Treatability Study Report

Penta Wood Products Town of Daniels, Wisconsin

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CH2MHILL

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United States Environmental Protection Agency
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Office of Superfund
77 West Jackson Boulevard
Chicago, Illinois 60604

List of Tables **follows Section**

Treatability Study Report

1 Introduction

This report describes three treatability studies conducted for the United States Environmental Protection Agency (U.S. EPA) as part of the Penta Wood Site Feasibility Study. The treatability studies consisted of a bioventing column study conducted in a controlled setting in a laboratory; a bioventing field study conducted at the site; and a groundwater photolysis study conducted at the site. The treatability studies were conducted in accordance with *Treatability Study Work Plan* (TS Work Plan) prepared by CH2M HILL dated September 10, 1997. This report discusses the purpose and scope, implementation and operation, and results and evaluation of each study. Each study is presented in a separate section of the report.

2 Bioventing Column Treatability Study

Bioventing is an in situ bioremediation process that involves oxygenating subsurface soils by distributing air through the unsaturated zone. The air stimulates in situ biological activity and promotes the bioremediation of residual organic contamination sorbed to the soils in the vadose zone. . Microorganisms consume the pentachlorophenol (PCP) and fuel oil components, either as a primary substrate or as an electron acceptor. Under aerobic conditions pentachlorophenol (PCP) eventually breaks down into carbon dioxide, water, and chloride. The *Remedial Investigation Report* prepared by CH2M HILL dated June 1998 describes PCP degradation pathways in detail. The intent of bioventing is to provide the necessary oxygen to maximize the indigenous microorganisms' use of the PCP and fuel oil contaminants and thereby reduce the mass of contaminants in the soils.

2.1 Purpose and Scope

The purpose of the bioventing column study was to investigate the feasibility of the degradation of PCP and fuel oil under simulated in situ soil bioventing conditions. The critical uncertainties with bioventing are: (1) its ability to effectively oxygenate the vadose zone; (2) the degree of contaminant removal that can potentially be achieved; and (3) the time required to reach the ultimate remedial goal. The goal of the column study was to focus on the degree of contaminant removal that can potentially be achieved. Contaminant degradation and respiration tests were performed to evaluate oxygen requirements and the extent and/or rate of contaminant removal achievable under optimal soil moisture and oxygen content conditions.

The column study was operated for 6 months, from February to August 1998. Implementation included sampling in triplicate the soil/wood debris before it was packed in the columns, packing the four soil columns, purging the anaerobic control column with nitrogen, and starting humidified air flow into the other three columns. During the first week air samples were collected from the column off gas and analyzed for PCP and diesel range organics. Operation included measurement of the in situ oxygen concentrations,

measurement of the soil off gas oxygen concentrations, and measurement of the air flow rates. Soil sample collection occurred prior to start up, after 2 months of operation, after 4 months of operation, and at 6 months for direct measurement of PCP and petroleum hydrocarbon reduction.

2.2 Implementation

2.2.1 Soil Sample Selection

Prior to set up of the bioventing columns, soil samples were collected from soil gas wells at the Penta Wood site to establish initial contaminant and soil parameter conditions. Results from these samples determined which soil samples would be used for the bioventing column study. The table below summarizes the samples selected for the column study and the initial PCP concentrations of those samples:

Sample Number	Sample Collection Date	Sample Interval (feet)	PCP Concentration (mg/kg)	Column Number
EW1CS	1/22/98	1-10	384	1 and 2
SG8CS	1/28/98	10-15	707	3
SG9CS	1/27/98	1-10	5,460	4

2.2.2 Laboratory Soil Sampling

The soil was sampled at the laboratory immediately before the soil was packed into the columns. Triplicate soil/wood debris samples were collected from the three 5 gallon buckets filled with the samples previously discussed in Section 2.2.1. The soil/wood debris from the 5 gallon buckets were mixed to homogenize the sample prior to sub-samples collection. Triplicate samples were collected to assess any variation in the PCP concentrations across the sample. The samples were collected with decontaminated equipment and analyzed for PCP, diesel-range organics (DRO), moisture, pH, and chloride. The samples were prepared and shipped following EPA-approved guidelines and chain-of-custody procedures (Sampling and Analysis Plan, Revision 1, November 1997).

2.2.3 Column Set-up

Four bioventing columns were set up as follows:

1. Column 1 - Contaminated soil with initial field PCP concentrations of 384 mg/kg which was not aerated (to simulate anaerobic conditions similar to those naturally occurring and serve as an experimental control column)
2. Column 2 – Same soil as Column 1 (PCP concentrations of 384 mg/kg) which was aerated
3. Column 3 - Contaminated soil with initial field PCP concentrations of 707 mg/kg which was aerated
4. Column 4 - Contaminated wood debris and soil with initial field PCP concentrations of 5,460 mg/kg which was aerated

Details on how the columns were set up and the operating conditions can be found in the Bioventing Column Study Memorandum in Attachment 1.

2.3 Start up and Operation of Column Study

Start-up of the bioventing columns included: turning the air on, measuring initial oxygen depletion, adjusting the air flow rate to each column to provide adequate in situ oxygen concentrations, and collecting two 7-day composite air samples from the soil off gas from columns 3 and 4.

The oxygen depletion was recorded by measuring the in situ oxygen concentration with the air on, turning the air off for 24 hours and measuring the resulting in situ oxygen concentration. This was done primarily to determine if oxygen depletion was occurring and to determine the relative oxygen use between each column. The column air flow rates were then adjusted accordingly, the greater the oxygen depletion the higher the required air flow rate to maintain aerobic conditions.

Air samples were collected from the off-gas lines to assess the potential for PCP volatilization (as opposed to biological degradation) and measure the rate of volatilization if it does occur. The air samples were collected in XAD tubes and were analyzed for PCP and DRO.

In-situ and off-gas oxygen readings and flow rates were monitored periodically throughout the study. A second 24-hour oxygen depletion event was conducted in April. Soil samples were collected from each of the soil columns at 2- , 4- and 6-months and analyzed for PCP, DRO, chloride, moisture, and pH. The soil was collected by emptying the soil from a column into a stainless steel bowl, thoroughly mixing the soil, and collecting a composite sample from different areas of the bowl in an effort to obtain a representative sample from each column. After each sampling, the soil was packed back into the column and the air flow rates adjusted.

2.4 Results

Soil analytical results, oxygen depletion and air flow measurements, and air samples from the column off gas are presented in the attached tables (Tables 2-1 through 2-4). A discussion of the results follows.

2.4.1 Soil/Wood Debris Sample Results

Table 2-1 presents initial triplicate analytical soil/wood debris results from the samples collected at the treatability study laboratory immediately prior to the soil being packed in the columns. The results present initial concentrations of PCP, DRO, moisture, pH, and chloride before the start of the treatability study. Moisture and pH are measured because optimum conditions for aerobic degradation to occur are dependent on pH and moisture. Chloride is measured because it is a degradation product of PCP.

The results of the triplicate samples show that there is some variability within each soil/wood debris sample used to fill the columns. An average concentration was calculated and used to represent the initial laboratory concentration. Table 2-2 presents the soil analytical results in the field during soil collection, the initial pre-start-up laboratory result, and at 2-months, 4-months, and 6-months of operation. A comparision of initial field PCP

concentrations to initial laboratory concentrations show an even greater variability within the same soil samples. This variability is likely due to the heterogeneity of soils, settling of PCP/oil during shipment of the soil from the field to the treatability lab (despite efforts to thoroughly mix soils prior to sampling), and soil matrix problems that hamper effective extraction during the analytical process. The samples collected at 2- , 4- and 6-months were a composite from the entire column in an effort to provide a representative sample to compare degradation results.

As is presented on Table 2-2, all of the soil columns showed a reduction of PCP. Column 1, the anaerobic column, showed the greatest PCP reduction at 69%, but showed increased fuel oil component concentration. Column 2, which consisted of native sand with initial PCP concentration of 384 mg/kg, showed a PCP reduction of 45%, and a 49% reduction of fuel oil components. The other aerobic columns, Column 3 and Column 4, showed 17% PCP reduction and 8% PCP reduction, respectively. These results are somewhat in contrast to the field bioventing results (described in Section 3), in which the soils with higher PCP/oil concentrations had greater reduction rates. All of the soil columns except the anaerobic column had an increase in chloride concentration, which is an end-product of PCP microbial degradation.. Each mg/l increase in chloride concentration represents a decrease of 1.49 mg/kg of PCP based on the stoichiometry of the PCP degradation reaction. Based on the chloride data the amounts of PCP reduction are 38%, 16%, and 111% in columns 2, 3 and 4 respectively. These percent reductions are comparable to the direct measurement reductions for PCP for Columns 2 and 3, but not for Column 4. The large difference in the Column 4 results could be based on contaminant heterogeneities through the soil column.

2.4.2 Oxygen Depletion and Air Flow Rates

The results of the oxygen depletion studies are shown in Table 2-3. The depletion of oxygen after the air is turned off indicates that aerobic degradation is occurring since all the columns are sealed and the only means whereby oxygen can be depleting is through microbial degradation. All of the aerobic columns showed oxygen depletion within the 24-hour test, with Columns 2 and 4 actually going to 0% oxygen at different times. Based on the average oxygen depletion rates, a corresponding TPH reduction rate can be calculated (Hinchee, et al, 1992.). The corresponding TPH reduction rates (based on the average oxygen utilization rates) for Columns 2, 3, and 4 are 409%, 303%, and 77%. Assuming that the amount of PCP in the PCP-TPH mixture is about 5%, then the corresponding PCP reductions are 20% for Column 2, 15% for Column 3, and 4% for Column 4. These percent reductions are comparable to the percent reductions calculated from the observed analytical data for PCP.

2.4.3 Air Samples

The air sample results, shown on Table 2-4, indicate the petroleum products (as shown by the DRO measurements) appear to be volatilizing, but the PCP does not appear to be volatilizing at detectable levels. Thus PCP reduction by volatilization is not a significant loss mechanism, and air quality during full-scale bioventing at the site should not be a concern based on PCP volatilization. The laboratory report for the air samples are in Attachment 2.

Table 2-1
February 11, 1998 Soil/Wood Debris Analytical Data
Column Treatability Study
Penta Wood Products

Column	Sample	Sample Date	PCP (mg/kg)	DRO (mg/kg)	moisture (%)	pH	Chloride (mg/kg)
1 and 2	1	2/11/98	95	1,000	8.3	5.71	20.3
1 and 2	2	2/11/98	150	1,600	8.1	5.75	15.1
1 and 2	3	2/11/98	130	880	8.7	5.84	15.9
Average			125	1,160	8.4		17.1
3	1	2/11/98	450	12,000	5.5	4.63	8.85
3	2	2/11/98	450	12,000	6.2	4.63	8.52
3	3	2/11/98	560	8,400	5.5	4.70	8.35
Average			487	10,800	5.7		8.57
4	1	2/11/98	1,100	43,000	51.6	4.27	75
4	2	2/11/98	930	39,000	52.6	4.23	103
4	3	2/11/98	760	9,300	44.8	4.38	53.3
Average			930	30,433	49.7		77.1

Note: Columns 1 and 2 contain the same soil. Column 1 is set up to maintain anaerobic conditions and Column 2 is set up to maintain aerobic conditions.

