injection Service
Fort McClellan, Alabama

Dear Tarek:

ARS Technologies, Inc. (ARS) is pleased to present Shaw Environmental & Infrastructure (Shaw) with this revised cost estimate to perform atomized injection service at your site in Fort McClellan, Alabama. The field service entails the injection of approximately 40,000 pounds of potassium permanganate into the subsurface within a 5,400 square ft. area within depths of 30 ft bgs to 10 ft bgs. The revision is based on a conversation with Josh Malino of your company; ARS is informed that the building near the work area will be demolished and therefore a structural analysis is not required. Other tasks and associated costs remain unchanged.

Scope of Work

The cost to perform the pilot test is estimated at **$173,500**. Please note the estimate was made based on conservative assumptions, such as the cost of nitrogen or compressed air used for the injection. The following sections outline the scope of each of the Cost groups:

Cost Group 1 – Project Management and Planning / Health and Safety *$12,500*

This cost group will include the management, coordination and design of the project as well as correspondences with the client. Included is a site visit by an ARS senior engineer in planning the injection. The visit is critical to ensure the field activities occur in a safe and efficient manner.

114 NORTH WARD STREET, NEW BRUNSWICK, NEW JERSEY 08901
TEL 732.296.6620 FAX 732.296.6625 WWW.ARSTECHNOLOGIES.COM

A concise injection plan will be produce for ARS' field personnel outlining the scope and design of the injection. ARS will also produce an addendum to the site-wide Health and Safety Plan for the field operation. The addendum will focus on safety issues specific to the operations of the injection equipment and operating compressed gas. Both documents will be provided to Shaw for review and comments.

Cost Group 2 – Mobilization/Demobilization and Setup ***$10,500***

This group includes the mobilization/demobilization of ARS' injection equipment, vehicles, materials and field personnel to and from the site. It also includes costs associated with the setting up and breaking down of ARS equipment onsite.

A hoist truck, a slurry injection trailer and an air injection module will be mobilized to the site. In addition, nitrogen (or compressed air) tube trailers will be delivered to the site by a bulk gas supplier.

Cost Group 3 – Field Injection Implementation ***$147,000***

This task group includes costs associated with field injection of the permanganate as well as costs of nitrogen gas or compressed air, equipment rental, consumable materials, health and safety equipment and royalties related to the pneumatic fracturing component. The cost of the bulk nitrogen or compressed air is estimated at $67,000. ARS assumes no buildings or above-ground structures to be within the vicinity of the work area; therefore no structural analysis and modeling will be performed.

The field service entails pneumatically injecting the potassium permanganate in a slurry form into eight (8) injection points within the injection area. The ratio of the permanganate powder to water is assumed 1 pound per gallon. Actual ratio will be determined and optimized based on site conditions.

Injection will be performed at depths of approximately 10 feet bgs to 30 feet bgs in discrete 3-ft intervals isolated by straddled packers starting at the bottom of each injection point. The injection points will likely be constructed of 5-inch open rock holes to a depth of 32 feet bgs (2 feet below the bottom of injection depth to accommodate a bottom packer).

The field injection activity may require 10 to 12 days. During the injection operation, ARS will monitor the pressure and flow of the system to quantify the injection volume and radii of influence.

Cost Group 4 - Field Summary Letter Report ***$3,500***

Upon the completion of the field injection, ARS will prepare and submit to Shaw a summary of the field operational parameters in the form of a concise letter report.

Assumptions

The following assumptions were made as part of the cost estimation:

- The level of document submittal is assumed minimum. Should the project require extensive and detailed work plan and reporting, the cost may increase for Cost Groups 1 and 4.
- ARS is not responsible for the derivation of permanganate dosage and reactivity of the material. ARS is acting solely as the injection service provider for this project.
- There are no aboveground or underground structures, tanks or utility lines within 25 feet of the injection area.
- Potable water is readily available within the injection area with a minimum supply rate of 30 GPM. Otherwise, a 500- or 1000-gal staging tank will be provided by others as a water supply. Or a water truck may be rented by ARS at additional costs.
- A 120-volt 15 amps power outlet is available within 100 feet of the injection points.
- ARS is not responsible for obtaining necessary regulatory approval or permits for the injection.

