

SOIL TREATABILITY PILOT STUDY

COWBOY TIMBER TREATING SITE Manderson, Big Horn County, Wyoming

1.0 INTRODUCTION

This soil treatability pilot study is being conducted to fulfill the requirements of Task Order (TO) 014 of the US Environmental Protection Agency (EPA) Region 8 Emergency and Rapid Response Services (ERRS) contract EP-S8-13-02. The Cowboy Timber site is located in Manderson, Big Horn County, Wyoming. Field activities associated with site soil acquisition occurred from August 21-23, 2013.

2.0 SITE BACKGROUND

The Cowboy Timber Treating Site is currently operated as a saw mill and carpentry shop for prefabricated wood structures. Previous uses of the site include a wood treatment facility, small refinery, and coal mining operation. April 2013 soil analytical results indicate the presence of pentachlorophenol (PCP) from 0 to 15 feet below ground surface (bgs) (UOS 2013). This soil treatment study is designed to identify an optimal PCP bioremediation system for the former refinery and wood treatment area of the Cowboy Timber Treating Site.

3.0 SCOPE OF WORK

Environmental Restoration, LLC (ER) received soil generated and containerized onsite by EPA Region 8 Superfund Technical Assessment and Response Team (START) during a hollow-stem auger drill investigation. The soil treatment study was conducted from September 2013 through November 2013, with additional evaluation through July of 2014.

4.0 TECHNICAL APPROACH

4.1 Soil Treatability Study Summary

This soil treatability pilot study consists of 7 study groups primarily composed of clean sand, site background soil, and site contaminated soil. Specifically, study groups consist of the following:

- C-1: Clean sand;
- C-2: Untreated site background soil;

- C-3: Untreated site homogenized contaminated soil;
- T-2: Site homogenized contaminated soil with sawdust additive;
- T-3: Site homogenized contaminated soil with sawdust, nitrogen, and sugar additives;
- T-5: Site homogenized contaminated soil with sawdust, and nitrogen-phosphorous-potassium-sulfur (NPKS) fertilizer additives; and
- T-6: Site homogenized contaminated soil with NPKS fertilizer additive.

Each study group was replicated in triplicate with consistent tilling and watering activities throughout the set.

4.2 Soil Acquisition

Site background soil was collected by US EPA Region 8 START contractors from 0-2 feet below ground surface (bgs), in an open area northeast of the sawmill/workshop and east of site operation waste wood piles.

Sawdust was obtained from old and new waste wood pile areas north of sawmill/workshop.

Site background soil, contaminated soil, and sawdust were collected by US EPA Region 8 START and subcontractor Drilling Engineers, Inc. from 5 hollow-stem auger drilling locations. Drilling locations were found to contain PCP concentrations consistent with those identified in the May 2013 site investigation conducted by URS Operating Services (UOS 2013).

4.3 Sample Group Preparation

Each sample group consisted of 3 5-gallon pails prepared in the same manner. Sample groups C-1 and C-2 were prepared independently. These consisted of filling 5-gallon pails halfway with clean sand and background soil, respectively. Background soil was homogenized in an open-top container prior to dividing into sample cells.

Preparation of sample groups C-3, T-2, T-3, T-5 and T-6 began with homogenization of site contaminated soil in an open-top container. Following homogenization, C-3 and T-6 were prepared in the same manner, with the addition of NPKS fertilizer for T-6.

Mulch additives for sample groups T-2 through T-5 consisted of a mixture of 25% weathered sawdust and 75% new sawdust collected onsite. Each of these three groups were prepared by filling 5-gallon pails halfway with homogenized site contaminated soil, then adding a four-inch layer of mulch to the cells. T-3 and T-5 were completed by the addition of nitrogen and sugar, and NPKS fertilizer, respectively.

4.4 Treatment Conditions

This treatability study was designed to reproduce onsite soil treatment activities and soil conditions as accurately as possible. Treatment cells are maintained within a containment, and surrounded by clean sand to a level consistent with soil volume within the cells. The surrounding material provides insulation from extreme temperature fluctuation.

5.0 SAMPLING AND ANALYSIS

Homogenized site contaminated soil, background soil, sand, and sawdust were analyzed for PCP at the onset of the study. Samples were then analyzed at a frequency of every week, every 3 weeks, once, or once at the beginning and end of the study to verify effectiveness of the various treatment approaches. The complete sample analysis scheme is presented in Table A.