Table 2-2
Soil Analytical Results
Column Treatability Study
Penta Wood Products

Sample: Column 1 - Anaerobic Conditions
Soil Type: Sand
Sample Depth: EW1 1-10 feet bgs

Parameter	Initial Field conc. 1/22/98		Initial Lab conc. 2/11/98		2-month concentration 4/8/98		4-month concentration 6/8/98		6-month concentration 8/6/98		overall % reduction
PCP	384	mg/kg	125	mg/kg	280	mg/kg	210	mg/kg	120	mg/kg	69
DRO	NA	NA	1,160	mg/kg	2,400	mg/kg	1,500	mg/kg	1,700	mg/kg	-47
Chloride	NA	NA	17	mg/kg	5.4 U	mg/kg	8	mg/kg	10	mg/kg	43
Moisture	NA	NA	8.4	%	8	%			8	%	NA
pH	NA	NA	5.77	S.U.	6	S.U.			6.4	NA	NA

Sample: Column 2 - Aerobic Conditions
Soil Type: Sand
Sample Depth: EW1 1-10 feet bgs

Parameter	Initial Field conc. 1/22/98		Initial Lab conc. 2/11/98		2-month concentration Apr-98		4-month concentration Jun-98		6-month concentration Sep-98		overall % reduction
PCP	384	mg/kg	125	mg/kg	210	mg/kg	330	mg/kg	210	mg/kg	45
DRO	NA	NA	1,160	mg/kg	630	mg/kg	1,400	mg/kg	590	mg/kg	49
Chloride	NA	NA	17	mg/kg	9	mg/kg	12	mg/kg	22	mg/kg	-30
Moisture	NA	NA	8.4	%	8	%			7	%	NA
pH	NA	NA	5.77	S.U.	5.3	S.U.			5.9	NA	NA

Table 2-2
Soil Analytical Results
Column Treatability Study
Penta Wood Products

Sample: Column 3 - Aerobic conditions
Soil Type: Sand
Sample Depth: SG8 10-15 feet bgs

Parameter	Initial Field Conc. 1/28/98		Initial lab conc. 2/11/98		2-month concentration 4/8/98		4-month concentration 6/8/98		6-month concentration 8/6/98		overall % reduction
PCP	707	mg/kg	487	mg/kg	540	mg/kg	850	mg/kg	590	mg/kg	17
DRO	NA	NA	10,800	mg/kg	5,200	mg/kg	4,400	mg/kg	6,900	mg/kg	36
Chloride	NA	NA	9	mg/kg	5.3 U	mg/kg	15	mg/kg	10	mg/kg	-13
Moisture	NA	NA	5.7	%	5	%			4	%	NA
pH	NA	NA	4.65	S.U.	5.4	S.U.			5.3	S.U.	NA

Sample: Column 4 - Aerobic Conditions
Soil Type: Wood Debris/Soil
Sample Depth: SG9 1-10 feet bgs

Parameter	Initial Field conc. 1/28/98		Initial Lab conc. 2/11/98		2-month concentration 4/8/98		4-month concentration 6/8/98		6-month concentration 8/6/98		overall % reduction
PCP	5460	mg/kg	930	mg/kg	5,200	mg/kg	5,000	mg/kg	5,000	mg/kg	8
DRO	NA	NA	30,433	mg/kg	46,000	mg/kg	30,000	mg/kg	44,000	mg/kg	-45
Chloride	NA	NA	77	mg/kg	314	mg/kg	101	mg/kg	101	mg/kg	-31
Moisture	NA	NA	49.7	%	45	%			37	%	NA
pH	NA	NA	4.29	S.U.	4.7	S.U.			5	S.U.	NA

Table 2-3
Oxygen Depletion and Air Flow Rate Data
Column Treatability Study
Penta Wood Products

Column	Sample Dates	Initial (2/11) In Situ Oxygen Conc. (% O_2)	Depleted (2/12) In Situ Oxygen Conc. (%O_2)	(2/12) Air Flow Rate (ml/min)	(2/16) In Situ Oxygen Conc. (%O_2)	(2/16) Adjusted Air Flow Rate (ml/min)	(2/19) In Situ Oxygen Conc. (%O_2)
1	2/11-2/19	0	0	NA	0	NA	0
2	2/11-2/19	20.0	0.0	14.3	13.0	15.2	19.0
3	2/11-2/19	21.0	19.0	5.2	16.5	16.3	20.0
4	2/11-2/19	20.5	14.1	12.7	18.0	20.6	19.0

Column	Sample Dates	4/16 In Situ Oxygen Conc. (% O_2)	Depleted (4/17) In Situ Oxygen Conc. (%O_2)	(4/16) Air Flow Rate (cc/min)
1	4/16-4/17	0	0	NA
2	4/16-4/17	18.8	17.0	7.1
3	4/16-4/17	18.5	0.0	71.0
4	4/16-4/17	17.0	13.5	69.6

The air flow rate was adjusted on 2/16 to increase the in situ oxygen concentrations to between 19 and 20 % oxygen.

Table 2-4
Off-Gas Air Sample Data
Column Treatability Study
Penta Wood Products

Column	Sample Tube[1]	Sample Dates	Time (hrs)	Air Flow Rate (ml/min)	Total Air Flow (L)	Total PCP (µg)	PCP Concentration (ug/L)	Total DRO (µg)	DRO Concentration (µg/L)
3	1a	2/16-2/23				<2		21,700	
3	1b	2/16-2/23				<2		4,150	
3	2a	2/16-2/23				<2		4,140	
3	2b	2/16-2/23				<2		1,690	
Total			167	13.5	135	<2	NA	31,680	234
4	1a	2/16-2/23				<2		12,300	
4	1b	2/16-2/23				<2		1,830	
4	2a	2/16-2/23				<2		2,270	
4	2b	2/16-2/23				<2		663	
Total			167	16.6	166	<2	NA	17,063	103

[1]There were two XAD tubes placed in series on each of the two columns. Each tube has two portions (a and b).

3 In Situ Field Bioventing Treatability Study

3.1 Purpose and Scope

The purpose of the in-situ bioventing study was to obtain site-specific data relating to the feasibility of using bioventing for the treatment of PCP and fuel oil-contaminated soils. The scope of the treatability study consisted of the implementation and operation of a bioventing system for six months. Implementation included the installation of a new 6-inch extraction/bioventing well identified as EW-1, the installation of three nests with three soil gas wells each (identified as SG-1 through SG-9), the placement of the bioventing building over EW-1, the connection of the blower to EW-1, and the hook-up of electrical power.

Operation included the measurement of initial subsurface soil gas composition, start-up of the bioventing system, the conduction of an initial soil gas permeability test to provide data to determine the radius of influence, and the performance of several oxygen uptake studies. In addition, soil from six of the nine soil gas wells was collected from the bottom of each well and analyzed for PCP, TPH, diesel-range organics (DRO), total organic carbon (TOC), moisture, pH, and chloride before system start-up, after two months of operation, and after six months of operation for direct measurement of PCP and petroleum hydrocarbon reduction.

Originally the soil sampling frequency was planned to occur at three months, and six months of operation. The three-month sampling interval was pushed up to two months because of the FS schedule. Although the bioventing system was in place seven months, from February to September, it was in known operation for six months. At some point in July the system automatically shut down when it became overheated.

3.2 Test Location and Installation

EW-1 is located in the former gully area approximately 150 feet south of the oil-water separator building. EW-1 is completed in the water table and is screened its entire length. SG-1 through SG-9 are located in three nests of three wells each at distances of 25, 50, and 100 feet away from EW-1. The depths of the soil gas wells in each nest are 5- 40-, and 80-feet below ground surface (bgs). The deep wells are completed approximately 20 feet above the water table.

A 8-1/4-inch diameter hollow stem auger was used to drill the first 100 feet of EW-1. A rotosonic rig was used to complete EW-1 to a total depth of 125 feet bgs. A 6-inch diameter well screened the entire depth with stainless steel slotted screen was used for EW-1. A 4-1/4-inch hollow stem auger was used to drill the nine soil gas wells. They were completed with 2-inch diameter schedule 80 PVC with 2 feet of 10-slot screen. The boring and well construction logs are included in the *Final Remedial Investigation Report, June 1998, CH2M HILL*. Figure 3-3 in the Final Remedial Investigation Report shows the well and boring locations.

A 500 standard cubic feet per minute (SCFM) blower housed in a 6 feet by 6 feet building was placed over EW-1 and electrical power was installed. The blower system was started on

February 8, 1998, and ran continuously thereafter until September 8, 1998, except during oxygen uptake tests, and a period in July when it overheated.

3.3 Soil and Gas Sampling

Soil samples were collected from the 5-foot and 40-foot deep borings from soil gas wells SG-1, SG-2, SG-4, SG-5, SG-7, and SG-8 to establish initial contaminant and soil parameter conditions for the bioventing study. Soil from the cuttings were first placed in a 5-gallon bucket. After the soil in the bucket was thoroughly mixed, a sub-sample was collected from the bucket. After sampling, the remaining contents of the bucket were poured back down the borehole immediately below the bottom of the well screen for resampling two and six months later.

Samples were collected with decontaminated equipment. Samples were analyzed for PCP, TPH, DRO, TOC, moisture, pH, and chloride. Samples were prepared and shipped following EPA-approved guidelines and chain-of-custody procedures (Sampling and Analysis Plan, Revision 1, November 1997).

Numerous soil gas tests were conducted, including initial subsurface soil gas composition conditions, a soil gas permeability test, initial soil gas composition at the start of the oxygen uptake studies, and four oxygen uptake studies (baseline, February test, April test, and September test). The tests were conducted using a Land-Tec GA-90 soil gas analyzer, and a Photo Ionization Detector (PID).

3.4 Results and Discussion

3.4.1 Soil Gas Composition Initial Conditions

As shown on Table 3-1, before the blower system was turned on oxygen levels in every soil gas well except two (SG-4 and SG-5) were below 5 percent oxygen while the carbon dioxide levels were above 10 percent. Initial low oxygen levels coupled with measurable carbon dioxide levels indicate that an oxygen limiting environment exists. Under such an environment, the enhancement of aerobic degradation may increase degradation rates.

3.4.2 System Influence

Data collected for the soil gas permeability test are presented in Table 3-2. All soil gas well points showed measurable levels of soil gas pressure when the blower was in operation. Data collected during the soil gas permeability test was used to calculate a conservative pressure radius of influence of 100 feet. The pressure radius of influence is used to determine the spacing of the bioventing wells for the full-scale system.

3.4.3 Oxygen Uptake Studies

The object of bioventing is to induce air flow through the vadose-zone soil to promote aerobic degradation, a process whereby microbes use oxygen as an electron acceptor to degrade the PCP/oil mixture.

To determine if oxygen is being inducted into the subsurface, methane, carbon dioxide, and oxygen are measured while the system is running. A decrease in both methane and carbon dioxide and an increase in oxygen versus time indicate that ambient air, which contains low carbon dioxide and no methane, is reaching the subsurface zone and air exchanges are

occurring. The data collected at the start of the oxygen uptake studies before the blower was turned off show that this phenomenon is occurring in most of the soil gas points (Table 3-3).

Soil gas well results from SG-1, SG-4, and SG-7, which are the three 5-foot wells, stand out from the rest of the well results because their oxygen readings with the blower on are consistently below 19%, while all other wells are near 21% oxygen. Soil gas well SG-4 is completed in a sandy soil, and its oxygen levels are relatively near 21%, at 16.5% (February), 18% (April), and 15% (September). Soil gas wells SG-1 and SG-7 are completed in a wood debris/soil layer that holds water (initial moisture levels of 23% and 41%, respectively), and is less permeable than the native sands. Soil gas well SG-1 oxygen levels dipped from 15% in February and April, to 4% in September. Soil gas well SG-7 oxygen levels also dipped, from 3-4% in February and April, to 0.2% in September. Carbon dioxide levels were elevated in the wells with depressed oxygen levels, indicating microbial degradation was occurring.

Oxygen uptake study results, which were measured with the system turned off, are shown in Tables 3-4 through 3-7. As shown, oxygen, carbon dioxide, methane, and VOCs were measured at each point during the study. The depletion of oxygen versus time in conjunction with the increase in carbon dioxide with the system turned off indicates that aerobic degradation is occurring. The microbes use oxygen as an electron acceptor, and respire carbon dioxide. As shown in Tables 3-4 through 3-5, which present the February results, oxygen is depleting at a slow rate while carbon dioxide is increasing. The April and September oxygen uptake results show little change in soil gas readings over time for the deeper wells, but in the 5-foot wells (SG-1, SG-4, and SG-7), the oxygen decreases with time while carbon dioxide generally goes up or remains constant. The exception is the September SG-7 results, where the oxygen levels are so low they are at the edge of the field instrument's capability to measure accurately. The April and September oxygen uptake results indicate microbial degradation is only occurring in the shallow soils, where the PCP/oil concentrations are higher.

Methane was measured because it is usually present in oxygen-limiting environments where there are high sources of carbon (PCP-TPH mixture). Oxygen is the preferred electron acceptor, but in its absence nitrate, iron (III), and sulfate (in that order) are used as electron acceptors for the anaerobic degradation of the PCP-TPH mixture. In the absence of the latter three, then anaerobic degradation via the conversion of carbon dioxide to methane would occur. As indicated on Tables 3-4 through 3-7, essentially no methane was measured in the soil gas wells.

Volatile organic carbon compounds, or VOCs, were also measured with a photo-ionization detector (PID). Measurable VOCs are the more volatile and readily degradable portions of the TPH in the soil. As indicated on Tables 3-4 through 3-6, detectable levels of VOCs were occasionally measured, most notably in soil gas wells SG-1 and SG-7, the more highly-contaminated wood debris/soil wells.