If you have any questions regarding this proposal, please contact me at (732) 296-6620 ext.14.

Sincerely,
ARS Technologies, Inc.

Steve Chen

Cc: John Liskowitz, ARS

Ladaa, Tarek I

From: Linda Warren [Linda.Warren@caruschem.com]
Sent: Friday, October 18, 2002 4:00 PM
To: tarek.ladaa@shawgrp.com
Cc: Bob Kelley; Kathy Kotecki; Kristine Metzke; Sharon Friedl
Subject: Ft. McCllellan, AL - CAIROX® Potassium Permanganate USP Code F - corrected pricing information

Mr. Tarek Ladaa
Shaw E&I
Knoxville, TN
Tele 865.670.2708

Hello Tarek,

I made a pricing mistake on the previous e-mail. Please see below for the corrected amount. My apologies.

It was a pleasure talking with you today regarding your remediation site at Fort McClellan, AL. As a follow up to our conversation, please find below pricing information on 54,210 lbs of CAIROX® Potassium Permanganate USP Code F. It is as follows:

* Product: CAIROX® Potassium Permanganate USP Code F
* Packaging: 150-kg drum
* Pricing: $1.59/lb
* Freight: FOB, LaSalle, IL
* Terms: Net 30 days
* Validity: This quote is firm through 18 January 2003

Also, please find below the most recent EPA ruling on the toxicity of manganese. It is:

EPA has made a preliminary determination not to regulate manganese with a NPDWR because it is generally not considered to be very toxic when ingested with the diet and because drinking water accounts for a relatively small proportion of manganese intake. Thus, regulation would not present a meaningful opportunity for health risk reduction for persons served by PWSs. Additionally, sodium and sulfate are two other priority contaminants that are among the nine EPA has decided not to regulate in drinking water.

This appeared on the proposed rules by EPA in the Federal Register: June 3, 2002 (Volume 67, Number 106)] [Page 38222-38244 - 40 CFR Part 141

Announcement of Preliminary Regulatory Determinations for Priority Contaminants on the Drinking Water Contaminant Candidate List

ACTION: Notice of preliminary regulatory determination.

SUMMARY: The Safe Drinking Water Act (SDWA), as amended in 1996, directs the Environmental Protection Agency (EPA) to publish a list of contaminants (referred to as the Contaminant Candidate List, or CCL) to assist in priority-setting efforts. SDWA also directs the Agency to select five or more contaminants from the current CCL and determine by August 2001 whether or not to regulate these contaminants with a National Primary Drinking Water Regulation (NPDWR). Today's action presents the preliminary regulatory determinations for nine contaminants and describes the supporting rationale for each.

DATES: Comments must be received on or before August 2, 2002.

4. Manganese
After reviewing the best available public health and occurrence information, EPA has made a preliminary decision not to regulate manganese with a National Primary Drinking Water Regulation (NPDWR). EPA's finding is that manganese is essential for normal physiological functioning in humans and all animal species, however, several diseases are associated with both deficiencies and excess intake of manganese. Nonetheless, manganese is generally considered to have low

toxicity when ingested orally. EPA also finds that manganese occurs in PWSs, with 6.1% of reporting ground water PWSs having detections above the \1/2\ health reference level (HRL) and 3.2% having detections above the HRL. But, because the toxicity of manganese by oral ingestion is low, EPA finds that regulation of manganese in drinking water does not present a meaningful opportunity for health risk reduction for persons served by PWSs.

I hope the information is helpful to you. I will follow up with you in a month or so to see how things are progressing on the Fort McClellan site. In the meantime, please feel free to call me if I can be of any other assistance.