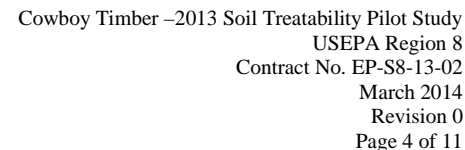


Table A
Sample Analysis Scheme

Parameter	Matrix	Analytical Location	Analysis Frequency	Sample Volume	Purpose	Acceptable Range	Optimal Range
pH	Soil	Field	Once a week	Approx 1 oz.	Evaluate suitability of environment to biological growth	6.0-8.0	6.5-7.5
Moisture			Once a week	All	Evaluate suitability of environment to biological growth	30-50	40% of pore space
Bulk Density (Gravimetric)			Beginning and End of Treatment Study	All	Evaluate soil structure	-	-
Bulk Density (Volumetric)			Beginning and End of Treatment Study	All	Evaluate soil structure	-	-
Porosity			Beginning and End of Treatment Study	All	Evaluate soil structure	-	-
Temperature			Once a week	All	Evaluate suitability of environment to biological growth	10-30 °C	15-25 °C
Microbial Community Structure (PFLA)	Soil	Lab (ORD)	Weeks 0, 3, and 6	8 oz.	Determine biological composition of soil	-	-
Routine Soil Package plus Total Nitrogen and Total Carbon (Routine analysis = pH, Electrical Conductivity, Organic Matter, Nitrate-nitrogen, Phosphorous, Potassium, Zinc, Iron, Manganese, Copper, and Lime and Texture estimates)	Soil	Lab (CSU)	Weeks 0, 3, and 6	16 oz.	Determine composition and nutrient content of soil	Nitrogen (NO ₃ ⁻)	
						-	1.3-1.5 g/cm ³
						Phosphorous (P ₂ O ₅)	
						7-20 ppm	>14 ppm
						Potassium (K ₂ O)	
						-	25 ppm
						Sulfur (SO ₄)	
						-	25 ppm

Table A
Sample Analysis Scheme

Parameter	Matrix	Analytical Location	Analysis Frequency	Sample Volume	Purpose	Acceptable Range	Optimal Range
Carbon Dioxide	Soil headspace	Field	Weeks 0, 3, and 6	N/A	Verify presence and health of bacteria in soil	-	1,500-2,500 ppm
PCP, 2,3,4,6-TeCP	Soil	Lab (Accutest)	Weeks 0, 3, and 6	4 oz.	Verify overall treatment effectiveness	-	-
PAHs						-	-
Total Carbon	Sawdust	Lab (CSU)	Once	10 g.	Determine CEC and nutrient contribution from sawdust additive	-	-
Total Nitrogen						-	-
PCP, 2,3,4,6-TeCP		Lab (Accutest)	Once	4 oz.	Verify no PCPs/PAHs are present in sawdust additive	-	-
PAHs						-	-

To assess the effectiveness of biological treatment, sample aliquots were collected from each cell and composited for analysis prior to weekly tilling activities.

5.1 Laboratory Analytical Procedures

Sample analysis was conducted by the following laboratories:

- Microbial community structure: EPA Office of Research and Development (ORD) laboratory, Cincinnati, Ohio;
- Routine soil package plus Total Carbon and Total Nitrogen: Colorado State University Soil, Water and Plant Testing Laboratory, Ft. Collins, Colorado; and
- Soil and sawdust PCP, PCP degradation products, and PAHs: Accutest Laboratories, Denver, Colorado.

All samples were shipped via FedEx or hand-delivered to the laboratory under ER chain of custody procedures. Microbial community structure samples were cooled to -20°C with dry ice during shipment. Organics samples were cooled to 4°C for laboratory delivery.

5.2 Field Analytical Procedures

Temperature, pH, bulk density, moisture, and porosity measurements for sample cells were collected at the ER warehouse facility in Commerce City, Colorado. Weekly pH measurements were collected by creating a slurry with soil and distilled water and measuring with a digital pH meter. A digital thermometer was used to monitor each sample cell on a weekly basis. Sample cells were weighed initially in order to calculate bulk density and porosity; then prior to and following sample collection, to maintain moisture content. Sample cells were constructed to allow drainage and prevent moisture saturation.

Sample containers were covered for a minimum of 24 hours prior to collection of carbon dioxide measurements. Samples were also covered at night and during rain or snow weather events.