3.4.4 Soil Sample Results

Table 3-8 presents analytical resultsand overall percent reduction for soil collected from the bottom of six soil gas wells at time intervals of; pre-start-up of bioventing system, at 2 months of operation, and at 6 months of operation. PCP, TPH, DRO, TOC, chloride, moisture, and pH were analyzed. The PCP, TPH, and DRO results give a direct

measurement of PCP and oil reduction. Chloride is a degradation product of PCP, and would be expected to increase in concentration with microbial degradation. However, chloride is also very mobile, and would be flushed from the vadose soils by infiltrating precipitation. Moisture and pH are measured because optimum conditions for aerobic degradation to occur are within a range of 30% and 60% moisture and 6 to 8 pH, though aerobic degradation can still occur above or below these ranges.

The soil at soil gas wells SG-1 and SG-7, the shallow wells completed in the wood debris/soil layer, indicated PCP reduction, at 65% reduction, and 86% reduction, respectively. However the lack of any increase in chloride concentration suggest that the declines may be related to a high degree of heterogeniety in the PCP concentration in the soil. These two wells had the highest starting concentrations of PCP and oil, and had positive oxygen uptake study results. The third shallow soil gas well, SG-4, also showed positive PCP reduction, at 38 percent. The three 40-foot soil gas wells all showed negative PCP reduction, meaning their end concentrations were higher than their starting concentrations.

The calculated TPH reductions in SG-1, SG-4, and SG-7 (based on the average oxygen uptake rates) are 29%, 109%, and 0%, respectively. The corresponding PCP reductions (assuming 5% PCP in the PCP-TPH mixture) are 1%, 5%, and 0%, respectively. These do not compare well with the analytical observed reductions. It is likely that the majority of the observed reduction is a result of sample heterogeneity.

Aerobic degradation appears to be occurring in the more heavily-contaminated soils. Microorganisms in the deeper sandy soils, which have less PCP/oil and thus less food source for the microorganisms, did not appear to respond to the addition of air to their environment. Because of the limitations of the study (deepest soil gas wells were completed well above the smear zone where PCP/oil concentrations increase again), it is unknown what affect the additional oxygen had on microbial degradation along the smear zone.

The remedial alternative for the site involves lowering the water table and delivering air at the newly-exposed smear zone where PCP/oil concentrations are at levels similar to the shallow soils. Aerobic microbial degradation is expected to occur at similar rates as the shallow soils. If PCP degradation appears recalcitrant, field modifications such as delivering heat (steam injection) are possible to enhance degradation.

Table 3-1
Initial Subsurface
Soil Gas Data
Field Bioventing Treatability Study
Penta Wood Products

Well	$\%CO_2$	$\%O_2$	% Methane (CH_4)	VOCs (ppm)
SG-1	10.4	2.6	0.1	2
SG-2	12.0	4.6	0	0.0
SG-3	14.9	1.7	0	0.0
SG-4	5.4	13.3	0	0.0
SG-5	11.5	6.42	0	0.0
SG-6	15.7	1.1	0	0.0
SG-7	11.5	2.6	0.1	1.6
SG-8	12.6	4.2	0.1	See Note 3
SG-9	15.1	0.9	0.0	0.0

Notes:

1. $\%CO_2$, $\%O_2$, and $\%CH_4$ measured with Land-Tec GA-90 soil gas analyzer.
2. VOC's measured with Multi-Rae photoionization dector (PID).
3. Multi-rae detector ceased to operate due to low battery.

Table 3-2
Soil Gas Permeability Data
Field Bioventing Treatability Study
Penta Wood Products

Date	Time	Air Flow [1]		P Well [1]	Temp [1]	Soil Gas Pressure Measurements ("H_2O)								
		" H_2O	Scfm	"H_2O	°F	SG-1 (5' bgs)	SG-2 (40' bgs)	SG-3 (80' bgs)	SG-4 (5' bgs)	SG-5 (40' bgs)	SG-6 (80' bgs)	SG-7 (5' bgs)	SG-8 (40' bgs)	SG-9 (80' bgs)
2/8/98	1335	0.5	158	1	100	.12	.47	.46	.15	.32	.36	.08	.21	.23
2/8/98	1505	1	224	2	100	.08	.54	.51	.10	.28	.31	.02	.13	.16
2/8/98	1700	1	224	2	100	.09	.54	.54	.09	.28	.29	.03	.10	.13
2/9/98	0740	1	227	0	85	.09	.62	.55	.10	.30	.32	.04	.12	.12
2/9/98	1225	3	397	5	80	.22	>1.0	>1.0	.26	.69	.72	.12	.35	.40
2/9/98	1750	3	397	4	80	.16	>1.0	>1.0	.16	.54	.55	.05	.20	.23
2/10/08	1200	5	522	7	64	.25	>1.0	>1.0	.30	.87	.88	.11	.37	.45
2/11/98	1420	5	517	6.5	73	.38	>1.0	>1.0	.36	.98	>1.0	.17	.45	.56
2/24/98	0850	4.9	506	1	77	.35	1.40	1.10	.14	.86	.87	.16	.38	.42
2/27/98	1115	9	511	1	79	.46	1.65	1.30	.32	1.0	1.0	.36	.55	.64

Notes:

1. Air flow, pressure, and temperature measured at inlet of bioventing well at point of injection.

Table 3-3
Soil Gas Data at Start of Oxygen Uptake Studies
Before Blower Shut Off
Field Bioventing Study
Penta Wood Products

Well	Date	Time	Hours	$\%CO_2$	$\%O_2$	% methane (CH_4)	VOCs (ppm)
February 10 - 11 Baseline Oxygen Uptake Study Data							
SG-2	2/10/98	1200	0	0.5	20.9	0.0	0.0
SG-3			0	0.0	21.1	0.0	0.0
SG-5			0	1.6	20.5	0.0	0.0
SG-6			0	0.4	21.0	0.0	0.0
SG-9			0	11.1	11.4	0.0	0.5
February 24 - 27 Oxygen Uptake Study Data							
SG-1	2/24/98	0915	0	1.9	**15.8**	0.0	2.9
SG-2	2/24/98	0916	0	0.1	20.6	0.0	0.0
SG-3	2/24/98	0919	0	0.0	20.5	0.0	0.1
SG-4	2/24/98	0922	0	3.9	**16.5**	0.0	0.5
SG-5	2/24/98	0924	0	0.1	20.5	0.0	0.1
SG-6	2/24/98	0927	0	0.0	20.5	0.0	0.0
SG-7	2/24/98	931	0	7.2	**3.8**	0.0	4.1
SG-8	2/24/98	0934	0	0.6	20.1	0.0	1.8
SG-9	2/24/98	0937	0	0.2	20.4	0.0	1.5
April 6-8 Oxygen Uptake Study Data							
SG-1	4/6/98	1837	0	3.9	**14.6**	0.0	14.8
SG-2	4/6/98	1840	0	0.0	21.1	0.0	0.0
SG-3	4/6/98	1842	0	0.0	21.1	0.0	0.0
SG-4	4/6/98	1844	0	2.2	**18.0**	0.0	0.0
SG-5	4/6/98	1846	0	0.0	21.1	0.0	0.0
SG-6	4/6/98	1848	0	0.0	21.0	0.0	0.0
SG-7	4/6/98	1849	0	10.2	**3.3**	0.0	0.0
SG-8	4/6/98	1851	0	0.2	20.7	0.0	0.0
SG-9	4/6/98	1852	0	0.0	20.9	0.0	0.0
September 8-9 Oxygen Uptake Study Data							
SG-1	9/8/98	1228	0	13.7	**4.2**	0.0	NM
SG-2	9/8/98	1229	0	0.0	20.6	0.0	NM
SG-3	9/8/98	1230	0	0.0	20.7	0.0	NM
SG-4	9/8/98	1232	0	4.6	**15.0**	0.0	NM
SG-5	9/8/98	1233	0	0.0	20.6	0.0	NM
SG-6	9/8/98	1234	0	0.0	20.7	0.0	NM
SG-7	9/8/98	1236	0	19.1	**0.2**	0.1	NM
SG-8	9/8/98	1237	0	0.1	20.3	0.0	NM
SG-9	9/8/98	1238	0	0.0	20.7	0.0	NM

Notes:
1. $\%CO_2$, $\%O_2$, and $\%CH_4$ measured with Land-Tec GA-90 soil gas analyzer.
2. VOC's measured with Multi-Rae photoioniation dector (PID).
3. Oxygen uptake studies were not conducted in soil gas wells SG-1, 4, 7, and 8 for the baseline study and in SG-7 for the February 24 -27 study because intial oxygen levels were below testable levels.
4. NM = Not Measured

Table 3-4
February 10 - 11
Baseline Oxygen Uptake Study Data
Field Bioventing Treatability Study
Penta Wood Products

Well	Date	Time	Hours	$\%CO_2$	$\%O_2$	% methane (CH_4)	VOCs (ppm)
SG-2	2/10/98	1200	0	0.5	20.9	0.0	0.0
	2/10/98	1413	2	0.5	20.7	0.0	0.0
	2/10/98	1708	5	0.7	20.2	0.1	1.6
	2/10/98	2010	8	0.7	20.1	0.0	2.0
	2/11/98	0715	19	0.9	21.0	0.0	0.0
	2/11/98	1208	24	1.1	20.0	0.0	See Note 3
SG-3	2/10/98	1220	0	0.0	21.1	0.0	0.0
	2/10/98	1420	2	0.0	20.9	0.0	0.0
	2/10/98	1713	5	0.0	20.6	0.0	2.2
	2/10/98	2015	8	0.1	20.2	0.0	2.5
	2/11/98	0721	19	0.0	21.4	0.0	0.0
	2/11/98	1217	24	0.1	20.5	0.1	See Note 3
SG-5	2/10/98	1225	0	1.6	20.5	0.0	0.0
	2/10/98	1425	2	2.1	20.1	0.0	0.5
	2/10/98	1720	5	2.1	19.8	0.1	2.0
	2/10/98	2020	8	1.7	19.8	0.0	2.3
	2/11/98	0727	19	2.4	20.2	0.0	0.0
	2/11/98	1224	24	2.6	19.4	0.1	See Note 3
SG-6	2/10/98	1235	0	0.4	21.0	0.0	0.0
	2/10/98	1435	2	0.5	20.8	0.0	0.0
	2/10/98	1728	5	0.6	20.4	0.0	2.5
	2/10/98	2025	8	0.5	20.3	0.1	2.1
	2/11/98	0732	19	0.9	21.0	0.0	0.0
	2/11/98	1230	24	1.0	20.2	0.1	See Note 3
SG-9	2/10/98	1245	0	11.1	11.4	0.0	0.5
	2/10/98	1445	2	10.9	11.8	0.0	1.8
	2/10/98	1735	5	8.8	13.6	0.1	2.7
	2/10/98	2030	8	9.1	13.4	0.1	2.7
	2/11/98	0741	19	10.6	12.9	0.1	1.1
	2/11/98	1236	24	10.7	12.4	0.0	See Note 3

Notes:
1. $\%CO_2$, $\%O_2$, and $\%CH_4$ measured with Land-Tec GA-90 soil gas analyzer.
2. VOC's measured with Multi-Rae photoioniation dector (PID).
3. Multi-rae meter not available because already shipped off-site before end of test.
4. Oxygen uptake studies were not conducted in soil gas wells SG-1, 4, 7, and 8 because intial oxygen levels were below testable levels.