With kind regard,

Linda S. Warren
Hazardous Remediation Program Specialist
Carus Chemical Company
315 Fifth Street
Peru, Illinois 61354
USA
Tele: 800.435.6856, ext. 6654
Fax: 815.224.6663
e-mail: linda.warren@caruschem.com

COST ESTIMATE FOR DEMOLITION OF BUILDING 335

Item	Description	Takeoff Qty		Labor Unit Cost	Material Unit Cost	Subcontract Unit Cost	Equipment Unit Cost	Other Unit Cost	Total Unit Cost	Amount
	01 PLANS									
01.01	WORK PLAN									
A00.000	OFFICE LABOR									
E415	Manager, Quality Control - E10	8.00	HR	96.686 /HR	-	-	-	-	96.686 /HR	773
E470	Proj Engr/Sr Scientist - E10	40.00	HR	94.74 /HR	-	-	-	-	94.74 /HR	3,790
E485	Project Manager III - E12	24.00	HR	125.051 /HR	-	-	-	-	125.051 /HR	3,001
E625	Superintendent II - E10	8.00	HR	95.361 /HR	-	-	-	-	95.361 /HR	763
N330	Word Processor III - N06	8.00	HR	40.434 /HR	-	-	-	-	40.434 /HR	323
	OFFICE LABOR									8,651
	01.01 WORK PLAN									8,651
01.02	HEALTH & SAFETY PLAN									
A00.000	OFFICE LABOR									
E330	H&S Coordinator III - E09	40.00	HR	79.852 /HR	-	-	-	-	79.852 /HR	3,194
E341	H&S Manager II - E12	8.00	HR	109.656 /HR	-	-	-	-	109.656 /HR	877
E485	Project Manager III - E12	8.00	HR	125.051 /HR	-	-	-	-	125.051 /HR	1,000
N140	Draftsperson III/Cad Cam Opr - N08	16.00	HR	58.677 /HR	-	-	-	-	58.677 /HR	939
N330	Word Processor III - N06	16.00	HR	40.434 /HR	-	-	-	-	40.434 /HR	647
	OFFICE LABOR									6,658
	01.02 HEALTH & SAFETY PLAN									6,658
01.03	PERMITS									
A00.000	OFFICE LABOR									
E285	Engr/Sci IV - E09	40.00	HR	88.537 /HR	-	-	-	-	88.537 /HR	3,541
E485	Project Manager III - E12	16.00	HR	125.052 /HR	-	-	-	-	125.052 /HR	2,001
	OFFICE LABOR									5,542
	01.03 PERMITS									5,542
	01 PLANS									**20,851**
	02 MOBILIZATION									
02.01	MOBE OF EQUIPMENT									
F00.000	OUTSIDE EQUIPMENT									
01	Mob 4-WD Artic. Wheel Loaders	1.00	EA	-	-	-	190.58 /EA	-	190.58 /EA	191
01	Mob Hydraulic Excavators	1.00	EA	-	-	-	190.57 /EA	-	190.57 /EA	191
01	Mob Excavatro w/ shear	1.00	EA	-	-	-	190.57 /EA	-	190.57 /EA	191
01	Mob Artic. Boom Aerial Lifts	1.00	EA	-	-	-	190.58 /EA	-	190.58 /EA	191
01	Mob Artic. Boom Aerial Lifts	1.00	EA	-	-	-	190.57 /EA	-	190.57 /EA	191
01	Mob Acetylene Torches	1.00	EA	-	-	-	190.58 /EA	-	190.58 /EA	191
01	Mob Field Office Trailers	1.00	EA	-	-	-	635.25 /EA	-	635.25 /EA	635
03	Block & Level Trailers	1.00	EA	-	-	-	362.09 /EA	-	362.09 /EA	362
01	Mob Water Trailers	1.00	EA	-	-	-	190.57 /EA	-	190.57 /EA	191
	OUTSIDE EQUIPMENT									2,331
	02.01 MOBE OF EQUIPMENT									2,331
02.02	SET UP PRIOR TO DEMO									