6.0 RESULTS

September to November 2013 sample results for the Cowboy Timber soil treatability pilot study are summarized in Tables 1-3. Collected soil parameters can be found in Table 4. The pilot study is projected to continue from March to July 2014.

TABLE 1
Analytical Results for Semivolatile Organic Compounds
Concentrations in micrograms per kilogram (µg/kg) parts per billion (ppb)

Analyte	CTT2: Mulch Only			CTT3: Mulch, N and Sugar			CTT5: Mulch, NPKS			CTT6: NPKS		
	CTT2_091013	CTT2_093013	CTT2_102013	CTT3_091013	CTT3_093013	CTT3_102013	CTT5_091013	CTT5_093013	CTT5_102013	CTT6_091013	CTT6_093013	CTT6_102013
Pentachlorophenol	44700	59900	25100	62400	103000	33800	80700	62000	32800	35600	64700	41900
2,3,4,6-Tetrachlorophenol	1460 J	1610	1210	1940 J	4030	1460	2360 J	2140	1360	1130	2160	1380
Acenaphthene	600	688	404	706	501	254	967	372	148	631	600	111
Acenaphthylene	153	175	96.6	184	129	54.7	268	84.5	32.0 J	169	148	24.7
Anthracene	469	469	235	567	431	186	609	367	197	467	486	71.6
Benzo(a)anthracene	77	113	41.6	88.9	130	33.6	97.9	90.1	57.4	85.6	110	20.3
Benzo(b)fluoranthene	ND (4.6)	50.1	ND (5.0)	ND (4.7)	46.7	ND (5.3)	ND (19)	34.1	ND (22)	61.3	37.1	10.6 J
Benzo(k)fluoranthene	ND (4.6)	ND (4.5)	ND (5.0)	ND (4.7)	9.3	ND (5.3)	ND (19)	ND (4.5)	ND (22)	ND (4.6)	ND (4.6)	ND (5.6)
Benzo(g,h,i)perylene	27.3	25.5	12.5	22.1	22.6	12.4	21.0 J	19.2	ND (22)	24	21.6	7.1 J
Benzo(a)pyrene	28.7	43.8	ND (5.0)	32.6	34.2	ND (5.3)	31.5 J	27.2	ND (22)	38.2	34.1	8.5 J
Chrysene	152	270	107	193	237	78.7	217	208	142	212	258	53.2
Dibenzo(a,h)anthracene	ND (4.6)	ND (4.5)	7.0 J	ND (4.7)	ND (4.5)	ND (5.3)	ND (19)	9.5	ND (22)	7.6 J	11.8	ND (5.6)
Fluoranthene	187	260	118	211	273	92.7	216	203	136	222	254	49.5
Fluorene	950	1170	558	1110	963	360	1460	769	287	975	1060	209
Indeno(1,2,3-cd)pyrene	10.3	13.6	6.4 J	10.1	13.4	ND (5.3)	ND (19)	9.2	ND (22)	13.3	11.8	ND (5.6)
1-Methylnaphthalene	6180	2690	822	6470	1110	319	5820	522	92.2	6830	2050	136
2-Methylnaphthalene	1760	780	140	2380	327	65.4	2450	175	34.6 J	2680	636	46.4
Naphthalene	81.8	22.1	ND (12)	125	ND (11)	ND (13)	187	11.7 J	ND (52)	153	ND (11)	ND (13)
Phenanthrene	7240	6320	3650	5770	6350	2220	5860	4680	1740	6190	5910	768
Pyrene	1130	1020	389	922	1310	311	1180	826	554	699	965	191

(##) Reporting Limit
 ND Analyte not detected at the reporting limit
 J The associated numerical value is an estimated quantity

TABLE 2
Analytical Results for Control Group Semivolatile Organic Compounds
Concentrations in micrograms per kilogram (µg/kg) parts per billion (ppb)