Table 3-5
February 24 - 27
Oxygen Uptake Study Data
Field Bioventing Treatability Study
Penta Wood Products

Well	Date	Time	Hours	$\%CO_2$	$\%O_2$	% methane (CH_4)	VOCs (ppm)
SG-1	2/24/98	0915	0	1.9	15.8	0.0	2.9
	2/25/98	0918	24	2.4	12.2	0.0	1.7
	2/26/98	0954	48	2.3	10.7	0.0	0.3
	2/27/98	0737	72	3.2	5.7	0.0	8.0
SG-2	2/24/98	0916	0	0.1	20.6	0.0	0.0
	2/25/98	0930	24	0.2	20.7	0.0	1.2
	2/26/98	1014	48	0.2	20.4	0.0	1.8
	2/27/98	0750	72	0.3	20.3	0.0	0.0
SG-3	2/24/98	0919	0	0.0	20.5	0.0	0.1
	2/25/98	0953	24	0.1	21.0	0.0	1.0
	2/26/98	1036	48	0.1	20.6	0.0	1.1
	2/27/98	0813	72	0.1	20.5	0.0	0.3
SG-4	2/24/98	0922	0	3.9	16.5	0.0	0.5
	2/25/98	1000	24	2.8	18.5	0.0	1.1
	2/26/98	1041	48	2.6	18.3	0.0	0.8
	2/27/98	0822	72	3.6	16.8	0.0	2.1
SG-5	2/24/98	0924	0	0.1	20.5	0.0	0.1
	2/25/98	1012	24	0.3	20.8	0.0	0.6
	2/26/98	1051	48	0.4	20.3	0.0	0.9
	2/27/98	0833	72	0.5	20.2	0.0	0.3
SG-6	2/24/98	0927	0	0.0	20.5	0.0	0.0
	2/25/98	1033	24	0.2	20.9	0.0	3.0
	2/26/98	1120	48	0.2	20.4	0.0	1.4
	2/27/98	0853	72	0.3	20.1	0.0	0.5
SG-8	2/24/98	0934	0	0.6	20.1	0.0	1.8
	2/25/98	1047	24	0.9	20.5	0.0	4.0*
	2/26/98	1136	48	0.8	20.1	0.0	2.5
	2/27/98	0903	72	1.0	19.9	0.0	0.9
SG-9	2/24/98	0937	0	0.2	20.4	0.0	1.5
	2/25/98	1107	24	0.3	20.9	0.0	7.7*
	2/26/98	1154	48	0.3	20.5-6	0.0	5.6*
	2/27/98	0924	72	0.4	20.4	0.0	4.1

Notes:
1. $\%CO_2$, $\%O_2$, and $\%CH_4$ measured with Land-Tec GA-90 soil gas analyzer.
2. VOC's measured with Multi-Rae photoioniation dector (PID).
3. Oxygen uptake study was not conducted in soil gas well SG-7 because intial oxygen levels were below testable levels.

Table 3-6
April 6 - 8
Oxygen Uptake Study Data
Field Bioventing Treatability Study
Penta Wood Products

Well	Date	Time	Hours	$\%CO_2$	$\%O_2$	% methane (CH_4)	VOCs (ppm)
SG-1	4/6/98	1837	0	3.9	**14.6**	0.0	14.8
	4/7/98	1824	24	3.5	**13.8**	0.0	0..0
	4/8/98	1126	40	2.5	**13.2**	0.0	0.0
	4/8/98	1809	48	3.8	**10.7**	0.0	0.0
	4/9/98	1336	68	3.7	**9.8**	0.0	0.0
SG-2	4/6/98	1840	0	0.0	21.1	0.0	0.0
	4/7/98	1835	24	0.0	21.6	0.0	0.0
	4/8/98	1005	40	0.0	21.7	0.0	0.0
	4/9/98	1344	68	0.0	22.2	0.0	0.0
SG-3	4/6/98	1842	0	0.0	21.1	0.0	0.0
	4/7/98	1856	24	0.0	21.4	0.0	0.0
	4/8/98	1030	40	0.0	21.2	0.0	0.0
	4/9/98	1403	68	0.0	22.2	0.0	0.0
SG-4	4/6/98	1844	0	2.2	**18.0**	0.0	0.0
	4/7/98	1902	24	2.6	**17.5**	0.0	0.0
	4/8/98	1126	40	2.4	**18.0**	0.0	0.0
	4/8/98	1816	48	2.5	**17.9**	0.0	0.0
	4/9/98	0822	72	3.6	**16.8**	0.0	2.1
SG-5	4/6/98	1846	0	0.0	21.1	0.0	0.0
	4/7/98	1911	24	0.0	21.3	0.0	0.0
	4/8/98	1117	40	0.0	21.8	0.0	0.0
	4/9/98	1421	68	0.0	22.5	0.0	0.0
SG-6	4/6/98	1848	0	0.0	21.0	0.0	0.0
	4/7/98	1933	24	0.0	21.3	0.0	0.0
	4/8/98	1101	40	0.0	21.9	0.0	0.0
	4/9/98	1450	68	0.0	22.7	0.0	0.0
SG-7	4/6/98	1849	0	10.2	**3.3**	0.0	0.0
	4/7/98	1940	24	10.7	**1.5**	0.0	0.4
	4/8/98	1148	40	10.2	**1.0**	0.0	1.1
	4/8/98	1822	47	10.4	**0.5**	0.0	0.4
	4/9/98	1457	72	10.2	**0.7**	0.0	0.0
SG-8	4/6/98	1851	0	0.2	20.7	0.0	0.0
	4/7/98	1949	24	0.0	21.2	0.0	0.0
	4/8/98	1151	40	0.0	21.9	0.0	0.0
	4/9/98	1506	68	0.0	22.7	0.0	0.0
SG-9	4/6/98	1852	0	0.0	20.9	0.0	0.0
	4/7/98	2010	24	0.0	21.1	0.0	0.0
	4/8/98	1210	40	0.0	22.3	0.0	0.0
	4/9/98	1533	68	0.0	22.8	0.0	0.0

Notes:
1. $\%CO_2$, $\%O_2$, and $\%CH_4$ measured with Land-Tec GA-90 soil gas analyzer.
2. VOC's measured with Multi-Rae photoioniation dector (PID).

Table 3-7
September 8 - 9
Oxygen Uptake Study Data
Field Bioventing Treatability Study
Penta wood Products

Well	Date	Time	Hours	$\%CO_2$	$\%O_2$	% methane (CH_4)	VOCs (ppm)
SG-1	9/8/98	1228	0	12.7	**4.2**	0.0	NM
	9/9/98	729	18	14.4	**0.8**	0.0	NM
	9/9/98	1707	27.5	14.5	**1.1**	0.0	NM
SG-2	9/8/98	1229	0	0.0	20.6	0.0	NM
	9/9/98	744	18	0.0	20.4	0.0	NM
	9/9/98	1711	27.5	0.0	20.6	0.0	NM
SG-3	9/8/98	1230	0	0.0	20.7	0.0	NM
	9/9/98	750	18	0.0	20.4	0.0	NM
	9/9/98	1717	27.5	0.0	20.7	0.0	NM
SG-4	9/8/98	1232	0	4.6	**15.0**	0.0	NM
	9/9/98	757	18	6.1	**12.4**	0.0	NM
	9/9/98	1725	27.5	6.5	**11.2**	0.0	NM
SG-5	9/8/98	1233	0	0.0	20.6	0.0	NM
	9/9/98	802	18	0.0	20.3	0.0	NM
SG-6	9/8/98	1234	0	0.0	20.7	0.0	NM
	9/9/98	810	18	0.0	20.3	0.0	NM
SG-7	9/8/98	1236	0	19.1	0.2	0.1	NM
	9/9/98	817	18	16.9	0.3	0.1	NM
	9/9/98	1733	27.5	17.5	1.2	0.1	NM
SG-8	9/8/98	1237	0	0.1	20.3	0.0	NM
	9/9/98	822	18	0.0	20.3	0.0	NM
SG-9	9/8/98	1238	0	0.0	20.7	0.0	NM
	9/9/98	830	18	0.0	20.4	0.0	NM

Notes:
1. $\%CO_2$, $\%O_2$, and $\%CH_4$ measured with Land-Tec GA-90 soil gas analyzer.
2. VOCs were not measured during this sampling event.

Table 3-8
Soil Concentrations Over Time
Field Bioventing Treatability Study
Penta Wood Products

Sample: SG-1
Soil Type: Wood Debris/Soil
Sample Depth: 5 feet

Parameter	Initial concentration Feb-98		2-month concentration Apr-98		6-month concentration Sep-98		overall % reduction
PCP	1,300	mg/kg	840	mg/kg	450	mg/kg	65
TPH	15,100	mg/kg	13,900	mg/kg	12,745	mg/kg	16
DRO	18,000	mg/kg	7,500	mg/kg	17,500	mg/kg	3
TOC	644	mg/kg	434	mg/kg	590	mg/kg	8
Chloride	25	mg/kg	20	mg/kg	11	mg/kg	58
Moisture	23	%	15	%	13	%	NA
pH	4.83	S. U.	5.20	S. U.			NA

Sample: SG-2
Soil Type: Sand
Sample Depth: 40 feet

Parameter	Initial concentration Feb-98		2-month concentration Apr-98		6-month concentration Sep-98		overall % reduction
PCP	180	mg/kg	200	mg/kg	200	mg/kg	-11
TPH	3,430	mg/kg	10,600	mg/kg	1,990	mg/kg	42
DRO	1,000	mg/kg	2,800	mg/kg	490	mg/kg	51
TOC	107	mg/kg	55	mg/kg	53	mg/kg	50
Chloride	5	mg/kg	5.4 U	mg/kg	10	mg/kg	-96
Moisture	7	%	7	%	6	%	NA
pH	6.57	S. U.	6.80	S. U.			NA

Table 3-8
Soil Concentrations Over Time
Field Bioventing Treatability Study
Penta Wood Products

Sample: SG-4
Soil Type: Sand
Sample Depth: 5 feet

Parameter	Initial concentration Feb-98		2-month concentration Apr-98		6-month concentration Sep-98		overall % reduction
PCP	160	mg/kg	390	mg/kg	100	mg/kg	38
TPH	3,670	mg/kg	7,360	mg/kg	NA	mg/kg	-101
DRO	1,100	mg/kg	21	mg/kg	NA	mg/kg	98
TOC	299	mg/kg	219	mg/kg	NA	mg/kg	27
Chloride	8	mg/kg	12	mg/kg	NA	mg/kg	-43
Moisture	7.6	%	13	%	11	%	NA
pH	5.31	S.U.	5.5	S.U.			NA

Sample: SG-5
Soil Type: Sand
Sample Depth: 40 feet

Parameter	Initial concentration Feb-98		2-month concentration Apr-98		6-month concentration Sep-98		overall % reduction
PCP	160	mg/kg	300	mg/kg	170	mg/kg	-6
TPH	7,010	mg/kg	6,840	mg/kg	3,820	mg/kg	46
DRO	1,900	mg/kg	5,200	mg/kg	590	mg/kg	69
TOC	144	mg/kg	57	mg/kg	53	mg/kg	63
chloride	10	mg/kg	12	mg/kg	11	mg/kg	-6
Moisture	6.5	%	8	%	6	%	NA
pH	5.88	S.U.	6.3	S.U.			NA

Table 3-8
Soil Concentrations Over Time
Field Bioventing Treatability Study
Penta Wood Products

Sample: SG-7
Soil Type: Wood Debris/Soil
Sample Depth: 5 feet

Parameter	Initial concentration Feb-98		2-month concentration Apr-98		6-month concentration Sep-98		overall % reduction
PCP	970	mg/kg	560	mg/kg	140	mg/kg	86
TPH	11,800	mg/kg	3,740	mg/kg	1,280	mg/kg	89
DRO	19,000	mg/kg	1,700	mg/kg	1,700	mg/kg	91
TOC	644	mg/kg	242	mg/kg	177	mg/kg	73
Chloride	19	mg/kg	38	mg/kg	8	mg/kg	55
Moisture	41.1	%	26	%	8	%	NA
pH	4.94	S.U.	4.8	S.U.			NA

Sample: SG-8
Soil Type: Sand
Sample Depth: 40 feet

Parameter	Initial concentration Feb-98		2-month concentration Apr-98		6-month concentration Sep-98		overall % reduction
PCP	350	mg/kg	650	mg/kg	710	mg/kg	-103
TPH	4,450	mg/kg	18,700	mg/kg	3,650	mg/kg	18
DRO	6,800	mg/kg	3,900	mg/kg	12,000	mg/kg	-76
TOC	229	mg/kg	184	mg/kg	260	mg/kg	-14
Chloride	10	mg/kg	24	mg/kg	20	mg/kg	-92
Moisture	4.4	%	7	%	14	%	NA
pH	6.81	S.U.	7	S.U.			NA

4 Photolysis Treatability Study

Extracted groundwater can potentially be treated using sunlight to photolytically degrade PCP. While this is not a typical treatment process used for treating PCP in water, the presence of the 3.5-acre concrete pad onsite makes this a potentially cost effective option by minimizing the initial construction costs of the pond necessary to allow photolysis of PCP.

Photolytic degradation of dissolved PCP in water is initiated by the ultraviolet wavelengths in sunlight. Literature photolytic half lives for PCP in water range from 24 minutes for midday sunlight in 1.6 cm diameter test tubes (Donaldson and Miller, 1997), 180 minutes in surface estuarine water in December (Hwang et. al., 1986) and 110 hours in a pond at midday in the fall (Howard et. al., 1991). The wide range of half lives may be a result of variations in the depth of the water and the presence of dissolved and suspended solids. The rate of degradation is decreased by the attenuation of light by natural chromophores present in the water (Pignatello et. al., 1983).