Item	Description	Takeoff Qty		Labor Unit Cost	Material Unit Cost	Subcontract Unit Cost	Equipment Unit Cost	Other Unit Cost	Total Unit Cost	Amount
M00.000	SUBCONTRACTS									
0025	Electric System Installation	1.00	LS	-	-	1,800.000 /LS	-	-	1,800.000 /LS	1,800
0100	Telephone System Installation	1.00	LS	-	-	500.000 /LS	-	-	500.000 /LS	500
	SUBCONTRACTS									2,300
	02.02 SET UP PRIOR TO DEMO									2,300
02.03	MOBE OF PERSONNEL									
B00.000	FIELD LABOR									
E625	Superintendent II - E10	8.00	HR	63.209 /HR	-	-	-	-	63.209 /HR	506
H255	Field Equip Oper IV - H06	8.00	HR	30.651 /HR	-	-	-	-	30.651 /HR	245
H260	Field Equip Oper V - H07	8.00	HR	33.699 /HR	-	-	-	-	33.699 /HR	270
H270	Field Equip Oper/Foreman II - H09	8.00	HR	42.238 /HR	-	-	-	-	42.238 /HR	338
H295	Field H&S Tech V - H08	8.00	HR	40.211 /HR	-	-	-	-	40.211 /HR	322
H440	Field Services Tech IV - H04	8.00	HR	25.595 /HR	-	-	-	-	25.595 /HR	205
H440	Field Services Tech IV - H04	8.00	HR	25.594 /HR	-	-	-	-	25.594 /HR	205
H442	Field Services Tech V - H05	8.00	HR	28.526 /HR	-	-	-	-	28.526 /HR	228
H442	Field Services Tech V - H05	8.00	HR	28.525 /HR	-	-	-	-	28.525 /HR	228
	FIELD LABOR									2,546
	02.03 MOBE OF PERSONNEL									2,546
	02 MOBILIZATION									7,177
	03 DEMO									
03.01	REMOVE ALL INTERIOR PIPING & EQUIP									
B00.000	FIELD LABOR									
H255	Field Equip Oper IV - H06	40.00	HR	30.65 /HR	-	-	-	-	30.65 /HR	1,226
H260	Field Equip Oper V - H07	40.00	HR	33.70 /HR	-	-	-	-	33.70 /HR	1,348
H270	Field Equip Oper/Foreman II - H09	40.00	HR	42.238 /HR	-	-	-	-	42.238 /HR	1,690
H295	Field H&S Tech V - H08	40.00	HR	40.211 /HR	-	-	-	-	40.211 /HR	1,608
H440	Field Services Tech IV - H04	40.00	HR	25.595 /HR	-	-	-	-	25.595 /HR	1,024
H440	Field Services Tech IV - H04	40.00	HR	25.594 /HR	-	-	-	-	25.594 /HR	1,024
H442	Field Services Tech V - H05	40.00	HR	28.526 /HR	-	-	-	-	28.526 /HR	1,141
H442	Field Services Tech V - H05	40.00	HR	28.526 /HR	-	-	-	-	28.526 /HR	1,141
	FIELD LABOR									10,202
F00.000	OUTSIDE EQUIPMENT									
I24D	Cat IT24 Tool Carrier	5.00	DY	-	-	-	279.51 /DY	-	279.51 /DY	1,398
I24f	FOGM Cat IT24 Tool Carrier	35.00	HR	-	-	-	-	8.919 /HR	8.919 /HR	312
330D	Cat 330L Excavator	5.00	DY	-	-	-	933.814 /DY	-	933.814 /DY	4,669
330f	FOGM Cat 330L Excavator	35.00	HR	-	-	-	-	18.841 /HR	18.841 /HR	659
HS-D	Hydraulic Shear S80 32"	5.00	DY	-	-	-	374.796 /DY	-	374.796 /DY	1,874
HS-f	FOGM Hydraulic Shear S80 32"	35.00	HR	-	-	-	-	1.525 /HR	1.525 /HR	53
AB3D	60HA Artic. Boom Lift	5.00	DY	-	-	-	304.92 /DY	-	304.92 /DY	1,525
AB3f	FOGM 60HA Artic. Boom Lift	35.00	HR	-	-	-	-	3.392 /HR	3.392 /HR	119
AT1D	Acetylene Torch Set Complete	5.00	DY	-	-	-	127.048 /DY	-	127.048 /DY	635
AT1D	Acetylene Torch Set Complete	5.00	DY	-	-	-	127.05 /DY	-	127.05 /DY	635
AT1f	FOGM Acetylene Torch Set Complete	70.00	HR	-	-	-	-	31.762 /HR	31.762 /HR	2,223
	OUTSIDE EQUIPMENT									14,103
	03.01 REMOVE ALL INTERIOR PIPING & EQUIP									24,304
03.02	DEMO TOP 20 FT OF BLDG									