Analyte	Composite Contaminated Soil	Sawdust	CTC1: Clean Sand			CTC2: Background Soil			CTC3: Contaminated Soil, No Additives		
	CTCS01	CTSW01	CTC1_091013	CTC1_093013	CTC1_102013	CTC2_091013	CTC2_093013	CTC2_102013	CTC3_091013	CTC3_093013	CTC3_102013
Pentachlorophenol	51100	ND (110)	ND (17)	ND (17)	ND (18)	ND (18)	ND (18)	ND (22)	77500	76700	60600
2,3,4,6-Tetrachlorophenol	1880	ND (120)	ND (19)	ND (19)	ND (19)	ND (19)	ND (20)	ND (25)	2560 J	2160	1700
Acenaphthene	570	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	787	765	ND (5.4)
Acenaphthylene	156	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	202	197	41.7
Anthracene	527	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	648	473	111
Benzo(a)anthracene	82	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	95.7	140	24.5
Benzo(b)fluoranthene	33	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	48.1	58.8	11.6
Benzo(k)fluoranthene	ND (4.5)	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	ND (4.6)	ND (4.5)	ND (5.4)
Benzo(g,h,i)perylene	14.9	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	19.4	45.9	7.2 J
Benzo(a)pyrene	27.9	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	35.2	59.8	8.8 J
Chrysene	186	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	251	298	58.8
Dibenzo(a,h)anthracene	7.4 J	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	10.3	ND (4.5)	ND (5.4)
Fluoranthene	239	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	302	302	62.2
Fluorene	992	ND (130)	ND (5.1)	ND (5.2)	ND (5.3)	ND (5.3)	ND (5.4)	ND (6.8)	1230	1120	325
Indeno(1,2,3-cd)pyrene	6.3 J	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	9.2	20.3	ND (5.4)
1-Methylnaphthalene	4600	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	5830	3640	191
2-Methylnaphthalene	1970	ND (140)	ND (5.4)	ND (5.6)	ND (5.7)	ND (5.7)	ND (5.8)	ND (7.2)	2140	1010	62.6
Naphthalene	123	ND (270)	ND (11)	ND (11)	ND (11)	ND (11)	ND (11)	ND (14)	146	40.8	ND (13)
Phenanthrene	6190	ND (110)	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	7900	8150	1360
Pyrene	858	447	ND (4.4)	ND (4.5)	ND (4.6)	ND (4.6)	ND (4.7)	ND (5.9)	827	1520	215

(##) Reporting Limit
ND Analyte not detected at the reporting limit
J The associated numerical value is an estimated quantity

TABLE 3
Analytical Results for Routine Soil Parameters plus Total Carbon and Nitrogen

Sample ID	pH	EC (mmhos/ cm)	Lime Estimate	OM (%)	AB-DTPA (ppm)							Texture Estimate	Total (%)	
					NO ₃ -N	P	K	Zn	Fe	Mn	Cu		N	C
CTSW01	-	-	-	-	-	-	-	-	-	-	-	-	9.431	44.73
CTC2_091013	8.3	6.2	Very High	2.7	1.8	2.5	116	0.25	1.44	1.58	1.23	Sandy Clay Loam	0.0541	1.127
CTC2_093013	8.1	8.2	Very High	6.6	6.2	3.5	107	0.3	2.5	2.3	1.8	Sandy Clay	0.0528	0.9190
CTC2_102013	8.1	6.6	Very High	0.6	4.3	3.0	139	0.57	4.1	5.9	1.7	Sandy Clay	0.0846	0.9467
CTC3_091013	8.1	3.1	Very High	2.8	0.4	0.1	176	0.68	5.31	13.7	1.2	Sandy Clay Loam	0.0325	0.633
CTC3_093013	8.0	4.4	High	0.8	1.3	<0.1	133	0.5	6.1	11.8	1.2	Sandy Clay	0.0351	0.8909
CTC3_102014	7.8	3.7	High	0.7	0.7	0.1	124	0.52	8.3	11.3	1.2	Clay	0.1734	0.8174
CTT2_091013	7.5	2.9	High	4.6	0.2	0.5	154	1.41	4.2	16.3	0.82	Sandy Loam	0.0432	4.689
CTT2_093013	7.7	3.2	High	0.6	0.3	0.5	122	1.2	8.2	19.5	1.4	Sandy Clay Loam	0.0588	4.161
CTT2_102013	7.7	3.1	High	4.3	1.2	0.4	122	1.2	9.4	19.4	1.7	Clay	0.1098	4.515
CTT3_091013	7.6	2.9	High	4.3	0.1	0.2	166	1.56	4.42	18.6	1.20	Sandy Loam	0.4343	6.169
CTT3_093013	7.7	3.2	Very High	3.6	0.1	<0.1	139	1.3	7.0	21.9	1.5	Sandy Clay Loam	0.0546	3.826
CTT3_102013	7.6	3.2	Medium	3.8	0.4	0.2	135	1.2	11.0	20.5	2.0	Clay	0.0881	4.012
CTT5_091013	7.7	3.0	High	5.2	1.6	2.0	161	1.23	4.06	14.3	0.79	Sandy Loam	0.0656	3.415
CTT5_093013	7.6	3.5	High	5.8	4.0	3.0	159	1.4	6.2	17.9	2.2	Sandy Clay Loam	0.0448	2.199
CTT5_102013	7.6	4.2	Medium	5.7	0.8	0.4	164	1.6	10.1	20.8	1.6	Clay	0.1193	5.625
CTT6_091013	8.2	2.9	Very High	3.2	7.1	7.0	215	0.78	4.88	11.0	1.42	Sandy Clay Loam	0.0359	1.883
CTT6_093013	7.9	4.0	High	0.4	10.3	2.0	153	0.65	7.6	11.9	1.9	Sandy Clay	0.0595	1.291
CTT6_102013	7.9	4.5	Medium	0.7	2.1	1.5	161	0.83	10.1	13.3	1.8	Clay	0.0838	1.011