4.1 Purpose and Scope

The objectives of the photolysis treatability study were to determine:

- the PCP photolytic degradation half lives at varying pond depths
- the amount of metal removal

The main uncertainty investigated by the treatability study was the PCP photolytic degradation half life at varying pond depths. The degree of metal removal was also investigated. Dissolved iron has been reported to range from 10 to 43 mg/l in the groundwater plume. The iron together with other inorganics such as manganese were expected to precipitate in the pond as oxygen naturally diffuses into the extracted groundwater.

4.2 Implementation

These objectives were investigated in a set of three cells filled with contaminated groundwater to depths of 1 inch, 3 inches and 6 inches. A fourth cell was filled to a depth of 3 inches and methylene blue, a photolytic sensitizer, was added. The cells were constructed on a 4 foot by 8 foot sheet of 0.75 inch plywood (used for cell floor and walls) lined with black polyethylene plastic. The cells will be placed on the existing concrete pad to most closely simulate the angle of incidence of sunlight and the wind conditions that would occur under full scale operation.

The TS test was conducted for two and a half days, from April 7-9, 1998. Weather conditions consisted of both cloudy and sunny conditions. Groundwater was pumped from MW 5 and immediately placed in the TS cells to avoid aeration and precipitation of inorganics prior to the start of the test. Once the cells were filled, a composite sample was obtained for PCP and metals analysis by sampling each of the three cells that did not contain methylene blue. A single grab sample was collected from the methylene blue cell. Metals samples were analyzed for total metals (unfiltered). In addition, pH, temperature, oxygen and ORP were measured in the field. Samples for PCP analysis and the field parameters were collected and analyzed from each cell thereafter over the course of the three day study. Samples were

obtained from mid-depth at the center of each cell. PCP analysis was performed onsite using the immunoassay method specified in the RI/FS Sampling and Analysis Plan. Nine samples and a field blank were also shipped offsite to a laboratory and analyzed for PCP, arsenic, copper, zinc, iron, and manganese.

Climatic conditions were recorded during the TS study at the time of each sample collection and included air temperature, wind speed and direction, and cloud cover. This information was obtained by observation, and from a weather station located at the Duluth Airport. Also visible characteristics of the water were noted such as the presence of iron precipitation.

4.3 Results

Tables 4-1 present the onsite immunoassay PCP results, and Table 4-2 presents results from the subset of samples that were analyzed offsite for PCP and total metals. The laboratory PCP results were consistently less than the onsite immunoassay kit results, on an order of one-half to one-fifth the concentration. As evidenced in Table 4-3, however, using either the immunoassay PCP results or the offsite laboratory PCP results results in approximately the same cumulative PCP half-life for each cell. The most rapid degradation was an 8-hour half life and occurred, as expected, in the 1 inch depth cell during sunny conditions. The optimal photodegradation rate in a cell depth of 3 inches was achieved with methylene blue sensitizer, which resulted in a 13-hour half life. The 3-inch cell without methylene blue had a half-life of 30 hours and the 6-inch deep cell had a half life of 34 hours. Total metal results remained rather consistent throughout the study, although the 1-inch cell had the appearance of iron flocs at the bottom of it on the last day of the study. Measured field parameters and observations are presented in Table 4-4.

Based on a half life of 13 hours, a pond depth of 3 inches and a groundwater collection flow rate of 50 gpm, a 15 acre pond would be needed to photolytically degrade PCP to the PAL assuming one cycle of the water on the pad. The existing concrete pad is about 3 acres in size. The existing pad is large enough to provide about a 90 % removal of PCP. Granular activated carbon (GAC) treatment would still be necessary to remove the remainder of the PCP. Carbon usage rates, which primarily effect the annual O & M costs, would be reduced somewhat although they would still be substantial because many of the breakdown products of the PCP would be adsorbed as well as the remaining organic carbon in the groundwater. A present worth savings for reduced carbon useage on the order of $50,000 would be expected over an estimated 5 year duration. This cost is far less than the cost to upgrade and line the pad, provide rainfall storage capacity and possibly cover the pond with netting to prevent wildlife access to the pond. Because photolytic degradation does not offer cost advantages and is operationally more complex than using GAC alone, it was not carried forward as a viable technology in the Feasibility Study (CH2M HILL, June 1998).

Table 4-1
Immunoassay PCP Results
Photolysis Treatability Study
Penta Wood Products

	Cell #1 1"	Sample ID	Cell #2 3"	Sample ID	Cell #3 3" Methylene Blue	Sample ID	Cell #4 6"	Sample ID	Comments
4/7/98 0745	60.0	Photox 1	60.0	Photox 1	69.2	Photox 2	60.0	Photox 1	cloudy
4/7/98 1200	57.9	Photox 3	48.5	Photox 4	40.5	Photox 5	81.3	Photox 6	cloudy
4/7/98 1800	38.4	Photox 7	40.5	Photox 8	27.8	Photox 9	32.7	Photox 10	cloudy
4/8/98 0800	49.3	Photox 11	56.9	Photox 12	38.4	Photox 13	87.3	Photox 14	cloudy
4/8/98 1200	41.3	Photox 15	74.3	Photox 16	30.9	Photox 17	60.0/43.6	Photox 18/18DUP	cloudy
4/8/98 1800	11.1	Photox 19	24.5	Photox 20	16.3	Photox 21	36.6	Photox 22	cloudy
4/9/98 0800	13.4	Photox 23	24.5	Photox 24	15.6	Photox 25	31.2	Photox 26	sunny
4/9/98 1200	6.2	Photox 27	31.5	Photox 28	16.7	Photox 29	40.1	Photox 30	sunny
4/9/98 1400	8.0	Photox 31	28.1/31.9	Photox 32/32DUP	12.9	Photox 33	61.9	Photox 34	sunny

All Results in mg/L.

Table 4-2
Laboratory PCP and Metals Results
Photolysis Treatability Study
Penta Wood Products

SAMPLE ID'S:		PHOTOX-1	PHOTOX-24	PHOTOX-25	PHOTOX-26	PHOTOX-31	PHOTOX-32	PHOTOX-32DUP	PHOTOX-33	PHOTOX-34	PHOTOX-FB
EPA SAMPLE ID'S:		98ZR02-50	98ZR02-66	98ZR02-67	98ZR02-68	98ZR02-69	98ZR02-70	98ZR02-71	98ZR02-72	98ZR02-73	98ZR02-74
FIELD GROUP:											
SEQUENCE #:											
DATE COLLECTED:		4/7/98	4/9/98	4/9/98	4/9/98	4/9/98	4/9/98	4/9/98	4/9/98	4/9/98	4/9/98
TIME COLLECTED:		7:45	8:00	8:00	8:00	14:00	14:00	14:00	14:00	14:00	14:00
PARAMETERS	**UNITS**										
Pentachlorophenol	UG/L	32,000	12,000	7,300	7,500	1,900	9,000	7,600	4,400	11,000	2
Arsenic,total	UG/L	4.9	NA	NA	NA	12.4	6.5	4.8	6.3	5.4	2.0 U
Copper,total	UG/L	47.2 J	NA	NA	NA	71.7	54.2	53.9	53.7	49.9 J	0.63 J
Zinc,total	UG/L	4.8	NA	NA	NA	10.3	15.9	15.1	7.4	7.4	2.2
Iron,total	UG/L	5,480	NA	NA	NA	6,610	6,080	5,930	5,800	5,790	18.1 J
Manganese,total	UG/L	13,200	NA	NA	NA	17,200	14,800	14,800	14,300	14,200	10 U

Table 4-3
PCP Results and Half-Lives
Photolysis Treatability Study
Penta Wood Products

	Cell #1 1" Depth			Cell #2 3" Depth			Cell #3 3" Depth Methylene Blue			Cell #4 6" Depth			
Sample Date and Time	Immunoassay PCP results (mg/l)	Ist Order Decay Rate (-hrs.)	Half Live (hrs.)	Immunoassay PCP results (mg/l)	Ist Order Decay Rate (-hrs.)	Half Live (hrs.)	Immunoassay PCP results (mg/l)	Ist Order Decay Rate (-hrs.)	Half Live (hrs.)	Immunoassay PCP results (mg/l)	Ist Order Decay Rate (-hrs.)	Half Live (hrs.)	Comments
4/7/98 0745	60.0			60.0			69.2			60.0			cloudy
4/7/98 1200	57.9	0.0084	82.7	48.5	0.0501	13.8	40.5	0.1260	5.5	81.3	-0.0715	-9.7	cloudy
4/7/98 1800	38.4	0.0684	10.1	40.5	0.0300	23.1	27.8	0.0627	11.1	32.7	0.1518	4.6	cloudy
4/8/98 0800	49.3	-0.0178	-38.8	56.9	-0.0243	-28.5	38.4	-0.0231	-30.0	87.3	-0.0701	-9.9	cloudy
4/8/98 1200	41.3	0.0443	15.7	74.3	-0.0667	-10.4	30.9	0.0543	12.8	60	0.0938 a.	7.4	cloudy
4/8/98 1800	11.1	0.2190	3.2	24.5	0.1849	3.7	16.3	0.1066	6.5	36.6	0.0824	8.4	cloudy
4/9/98 0800	13.4	-0.0135	-51.5	24.5	0.0000	0.0	15.6	0.0031	0.0	31.2	0.0114	0.0	sunny
4/9/98 1200	6.2	0.1927	3.6	31.5	-0.0628	-11.0	16.7	-0.0170	-40.7	40.1	-0.0627	-11.0	sunny
4/9/98 1400	8.0	-0.1274	-5.4	28.1	0.0571 a.	12.1	12.9	0.1291	5.4	61.9	-0.2171	-3.2	sunny
Cloudy Conditions		0.0600	11.6		0.0358	19.3		0.0596	11.6		0.0262	26.5	
Sunny Conditions		0.0860	8.1		-0.0228	-30.3		0.0317	21.9		-0.1142	-6.1	
Cummulative Daytime Conditions		0.0620	11.2		0.0233	29.7		0.0517	13.4		0.0201 b.	34.4	

a. Duplicate results: Cell # 2 4/9/98 1400 = 31.9 mg/l; cell #4 4/8/98 1200 = 43.6 mg/l.
b. Cumulative decay rate based on lowest reported PCP concentration of 31.2 mg/l

	Cell #1 1" Depth			Cell #2 3" Depth			Cell #3 3" Depth Methylene Blue			Cell #4 6" Depth			
Sample Date and Time	Laboratory PCP results (mg/l)	Ist Order Decay Rate (-hrs.)	Half Live (hrs.)	Laboratory PCP results (mg/l)	Ist Order Decay Rate (-hrs.)	Half Live (hrs.)	Laboratory PCP results (mg/l)	Ist Order Decay Rate (-hrs.)	Half Live (hrs.)	Laboratory PCP results (mg/l)	Ist Order Decay Rate (-hrs.)	Half Live (hrs.)	Comments
4/7/98 0745	32.0			32.0			32.0			32.0			cloudy
4/9/98 1400	1.9	0.0869	8.0	9	0.0390	17.8	4.4	0.0611	11.4	11	0.0329	21.1	sunny

Table 4-4
Field Parameters and Observations
Photolysis Treatability Study
Penta Wood Products

Sample No.	Cell No.	Date	Time	pH	ORP	Temperature[a]	Oxygen[b]	Specific Conductivity	Comments
1, 2, 3, 4	1, 2, 3, 4	4/7/98	1015	7.41	58.7	8.65	6.76	0.867	rainy, 50's, slight wind
6	4	4/7/98	1200	7.3	150	9.1	6.7	0.86	rain stopped, cloudy, wind from east
8	2	4/7/98	1800	7.4	198	8.1	9.4	0.87	no rain, cloudy, windy, 35
9	3	4/7/98	1800	7.4	198	7.7	9.5	0.873	no rain, cloudy, windy
10	4	4/7/98	1800	7.8	175	8.9	9.7	0.859	no rain, cloudy, windy
14	4	4/8/98	800	7.7	210	4.5	10	0.912	part cloud/part sun, windy, 40s
18	4	4/8/98	1200	6.9	194	8.3	9.3	0.879	part cloud/part sun, windy, 40s
22	4	4/8/98	1800	7.1	185	11.4	8.8	0.885	cloudy, winds 15 mph, level in each cell dropped .25 in.
26	4	4/9/98	800	7.3	175	3.1	10.9	0.48	sunny, thin clouds, 35, light east winds, thin layer of ice on cell 4. Cell 1 had small trace of iron floc on bottom; dissolved when mixed.
27	1	4/9/98	1200	8	155	15.2	9.5	1.03	bright sun, 10 mph winds
28	2	4/9/98	1200	7.5	167	12.6	9.4	0.92	
29	3	4/9/98	1200	7.8	158	12.9	9.9	0.938	
30	4	4/9/98	1200	7.3	179	9.7	9.3	0.894	
31	1	4/9/98	1400	7.8	113	18	9.6	0.946	sunny, 15 mph winds, 50s

a. degrees Celsius
b. mg/L

5 Conclusions and Uncertainties

The bioventing column study and in-situ field study results were not as conclusive as would be liked. Soil hetergeneity, and laboratory matrix extraction difficulties with elevated levels of oily-contaminated soil add variables that make it difficult to assess percent reduction by direct analytical measurement. Assessing percent reduction by oxygen uptake is a standard practice for petroleum sites. An uncertainity factor is added with apportioning how much of the oxygen uptake is the microorgamism's reduction of TPH, versus PCP.