Item	Description	Takeoff Qty		Labor Unit Cost	Material Unit Cost	Subcontract Unit Cost	Equipment Unit Cost	Other Unit Cost	Total Unit Cost	Amount
B00.000	*FIELD LABOR*									
H255	Field Equip Oper IV - H06	40.00	HR	30.65 /HR	-	-	-	-	30.65 /HR	1,226
H260	Field Equip Oper V - H07	40.00	HR	33.70 /HR	-	-	-	-	33.70 /HR	1,348
H270	Field Equip Oper/Foreman II - H09	40.00	HR	42.238 /HR	-	-	-	-	42.238 /HR	1,690
H295	Field H&S Tech V - H08	40.00	HR	40.211 /HR	-	-	-	-	40.211 /HR	1,608
H440	Field Services Tech IV - H04	40.00	HR	25.594 /HR	-	-	-	-	25.594 /HR	1,024
H440	Field Services Tech IV - H04	40.00	HR	25.595 /HR	-	-	-	-	25.595 /HR	1,024
H442	Field Services Tech V - H05	40.00	HR	28.526 /HR	-	-	-	-	28.526 /HR	1,141
H442	Field Services Tech V - H05	40.00	HR	28.526 /HR	-	-	-	-	28.526 /HR	1,141
	FIELD LABOR									*10,202*
F00.000	*OUTSIDE EQUIPMENT*									
I24D	Cat IT24 Tool Carrier	5.00	DY	-	-	-	279.51 /DY	-	279.51 /DY	1,398
I24f	FOGM Cat IT24 Tool Carrier	35.00	HR	-	-	-	-	8.919 /HR	8.919 /HR	312
330D	Cat 330L Excavator	5.00	DY	-	-	-	933.814 /DY	-	933.814 /DY	4,669
330D	Cat 330L Excavator	5.00	DY	-	-	-	933.814 /DY	-	933.814 /DY	4,669
330f	FOGM Cat 330L Excavator	35.00	HR	-	-	-	-	18.841 /HR	18.841 /HR	659
330f	FOGM Cat 330L Excavator	35.00	HR	-	-	-	-	18.841 /HR	18.841 /HR	659
BT-D	Hydraulic Bucket Thumb 20MT Wide	5.00	DY	-	-	-	100.37 /DY	-	100.37 /DY	502
HS-D	Hydraulic Shear S80 32"	5.00	DY	-	-	-	374.796 /DY	-	374.796 /DY	1,874
HS-f	FOGM Hydraulic Shear S80 32"	35.00	HR	-	-	-	-	1.525 /HR	1.525 /HR	53
AB3D	60HA Artic. Boom Lift	5.00	DY	-	-	-	304.92 /DY	-	304.92 /DY	1,525
AB3D	60HA Artic. Boom Lift	5.00	DY	-	-	-	304.918 /DY	-	304.918 /DY	1,525
AB3f	FOGM 60HA Artic. Boom Lift	35.00	HR	-	-	-	-	3.392 /HR	3.392 /HR	119
AB3f	FOGM 60HA Artic. Boom Lift	35.00	HR	-	-	-	-	3.392 /HR	3.392 /HR	119
AT1D	Acetylene Torch Set Complete	5.00	DY	-	-	-	127.05 /DY	-	127.05 /DY	635
AT1D	Acetylene Torch Set Complete	5.00	DY	-	-	-	127.05 /DY	-	127.05 /DY	635
AT1f	FOGM Acetylene Torch Set Complete	70.00	HR	-	-	-	-	31.762 /HR	31.762 /HR	2,223
	OUTSIDE EQUIPMENT									*21,576*
M00.000	*SUBCONTRACTS*									
4002	Trans. & Disp. Non-Haz. Waste	375.00	TON	-	-	59.936 /TON	-	-	59.936 /TON	22,476
	SUBCONTRACTS									*22,476*
	03.02 DEMO TOP 20 FT OF BLDG									**54,254**
03.03	**DEMO BLOCK WALL TO GRADE**									
B00.000	*FIELD LABOR*									
H255	Field Equip Oper IV - H06	40.00	HR	30.65 /HR	-	-	-	-	30.65 /HR	1,226
H260	Field Equip Oper V - H07	40.00	HR	33.70 /HR	-	-	-	-	33.70 /HR	1,348
H270	Field Equip Oper/Foreman II - H09	40.00	HR	42.238 /HR	-	-	-	-	42.238 /HR	1,690
H295	Field H&S Tech V - H08	40.00	HR	40.211 /HR	-	-	-	-	40.211 /HR	1,608
H440	Field Services Tech IV - H04	40.00	HR	25.594 /HR	-	-	-	-	25.594 /HR	1,024
H440	Field Services Tech IV - H04	40.00	HR	25.594 /HR	-	-	-	-	25.594 /HR	1,024
	FIELD LABOR									*7,919*
F00.000	*OUTSIDE EQUIPMENT*									
I24D	Cat IT24 Tool Carrier	5.00	DY	-	-	-	279.508 /DY	-	279.508 /DY	1,398
I24f	FOGM Cat IT24 Tool Carrier	35.00	HR	-	-	-	-	8.919 /HR	8.919 /HR	312
330D	Cat 330L Excavator	5.00	DY	-	-	-	933.814 /DY	-	933.814 /DY	4,669
330f	FOGM Cat 330L Excavator	35.00	HR	-	-	-	-	18.841 /HR	18.841 /HR	659
BT-D	Hydraulic Bucket Thumb 20MT Wide	5.00	DY	-	-	-	100.37 /DY	-	100.37 /DY	502
	OUTSIDE EQUIPMENT									*7,540*
M00.000	*SUBCONTRACTS*									
4002	Trans. & Disp. Non-Haz. Waste	1,047.00	TON	-	-	59.936 /TON	-	-	59.936 /TON	62,753