The two bioventing studies did show that microbial degradation was occuring. The field study showed no microbial activity in the deeper vadose zone soils, however. The PCP/oil levels may not be high enough in this zone to sustain a microbial population. During design consideration will be given whether to screen the air wells at this zone at all.

The treatability study did not test how microbial activity at the smear zone will react if the water table is lowered and oxygen added. This could be tested during the pre-design pump test (planned to verify the water table within the LNAPL zone can be lowered ten feet). Oxygen uptake studies could be conducted at a few wells around the extraction well to verify increased microbial activity with the addition of air.

6 References

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Attachment 1

CH2M HILL
411 E. Wisconsin Avenue
Suite 1600
Milwaukee, WI
53202-4421
Mailing address:
P.O. Box 2090
Milwaukee, WI
53201-2090
Tel 414.272.2426
Fax 414.272.4408

CH2MHILL

April 3, 1998

Mr. Ken Glatz
Work Assignment Manager
U.S. Environmental Protection Agency
Remedial Response Branch (SR-6J)
77 West Jackson Boulevard
Chicago, IL 60604-3590

Dear Ken:

Subject: Bioventing Treatability Study Technical Memorandums
Penta Wood Products Site
Town of Daniels, Wisconsin
Work Assignment No. 001-RICO-05WE
Contract No. 68-W6-0025

Enclosed please find the Bioventing Column Study Technical Memorandum and the In Situ Field Bioventing Treatability Technical Memorandum that describe the setup and present the initial results of the two treatability studies. Please call me if you have any questions or concerns.

Sincerely,

CH2M HILL

Regina Bayer

Regina Bayer

Site Manager

c: Stephen Nathan/PO/USEPA (w/o enclosure)
Peggy Hendrixson/CO/USEPA (w/o enclosure)
Tom Kendzierski/WDNR
Ike Johnson/PM/CH2M HILL, Milwaukee
John Fleissner/QAM/CH2M HILL, Milwaukee
Phil Smith/RTL/CH2M HILL, Milwaukee
Dong-Son Pham/ASM/CH2M HILL, Milwaukee
Cherie Wilson/AA/CH2M HILL, Milwaukee

Bioventing Column Study Technical Memorandum

1 Introduction

This memorandum describes the implementation, start-up, initial operation, and the preliminary results of the bioventing column study. These activities are fully described in the Treatability Study Work Plan (TS Work Plan) dated September 10, 1997, for the Penta Wood Products Superfund Site in Town of Daniels, Wisconsin. This memorandum discusses the purpose and scope of the bioventing column study, the activities that occurred, the data collected and the preliminary results.

2 Purpose and Scope

As described in the TS Work Plan, the purpose of the bioventing column study is to investigate the feasibility for the degradation of pentachlorophenol (PCP) under simulated in situ soil bioventing conditions. The collected data will provide information to aid in the preparation of the Feasibility Study (FS).

According to the TS Work Plan the four bioventing columns were to be set up as follows:

1. Contaminated soil with PCP concentrations ranging from 100 - 200 mg/kg which will not be aerated (to simulate anaerobic conditions and serve as an experimental control column)
2. Contaminated soil with PCP concentrations ranging from 100 - 200 mg/kg which will be aerated
3. Contaminated soil with PCP concentrations ranging from 700 - 1000 mg/kg which will be aerated
4. Contaminated wood debris with PCP concentrations ranging from 700 - 1000 mg/kg which will be aerated

The scope of the column study consists of the implementation and operation of bioventing columns for six months. Implementation includes setting up the four soil columns, collecting initial soil/wood debris samples, starting the bioventing activities, and collecting initial air samples from the column off gas. Operation includes measurement of the in situ oxygen concentrations, measurement of the soil off gas oxygen concentrations, and measurement of the air flow rates. Soil sample collection occurs prior to start up, after 2 months of operation, and after 6 months of operation for direct measurement of PCP reduction.

3 Activities

3.1 Soil Sample Selection

Prior to set up of the bioventing columns, soil samples were collected from soil gas wells at the Penta Wood site to establish initial contaminant and soil parameter conditions. Results from these samples determined which soil samples would be used for the bioventing column study. The following table summarizes the samples selected for the column study and the initial PCP concentrations of those samples:

Sample Number	Sample Collection Date	Sample Interval (feet)	PCP Concentration (mg/kg)	Column Number
EW1CS	1/22/98	1-10	384	1 and 2
SG8CS	1/28/98	10-15	707	3
SG9CS	1/27/98	1-10	5,460	4

3.2 Column Set up

3.2.1 Column Preparation

Preparation of the columns included purchasing and modifying four clear acrylic columns. The 6 inch diameter by 16 inch high columns were purchased with the following features: two rubber gaskets to provide an air tight seal on the top and bottom ends, four 16 inch screws with washers and nuts used to tighten the top and bottom ends to the column, an air inlet at the center of the top end of the column, an air outlet halfway between the center and the side of the top end of the column, and a pressure release valve at the top end of the column.

The columns were modified as follows:

- one air inlet was installed in the center of the bottom ends of the three aerobic columns for aeration purposes
- one plug was installed in the air outlet in the top end of the anaerobic column to form an airtight seal
- one oxygen sensor was installed in an air inlet or outlet in the top end of each of the four columns to measure the in situ oxygen concentration

3.2.2 Initial Soil Sample Collection

Initial soil samples were collected after modifying the columns. Triplicate soil/wood debris samples were collected from the three 5 gallon buckets filled with the samples previously discussed in Section 3.1. The soil/wood debris from the 5 gallon buckets were mixed to homogenize the sample prior to sub-samples collection. Triplicate samples were collected to assess any variation in the PCP concentrations across the sample. The samples were collected with decontaminated equipment and analyzed for PCP, diesel-range organics (DRO), moisture, pH, and chloride. The samples were prepared and shipped following

EPA-approved guidelines and chain-of-custody procedures (Sampling and Analysis Plan, Revision 1, November 1997).

3.2.3 Column Set up

Column set up included the following steps:

- filling the columns with the contaminated soil/wood debris (as described in Section 3.1)
- adding an air diffuser system (pea gravel) at the base of the three aerated columns to distribute the air evenly throughout the column
- purging the anaerobic column with nitrogen to obtain anaerobic conditions
- sealing the anaerobic column to maintain anaerobic conditions
- connecting a humidified air source to the three aerobic columns
- setting up a compressed air cylinder to provide the air source to the aerobic columns

3.3 Start up of Bioventing System

Start-up of the bioventing columns included: turning the air on, measuring initial oxygen depletion, adjusting the air flow rate to each column to provide adequate in situ oxygen concentrations, and collecting two 7-day composite air samples from the soil off gas from columns 3 and 4.

The oxygen depletion was recorded by measuring the in situ oxygen concentration with the air on, turning the air off for 24 hours and measuring the resulting in situ oxygen concentration. This was done primarily to determine if oxygen depletion was occurring and to determine the relative oxygen use between each column. The column air flow rates were then adjusted accordingly, the greater the oxygen depletion the higher the required air flow rate to maintain aerobic conditions.

The air samples were collected to assess the potential for PCP volatilization (as opposed to biological degradation) and measure the rate of volatilization if it does occur. The air samples were collected in XAD tubes and were analyzed for PCP and DRO.

3.4 Summary of Activities

A summary of the activities are presented below.

Date	Activity
February 11, 1998	Initial soil samples collected. Bioventing column system started at 4:00 p.m.
February 11, 1998	Bioventing column system turned off at 5:25 p.m. to conduct first oxygen uptake study.
February 11 - 12, 1998	First oxygen uptake study conducted.
February 12, 1998	Bioventing column system turned on at 5:45 p.m.
February 16 -23, 1998	7-day composite off gas air samples collected.
February 12 - March, 1998	Operation of bioventing column system.

4 Preliminary Results

Preliminary results for the initial soil/wood debris samples, oxygen depletion and air flow measurements, and air samples from the bioventing column off gas are presented in the tables attached (Tables 1, 2, and 3). A discussion of the results follows.

4.1 Initial Soil/Wood Debris Sample Results

Table 1 presents analytical results for the initial soil/wood debris. The results present initial concentrations of PCP, DRO, moisture, pH, and chloride before the start of the bioventing system. Additional soil/wood debris samples will be collected from the four columns after 2- and 6-months to determine direct measurement of PCP and DRO reduction.

The other parameters (moisture, pH, and chloride) will be used to quantify aerobic degradation reduction. Moisture and pH are measured because optimum conditions for aerobic degradation to occur are dependent on pH and moisture. Chloride is measured because it is a degradation product of PCP.

The results of the triplicate samples show that there is some variability within each soil/wood debris sample used to fill the columns. The samples which will be collected at 2- and 6-months will be a composite from the entire column in an effort to provide a representative sample to compare degradation results. The 2- and 6-month results will be compared against the averages of the results obtained from the initial samples as shown in Table 1.

4.2 Oxygen Depletion and Air Flow Rates

The initial 24 hour oxygen depletion rate and air flow rates required to maintain aerobic conditions in Columns 2, 3 and 4 are shown in Table 2. Column 1 has maintained in situ oxygen concentrations of zero which reveals the column is completely sealed and maintaining anaerobic conditions.

4.3 Air Samples

The air sample results, shown on Table 3, indicate the petroleum products (as shown by the DRO measurements) appear to be volatilizing, but the PCP does not appear to be volatilizing at detectable levels.

Table 1

February 11, 1998 Soil/Wood Debris Analytical Data

Column	Sample	Sample Date	PCP (mg/kg)	DRO (mg/kg)	moisture (%)	pH	Chloride (mg/kg)
1 and 2	1	2/11/98	95	1,000	8.3	5.71	20.3
1 and 2	2	2/11/98	150	1,600	8.1	5.75	15.1
1 and 2	3	2/11/98	130	880	8.7	5.84	15.9
Average			125	1,160	8.4		17.1
3	1	2/11/98	450	12,000	5.5	4.63	8.85
3	2	2/11/98	450	12,000	6.2	4.63	8.52
3	3	2/11/98	560	8,400	5.5	4.70	8.35
Average			487	10,800	5.7		8.57
4	1	2/11/98	1,100	43,000	51.6	4.27	75
4	2	2/11/98	930	39,000	52.6	4.23	103
4	3	2/11/98	760	9,300	44.8	4.38	53.3
Average			930	30,433	49.7		77.1

Note: Columns 1 and 2 contain the same soil. Column 1 is set up to maintain anaerobic conditions and Column 2 is set up to maintain aerobic conditions.

Table 2

Initial Oxygen Depletion and Air Flow Rate Data

Column	Sample Dates	Initial (2/11) In Situ Oxygen Conc. (% O_2)	Depleted (2/12) In Situ Oxygen Conc. (%O_2)	(2/12) Air Flow Rate (ml/min)	(2/16) In Situ Oxygen Conc. (%O_2)	(2/16) Adjusted Air Flow Rate (ml/min)	(2/19) In Situ Oxygen Conc. (%O_2)
2	2/11-2/19	20.0	19.2	14.3	13.0	15.2	19.0
3	2/11-2/19	21.0	19.0	5.2	16.5	16.3	20.0
4	2/11-2/19	20.5	14.1	12.7	18.0	20.6	19.0

The air flow rate was adjusted on 2/16 to increase the in situ oxygen concentrations to between 19 and 20 % oxygen.

Table 3

Air Sample Data

Column	Sample Tube[1]	Sample Dates	Time (hrs)	Air Flow Rate (ml/min)	Total Air Flow (L)	Total PCP (µg)	PCP Concentration (ug/L)	Total DRO (µg)	DRO Concentration (µg/L)
3	1a	2/16-2/23				<2		21,700	
3	1b	2/16-2/23				<2		4,150	
3	2a	2/16-2/23				<2		4,140	
3	2b	2/16-2/23				<2		1,690	
Total			167	13.5	135	<2	NA	31,680	234
4	1a	2/16-2/23				<2		12,300	
4	1b	2/16-2/23				<2		1,830	
4	2a	2/16-2/23				<2		2,270	
4	2b	2/16-2/23				<2		663	
Total			167	16.6	166	<2	NA	17,063	103

[1]There were two XAD tubes placed in series on each of the two columns. Each tube has two portions (a and b).

In Situ Field Bioventing Treatability Study Technical Memorandum

1 Introduction

This memorandum describes the implementation, start-up, initial operation, and the preliminary results of the onsite in situ bioventing system, which is fully described in the Treatability Study Work Plan (TS Work Plan) dated September 10, 1997, at the Penta Wood Products Superfund Site in Town of Daniels, Wisconsin. This memorandum discusses the purpose and scope of the field bioventing study, the field activities that occurred, the data collected, and presents the preliminary results.

2 Purpose and Scope

As described in the TS Work Plan, the purpose of the in-situ bioventing study is to obtain site-specific data relating to the feasibility of using bioventing for the treatment of PCP-contaminated soils. The collected data will provide information to aid in the preparation of the Feasibility Study (FS).

The scope of the treatability study consists of the implementation and operation of the bioventing system for six months. Implementation included the installation of a new 6-inch extraction/bioventing well identified as EW-1, the installation of three nests of three soil gas wells each identified as SG-1 through SG-9, the placement of the bioventing building over EW-1, the connection of the blower to EW-1, and the hook-up of electrical power.

Operation includes the measurement of initial subsurface soil gas composition, start-up of the bioventing system, the conduction of an initial soil gas permeability test to provide data to determine the radius of influence, and the conduction of several oxygen uptake studies to provide data to determine degradation rates. In addition, soil from 6 of the nine soil gas wells were collected from the bottom of each well and analyzed for PCP, TPH, diesel-range organics (DRO), total organic carbon (TOC), moisture, pH, and chloride before system start-up. The soil will also be collected and analyzed after 3 months of operation and after 6 months for direct measurement of PCP reduction.

3 Field Activities

3.1 Personnel

The bioventing system was leased from Carbonair Environmental Services of New Hope, Minnesota. Electrical work was performed by ALDEN Electric of Siren, Wisconsin. The extraction/bioventing well EW-1 and the nine soil gas wells (SG-1 through SG-9) were installed by Boart Longyear of Minnesota. Implementation, start-up, and operation of the system was performed by Dave Shekoski and Erik White of CH2M HILL.

3.2 Location

EW-1 is located in the former gully area approximately 150 feet south of the oil-water separator building. SG-1 through SG-9 are located in three nests of three wells each at distances of 25, 50, and 100 feet away from EW-1. The depths of the soil gas wells in each nest are 5- 40-, and 80 feet below ground surface (bgs).

3.3 Installation

A 8-1/4-inch diameter hollow stem auger was used to drill the first 100 feet of EW-1. A rotosonic rig was used to complete EW-1 to a total depth of 125 feet bgs. A 6-inch diameter well screened the entire depth with stainless steel slotted screen was used for EW-1. A 4-1/4-inch hollow stem auger was used to drill the nine soil gas wells. They were completed with 2-inch diameter schedule 80 PVC with 2 feet of 10-slot screen. Additional boring and well construction detail log data are included in the Remedial Investigation (RI) report.

3.4 Soil Sampling

Soil samples were collected from the borings from soil gas wells SG-1, 2, 4, 5, 7, and 8 to establish initial contaminant and soil parameter conditions for the bioventing study. Soil from the cuttings were first placed in a 5-gallon bucket. After the soil in the bucket was thoroughly mixed, a sub-sample was collected from the bucket. After sampling, most of the contents of the bucket were poured back down the borehole immediately below the bottom of the well screen.

Samples were collected with decontaminated equipment. Samples were analyzed for PCP, TPH, DRO, TOC, moisture, pH, and chloride. Samples were prepared and shipped following EPA-approved guidelines and chain-of-custody procedures (Sampling and Analysis Plan, Revision 1, November 1997).

3.5 Summary of Activities

A summary of the activities are presented below.

Date	Activity
January 23 - 30, 1998	Extraction/bioventing well EW-1 installed.
February 4, 1998	Installation of soil gas wells SG-1 through SG-9 completed. Soil collected from SG-1, 2, 4, 5, 7, and 8 for initial concentrations.
February 4, 1998	Building housing bioventing system arrives on-site. Building placed over extraction/bioventing well EW-1.
February 5, 1998	Electrical power connected to bioventing system.
February 5 - 8, 1998	Blower system tested without connection to extraction/bioventing well EW-1.
February 7, 1998	Initial subsurface soil gas composition measured.
February 8, 1998	Blower connected to extraction/bioventing well EW-1. Bioventing system started at 10:00 a.m.
February 8 -9, 1998	Soil gas permeability test conducted.
February 10, 1998	Bioventing system turned off at 12:00 p.m. to conduct baseline oxygen uptake study.
February 10 - 11, 1998	Baseline oxygen uptake study conducted.
February 11, 1998	Bioventing system turned on at 12:40 p.m. for continuation of test.
February 11 - 24, 1998	Operation of bioventing system.
February 24, 1998	Bioventing system turned off at 9:30 a.m. to conduct first oxygen uptake study.
February 24 - 27, 1998	First oxygen uptake study conducted.
February 27, 1998	Bioventing system turned on at 9:30 a.m. for continuation of test.
February 27 - March, 1998	Operation of bioventing system.

4 Preliminary Results

Preliminary results for the initial subsurface soil gas composition conditions, soil gas permeability test, initial soil gas composition at the start of the oxygen uptake studies, two

oxygen uptake studies (baseline and February test), and initial soil concentrations for PCP, TPH, DRO, TOC, moisture, pH, and chloride from the bottom of the six soil gas wells (SG-1, 2, 4, 5, 7, and 8) are presented in the tables attached (Tables 1, 2, 3, 4, 5, and 6). A discussion of the results follows.

4.1 Soil Gas Composition Initial Conditions

As shown on Table 1, most of the oxygen levels are below 5 percent oxygen while most of the carbon dioxide levels are above 10 percent. Initial low oxygen levels coupled with measurable carbon dioxide levels indicate that an oxygen limiting environment exists. Under such an environment, the enhancement of aerobic degradation may increase degradation rates.

4.2 System Influence

Data collected for the soil gas permeability test are shown on Table 2. All soil gas well points showed measurable levels of soil gas pressure. This data will be used to calculate the pressure radius of influence. The pressure radius of influence will be used to determine the spacing of the bioventing wells for the full-scale system.

4.3 Oxygen Uptake Studies

The object of bioventing is to induce air flow through the vadose-zone soil to promote aerobic degradation, a process whereby microbes use oxygen as an electron acceptor to degrade the PCP-TPH mixture.

To determine if oxygen is being inducted into the subsurface, methane, carbon dioxide, and oxygen are measured while the system is running. A decrease in both methane and carbon dioxide and an increase in oxygen versus time indicate that ambient air, which contains low carbon dioxide and no methane, is reaching the subsurface zone and air exchanges are occurring. The data collected at the start of the oxygen uptake studies show that this phenomenon is occurring in all of the soil gas points (Table 3).

Oxygen uptake study results which were measured with the system turned off, are shown in Tables 4 and 5. As shown, oxygen, carbon dioxide, methane, and VOCs were measured at each point during the study. The depletion of oxygen versus time in conjunction with the increase in carbon dioxide with the system turned off indicates that aerobic degradation is occurring. The microbes use oxygen as an electron acceptor, and respire carbon dioxide. As shown on Tables 4 and 5, oxygen is depleting at a slow rate while carbon dioxide is increasing.

Methane was measured because it is usually present in oxygen-limiting environments where there are high sources of carbon (PCP-TPH mixture). Oxygen is the preferred electron acceptor, but in its absence nitrate, iron (III), and sulfate (in that order) are used as electron acceptors for the anaerobic degradation of the PCP-TPH mixture. In the absence of the latter three, then anaerobic degradation via the conversion of carbon dioxide to methane would occur. As indicated on Tables 4 and 5, essentially no methane was measured in the soil gas wells.

Volatile organic carbon compounds, or VOCs, were also measured with a photo-ionization detector (PID). Measurable VOCs are the more volatile and readily degradable portions of

the TPH in the soil. As indicated on Tables 4 and 5, detectable levels of VOCs were measured in several soil gas wells.

4.4 Soil Sampling

Table 6 presents analytical results for soil collected from the bottom of 6 of the 9 soil gas wells. The results present initial concentrations of PCP, TPH, DRO, TOC, moisture, pH, and chloride before the start of the bioventing system. Additional soil will be collected from the same 6 soil gas wells after 3- and 6-months to determine direct measurement of PCP and TPH reduction.

The other parameters (DRO, TOC, moisture, pH, and chloride) will be used to quantify aerobic degradation reduction. The results of DRO and TOC are used to determine how much of the shorter and more readily degradable portions of the TPH would be degraded. Moisture and pH are measured because optimum conditions for aerobic degradation to occur are dependent on pH and moisture. Finally, chloride is measured because it is a degradation product of PCP.

Table 1

Initial Subsurface Soil Gas Data

Well	$\%CO_2$	$\%O_2$	% Methane (CH_4)	VOCs (ppm)
SG-1	10.4	2.6	0.1	2
SG-2	12.0	4.6	0	0.0
SG-3	14.9	1.7	0	0.0
SG-4	5.4	13.3	0	0.0
SG-5	11.5	6.42	0	0.0
SG-6	15.7	1.1	0	0.0
SG-7	11.5	2.6	0.1	1.6
SG-8	12.6	4.2	0.1	See Note 3
SG-9	15.1	0.9	0.0	0.0

Notes:
1. $\%CO_2$, $\%O_2$, and $\%CH_4$ measured with Land-Tec GA-90 soil gas analyzer.
2. VOC's measured with Multi-Rae photoioniation dector (PID).
3. Multi-rae detector ceased to operate due to low battery.

Table 2

Soil Gas Permeability Data

Date	Time	Flow [1]		P Well [1]	Temp [1]	Soil Gas Pressure Measurements ("H_2O)								
		H_2O	Scfm	"H_2O	°F	SG-1 (5' bgs)	SG-2 (40' bgs)	SG-3 (80' bgs)	SG-4 (5' bgs)	SG-5 (40' bgs)	SG-6 (80' bgs)	SG-7 (5' bgs)	SG-8 (40' bgs)	SG-9 (80' bgs)
2/8/98	1335	0.5	158	1	100	.12	.47	.46	.15	.32	.36	.08	.21	.23
2/8/98	1505	1	224	2	100	.08	.54	.51	.10	.28	.31	.02	.13	.16
2/8/98	1700	1	224	2	100	.09	.54	.54	.09	.28	.29	.03	.10	.13
2/9/98	0740	1	227	0	85	.09	.62	.55	.10	.30	.32	.04	.12	.12
2/9/98	1225	3	397	5	80	.22	>1.0	>1.0	.26	.69	.72	.12	.35	.40
2/9/98	1750	3	397	4	80	.16	>1.0	>1.0	.16	.54	.55	.05	.20	.23
2/10/08	1200	5	522	7	64	.25	>1.0	>1.0	.30	.87	.88	.11	.37	.45
2/11/98	1420	5	517	6.5	73	.38	>1.0	>1.0	.36	.98	>1.0	.17	.45	.56
2/24/98	0850	4.9	506	1	77	.35	1.40	1.10	.14	.86	.87	.16	.38	.42
2/27/98	1115	9	511	1	79	.46	1.65	1.30	.32	1.0	1.0	.36	.55	.64

Notes:

1. Air flow, pressure, and temperature measured at inlet of bioventing well at point of injection.

Table 3

Soil Gas Data at Start of Oxygen Uptake Studies

Well	Date	Time	Hours	$\%CO_2$	$\%O_2$	% methane (CH_4)	VOCs (ppm)
February 10 - 11 Baseline Oxygen Uptake Study Data							
SG-2	2/10/98	1200	0	0.5	20.9	0.0	0.0
SG-3			0	0.0	21.1	0.0	0.0
SG-5			0	1.6	20.5	0.0	0.0
SG-6			0	0.4	21.0	0.0	0.0
SG-9			0	11.1	11.4	0.0	0.5
February 24 - 27 Oxygen Uptake Study Data							
SG-1	2/24/98	0915	0	1.9	15.8	0.0	2.9
SG-2	2/24/98	0916	0	0.1	20.6	0.0	0.0
SG-3	2/24/98	0919	0	0.0	20.5	0.0	0.1
SG-4	2/24/98	0922	0	3.9	16.5	0.0	0.5
SG-5	2/24/98	0924	0	0.1	20.5	0.0	0.1
SG-6	2/24/98	0927	0	0.0	20.5	0.0	0.0
SG-8	2/24/98	0934	0	0.6	20.1	0.0	1.8
SG-9	2/24/98	0937	0	0.2	20.4	0.0	1.5

Notes:

1. $\%CO_2$, $\%O_2$, and $\%CH_4$ measured with Land-Tec GA-90 soil gas analyzer.
2. VOC's measured with Multi-Rae photoioniation dector (PID).
3. Oxygen uptake studies were not conducted in soil gas wells SG-1, 4, 7, and 8 for the baseline study and in SG-7 for the February 24 -27 study because intial oxygen levels were below testable levels.