Item	Description	Takeoff Qty		Labor Unit Cost	Material Unit Cost	Subcontract Unit Cost	Equipment Unit Cost	Other Unit Cost	Total Unit Cost	Amount
	SUBCONTRACTS									*62,753*
	03.03 DEMO BLOCK WALL TO GRADE									78,213
03.04	DEMOBE									
F00.000	*OUTSIDE EQUIPMENT*									
01	Mob 4-WD Artic. Wheel Loaders	1.00	EA	-	-	-	190.58 /EA	-	190.58 /EA	191
01	Mob Hydraulic Excavators	1.00	EA	-	-	-	190.57 /EA	-	190.57 /EA	191
01	Mob Excavatro w/ shear	1.00	EA	-	-	-	190.57 /EA	-	190.57 /EA	191
01	Mob Artic. Boom Aerial Lifts	1.00	EA	-	-	-	190.58 /EA	-	190.58 /EA	191
01	Mob Artic. Boom Aerial Lifts	1.00	EA	-	-	-	190.57 /EA	-	190.57 /EA	191
01	Mob Acetylene Torches	1.00	EA	-	-	-	190.58 /EA	-	190.58 /EA	191
01	Mob Field Office Trailers	1.00	EA	-	-	-	635.25 /EA	-	635.25 /EA	635
03	Block & Level Trailers	1.00	EA	-	-	-	362.09 /EA	-	362.09 /EA	362
01	Mob Water Trailers	1.00	EA	-	-	-	190.57 /EA	-	190.57 /EA	191
	OUTSIDE EQUIPMENT									*2,331*
	03.04 DEMOBE									2,331
03.05	DEMOBE PERSONNEL									
B00.000	*FIELD LABOR*									
E625	Superintendent II - E10	8.00	HR	63.209 /HR	-	-	-	-	63.209 /HR	506
H255	Field Equip Oper IV - H06	8.00	HR	30.651 /HR	-	-	-	-	30.651 /HR	245
H260	Field Equip Oper V - H07	8.00	HR	33.699 /HR	-	-	-	-	33.699 /HR	270
H270	Field Equip Oper/Foreman II - H09	8.00	HR	42.238 /HR	-	-	-	-	42.238 /HR	338
H295	Field H&S Tech V - H08	8.00	HR	40.211 /HR	-	-	-	-	40.211 /HR	322
H440	Field Services Tech IV - H04	8.00	HR	25.595 /HR	-	-	-	-	25.595 /HR	205
H440	Field Services Tech IV - H04	8.00	HR	25.594 /HR	-	-	-	-	25.594 /HR	205
H442	Field Services Tech V - H05	8.00	HR	28.526 /HR	-	-	-	-	28.526 /HR	228
H442	Field Services Tech V - H05	8.00	HR	28.525 /HR	-	-	-	-	28.525 /HR	228
	FIELD LABOR									*2,546*
	03.05 DEMOBE PERSONNEL									2,546
	03 DEMO									***161,648***
	04 SITE SUPPORT									
04.01	SITE SUPPORT									
B00.000	*FIELD LABOR*									
E625	Superintendent II - E10	160.00	HR	63.209 /HR	-	-	-	-	63.209 /HR	10,113
	FIELD LABOR									*10,113*
E00.000	*SHAW EQUIPMENT*									
V52D	Pick-Up Truck, 4WD	30.00	DY	-	-	-	47.686 /DY	-	47.686 /DY	1,431
V52f	FOGM Pick-Up Truck, 4WD	120.00	HR	-	-	-	-	4.536 /HR	4.536 /HR	544
V68D	Water Truck, 1500-2000 Gallon	22.00	DY	-	-	-	99.988 /DY	-	99.988 /DY	2,200
V68f	FOGM Water Truck, 1500-2000 Gallon	88.00	HR	-	-	-	-	11.79 /HR	11.79 /HR	1,038
V78D	Van	22.00	DY	-	-	-	32.304 /DY	-	32.304 /DY	711
V78f	FOGM Van	88.00	HR	-	-	-	-	4.485 /HR	4.485 /HR	395
	SHAW EQUIPMENT									*6,317*
F00.000	*OUTSIDE EQUIPMENT*									
OT-D	Office Trailer	22.00	DY	-	-	-	27.951 /DY	-	27.951 /DY	615
	OUTSIDE EQUIPMENT									*615*

Item	Description	Takeoff Qty		Labor Unit Cost	Material Unit Cost	Subcontract Unit Cost	Equipment Unit Cost	Other Unit Cost	Total Unit Cost	Amount
M00.000	*SUBCONTRACTS*									
0175	Mth. Elect. Bill	1.00	MO	-	-	400.000 /MO	-	-	400.000 /MO	400
0275	Mth. Telephone Bill (L Dist.)	1.00	MO	-	-	350.00 /MO	-	-	350.00 /MO	350
0050	Wk. Operating Supplies	3.00	EA	-	-	1,750.00 /EA	-	-	1,750.00 /EA	5,250
0100	Consumable Materials	1.00	LS	-	-	5,000.000 /LS	-	-	5,000.000 /LS	5,000
0020	Phone/Fax/Modem Charges	1.00	MO	-	-	450.00 /MO	-	-	450.00 /MO	450
0025	Bottle Water Service	1.00	MO	-	-	100.000 /MO	-	-	100.000 /MO	100
0050	Trash/Garbage Pickup	1.00	MO	-	-	130.00 /MO	-	-	130.00 /MO	130
0100	Porta-John	1.00	MO	-	-	100.000 /MO	-	-	100.000 /MO	100
001	Cell Phone Charges	30.00	DY	-	-	15.00 /DY	-	-	15.00 /DY	450
	SUBCONTRACTS									*12,230*
	04.01 SITE SUPPORT									**29,276**
04.02	**OVERSITE**									
A00.000	*OFFICE LABOR*									
E155	Buyer II - E07	40.00	HR	68.687 /HR	-	-	-	-	68.687 /HR	2,747
E205	Cost Scheduling Engr III - E09	80.00	HR	91.075 /HR	-	-	-	-	91.075 /HR	7,286
E245	Dir, Project II - E14	8.00	HR	143.944 /HR	-	-	-	-	143.944 /HR	1,152
E460	Proj Bus Admin II - E06	80.00	HR	59.494 /HR	-	-	-	-	59.494 /HR	4,760
E470	Proj Engr/Sr Scientist - E10	24.00	HR	94.74 /HR	-	-	-	-	94.74 /HR	2,274
E485	Project Manager III - E12	100.00	HR	125.051 /HR	-	-	-	-	125.051 /HR	12,505
	OFFICE LABOR									*30,723*
	04.02 OVERSITE									**30,723**
	04 SITE SUPPORT									***59,999***

Estimate Totals

Labor	95,102	
Subcontract	99,759	
Equipment	44,354	
Other	10,460	
	249,675	249,675
	Total	***249,675***