Table 4

February 10 - 11
Baseline Oxygen Uptake Study Data

Well	Date	Time	Hours	%CO_2	%O_2	% methane (CH_4)	VOCs (ppm)
SG-2	2/10/98	1200	0	0.5	20.9	0.0	0.0
	2/10/98	1413	2	0.5	20.7	0.0	0.0
	2/10/98	1708	5	0.7	20.2	0.1	1.6
	2/10/98	2010	8	0.7	20.1	0.0	2.0
	2/11/98	0715	19	0.9	21.0	0.0	0.0
	2/11/98	1208	24	1.1	20.0	0.0	See Note 3
SG-3			0	0.0	21.1	0.0	0.0
	2/10/98	1420	2	0.0	20.9	0.0	0.0
	2/10/98	1713	5	0.0	20.6	0.0	2.2
	2/10/98	2015	8	0.1	20.2	0.0	2.5
	2/11/98	0721	19	0.0	21.4	0.0	0.0
	2/11/98	1217	24	0.1	20.5	0.1	See Note 3
SG-5			0	1.6	20.5	0.0	0.0
	2/10/98	1425	2	2.1	20.1	0.0	0.5
	2/10/98	1720	5	2.1	19.8	0.1	2.0
	2/10/98	2020	8	1.7	19.8	0.0	2.3
	2/11/98	0727	19	2.4	20.2	0.0	0.0
	2/11/98	1224	24	2.6	19.4	0.1	See Note 3
SG-6			0	0.4	21.0	0.0	0.0
	2/10/98	1435	2	0.5	20.8	0.0	0.0
	2/10/98	1728	5	0.6	20.4	0.0	2.5
	2/10/98	2025	8	0.5	20.3	0.1	2.1
	2/11/98	0732	19	0.9	21.0	0.0	0.0
	2/11/98	1230	24	1.0	20.2	0.1	See Note 3
SG-9			0	11.1	11.4	0.0	0.5
	2/10/98	1445	2	10.9	11.8	0.0	1.8
	2/10/98	1735	5	8.8	13.6	0.1	2.7
	2/10/98	2030	8	9.1	13.4	0.1	2.7
	2/11/98	0741	19	10.6	12.9	0.1	1.1
	2/11/98	1236	24	10.7	12.4	0.0	See Note 3

Notes:
1. %CO_2, %O_2, and %CH_4 measured with Land-Tec GA-90 soil gas analyzer.
2. VOC's measured with Multi-Rae photoioniation dector (PID).
3. Multi-rae meter not available because already shipped off-site before end of test.
4. Oxygen uptake studies were not conducted in soil gas wells SG-1, 4, 7, and 8 because intial oxygen levels were below testable levels.

Table 5

February 24 - 27
Oxygen Uptake Study Data

Well	Date	Time	Hours	$\%CO_2$	$\%O_2$	% methane (CH_4)	VOCs (ppm)
SG-1	2/24/98	0915	0	1.9	15.8	0.0	2.9
	2/25/98	0918	24	2.4	12.2	0.0	1.7
	2/26/98	0954	48	2.3	10.7	0.0	0.3
	2/27/98	0737	72	3.2	5.7	0.0	8.0
SG-2	2/24/98	0916	0	0.1	20.6	0.0	0.0
	2/25/98	0930	24	0.2	20.7	0.0	1.2
	2/26/98	1014	48	0.2	20.4	0.0	1.8
	2/27/98	0750	72	0.3	20.3	0.0	0.0
SG-3	2/24/98	0919	0	0.0	20.5	0.0	0.1
	2/25/98	0953	24	0.1	21.0	0.0	1.0
	2/26/98	1036	48	0.1	20.6	0.0	1.1
	2/27/98	0813	72	0.1	20.5	0.0	0.3
SG-4	2/24/98	0922	0	3.9	16.5	0.0	0.5
	2/25/98	1000	24	2.8	18.5	0.0	1.1
	2/26/98	1041	48	2.6	18.3	0.0	0.8
	2/27/98	0822	72	3.6	16.8	0.0	2.1
SG-5	2/24/98	0924	0	0.1	20.5	0.0	0.1
	2/25/98	1012	24	0.3	20.8	0.0	0.6
	2/26/98	1051	48	0.4	20.3	0.0	0.9
	2/27/98	0833	72	0.5	20.2	0.0	0.3
SG-6	2/24/98	0927	0	0.0	20.5	0.0	0.0
	2/25/98	1033	24	0.2	20.9	0.0	3.0
	2/26/98	1120	48	0.2	20.4	0.0	1.4
	2/27/98	0853	72	0.3	20.1	0.0	0.5
SG-8	2/24/98	0934	0	0.6	20.1	0.0	1.8
	2/25/98	1047	24	0.9	20.5	0.0	4.0*
	2/26/98	1136	48	0.8	20.1	0.0	2.5
	2/27/98	0903	72	1.0	19.9	0.0	0.9
SG-9	2/24/98	0937	0	0.2	20.4	0.0	1.5
	2/25/98	1107	24	0.3	20.9	0.0	7.7*
	2/26/98	1154	48	0.3	20.5-6	0.0	5.6*
	2/27/98	0924	72	0.4	20.4	0.0	4.1

Notes:

1. $\%CO_2$, $\%O_2$, and $\%CH_4$ measured with Land-Tec GA-90 soil gas analyzer.
2. VOC's measured with Multi-Rae photoioniation dector (PID).
3. Oxygen uptake study was not conducted in soil gas well SG-7 because intial oxygen levels were below testable levels.

Table 6

Initial Soil Data

Well	Depth (feet bgs)	PCP (ppm)	TPH (ppm)	DRO (ppm)	TOC (ppm)	moisture (%)	pH	Chloride (ppm)
SG-1	5	1,290	15,100	18,000	644	22.7	4.83	25.1
SG-2	40	179	3,430	1,000	107	7.4	6.57	<5.4
SG-4	5	157	3,670	1,100	299	7.6	5.31	8.1
SG-5	40	155	7,010	1,900	144	6.5	5.88	10.0
SG-7	5	973	11,800	19,000	644	41.1	4.94	18.6
SG-8	40	317	4,450	7,300	229	4.4	6.81	10.2

Attachment 2

ENVIRONMENTAL MONITORING AND TECHNOLOGIES, INC.

8100 North Austin Avenue
Morton Grove, Illinois 60053-3203
847-967-6666
FAX: 847-967-6735

Groundwater Monitoring
Laboratory Services
Mobile Laboratory Services
Source Emissions

Waste Characterization (RCRA)
Wastewater Compliance Monitoring
• Pretreatment
• User Charge

FAX TRANSMISSION NOTICE

Date: 3/20

Time: 9:45

To: Dong Son Pham

Company: CH2M Hill

Fax Number: 414-272-4408

Sender: Greg Dennis

You should receive 4 *pages, including this notice. If you do not receive all pages, please call the sender immediately. This transmission includes:*

Comments:

FAX Number is: (847) 967-6735 *Telephone Number is (847) 967-6666*

ENVIRONMENTAL MONITORING AND TECHNOLOGIES, INC.

8100 North Austin Avenue
Morton Grove, Illinois 60053-3203
847-967-6666
FAX: 847-967-6735

LABORATORY REPORT

178205

CH2M Hill, Inc.
411 E. Wisconsin Avenue, Suite 1600
P.O. Box 2090
Milwaukee, WI 53201-2090

Report Date: 3/20/98
Sample Received: 2/24/98

The samples were desorbed with an acidified methanol/methylene chloride mixture. The samples were then split to run by two different methods.

On the DRO (Diesel Range Organics) there was significant breakthrough between parts 1 and 2. Common wisdom says that 10-15% breakthrough of the first part when found in the second part is an indicator of excessive breakthrough. After breakthrough you tend to get a steady state situation and concentration is not able to be measured with a high degree of accuracy.

The pattern in the hydrocarbons was different than our diesel standard. It was lighter and more volatile. It does have the aromatics of diesel though. The recovery of the diesel spike for this sample was 104% and the duplicate was 107%.

We saw no pentachlorophenol in any of the eight samples. (3,3',4,4'-each with parts 1 and 2). Our spike recovery for the pentachlorophenol was 28% and 33% for the duplicate. This is rather typical of this compound on a lot of resins.

Leah E. Zhou

LABORATORY DIRECTOR

ENVIRONMENTAL MONITORING AND TECHNOLOGIES, INC.

8100 North Austin Avenue
Morton Grove, Illinois 60053-3203
847-967-6666
FAX: 847-967-6735

LABORATORY REPORT

178205

CH2M Hill, Inc.
411 E. Wisconsin Avenue, Suite 1600
P.O. Box 2090
Milwaukee, WI 53201-2090

Report Date: 3/20/98
Sample Received: 2/24/98

Diesal Range Organics

EMT #	Station Location	Tube portion 1	Tube portion 2
035312	XAD-3	21700 µg	4150 µg 19% breakthrough
035313	XAD-4	12300 µg	1830 µg 15% breakthrough
035312	XAD-3'	4140 µg	1690 µg 40% breakthrough
035313	XAD-4'	2270 µg	663 µg 29% breakthrough

Pentachlorophenol

035312	XAD-3	<2 µg	<2 µg
035313	XAD-4	<2 µg	<2 µg
035312	XAD-3'	<2 µg	<2 µg
035313	XAD-4'	<2 µg	<2 µg

Leil E. Zhree

LABORATORY DIRECTOR

EPA — Special Analytical Services Packing List/Chain of Custody

United States Environmental Protection Agency
Contract Laboratory Program

SAS No. | Case No.

1. Matrix (Enter in Column A)
1. Surface Water
2. Ground Water
3. Leachate
4. Field QC
5. Soil/Sediment
6. Oil
7. Waste
8. Other (Specify in Column A)

2. Preservative (Enter in Column D)
1. HCl
2. HNO3
3. NAHSO4
4. H2SO4
5. NAOH
6. Ice Only
7. Other (Specify in Column D)
N. Not Preserved

2. Region No. | Sampling Co. | 4. Date Shipped | Carrier | 6. Date Received--Received by:

Sampler (Name) | Airbill Number | Laboratory Contract Number | Unit Price

Sampler Signature | 5. Ship To | 7. Transfer to: | Date Received

3. Purpose*
Lead: [X] SF [ ] PRP [ ] ST [ ] FED
Early Action: [ ] CLEM [ ] PA [ ] REM
[ ] SI [ ] ESI [X] RI [ ] OIL [ ] UST
Long-Term Action: [X] FS [ ] RD [ ] RA [ ] O&M [ ] NPLD

ATTN:

Received by | Contract Number | Price

Sample Numbers (From Labels)	A Matrix (from Box 6) / Other:	B Conc.: Low Med High	C Sample Type Comp./ Grab	D Preservative (from Box 7) / Other:	E Analysis	F Regional Specific Tracking Number or Tag Numbers	G Station Location Identifier	H Mo/Day/ Year/Time Sample Collection	I Sampler Initials	J High Phases: Solids	Water-Miscible Liq.	Water-Immis Liq.
[illegible]	B	L	C	N	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	B	L	C	N	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

35312
35313

Shipment for SAS Complete? (Y / N) | Page 1 of 1 | Sample(s) to be Used for Laboratory QC | Additional Sampler Signatures | Chain of Custody Seal Number(s)

CHAIN OF CUSTODY RECORD

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
[illegible]	[illegible]	[illegible]	[illegible]	2-24-98 10:30A	[illegible]
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks Is custody seal intact? Y / N / none	
		[illegible]	2/24/98 10:50		

A21-012-7 REV. 3/94

DISTRIBUTION: White – Region Copy; Gold – Lab Copy for Return to Region; Yellow – Data User**; Pink – Lab Copy for Return to Data User**

EPA Form 9110-3

SEE REVERSE FOR ADDITIONAL STANDARD INSTRUCTIONS
*SEE REVERSE FOR PURPOSE CODE DEFINITIONS

**[illegible] user [illegible] the organization [illegible] contract [illegible] the laboratory [illegible] services [illegible].