TABLE 4
Field Parameters

Treatment Cell	9/10/2013			9/18/2013			9/22/2013			10/1/2013			10/9/2013			10/13/2013			10/20/2013		
	pH	Temperature (°C)	CO ₂ (ppm)	pH	Temperature (°C)	CO ₂ (ppm)	pH	Temperature (°C)	CO ₂ (ppm)	pH	Temperature (°C)	CO ₂ (ppm)	pH	Temperature (°C)	CO ₂ (ppm)	pH	Temperature (°C)	CO ₂ (ppm)	pH	Temperature (°C)	CO ₂ (ppm)
CTC1-1	7.35	23.0	N/A	8.22	16.5	-	8.66	16	N/A	8.52	18.4	-	9.08	13.6	N/A	8.85	7.8	N/A	9.06	24.2	-
CTC1-2	7.39	22.4	N/A	8.15	17.0	-	8.51	16	N/A	8.32	19.5	-	8.46	12.2	N/A	9.03	8.7	N/A	9.03	25.5	-
CTC1-3	7.28	21.9	N/A	8.32	16.6	-	8.55	16	N/A	8.36	20.9	-	8.10	12.4	N/A	9.04	8.2	N/A	9.11	24.6	-
CTC2-1	8.56	23.7	N/A	8.50	18.3	500	8.85	15	N/A	8.69	19.2	-	8.83	10.5	N/A	9.64	8.6	N/A	8.87	19.4	-
CTC2-2	8.35	23.7	N/A	8.44	18.3	-	8.50	17	N/A	9.15	19.7	-	8.86	10.8	N/A	9.13	9.1	N/A	8.91	20.6	-
CTC2-3	8.51	23.8	N/A	8.47	18.0	-	7.31	17	N/A	8.92	20.9	-	9.00	10.8	N/A	9.16	9	N/A	8.89	21	-
CTC3-1	8.15	23.8	N/A	8.54	17.6	-	8.87	15	N/A	8.84	18.9	-	8.26	11.4	N/A	8.90	8.7	N/A	8.57	25.6	-
CTC3-2	8.19	23.8	N/A	8.65	17.7	-	8.79	16	N/A	8.85	19.4	-	8.64	11.5	N/A	9.20	9	N/A	8.63	26.6	-
CTC3-3	8.18	23.8	N/A	8.46	17.5	-	8.43	16	N/A	8.85	18.9	-	8.72	11.1	N/A	9.01	9.2	N/A	8.66	26.8	-
CTT2-1	7.59	23.4	N/A	8.13	17.3	7400	8.78	16	N/A	8.33	17.5	3500	8.74	11.4	N/A	9.01	8.9	N/A	8.90	30.6	1300
CTT2-2	7.84	23.6	N/A	8.15	17.6	1.33%*	8.83	16	N/A	8.66	18.2	3200	8.88	11.3	N/A	9.00	9.2	N/A	8.93	29.6	1300
CTT2-3	8.06	23.8	N/A	8.45	17.5	1.35%*	8.65	16	N/A	8.71	18.9	3200	8.84	11.4	N/A	8.81	9.1	N/A	8.88	28.4	1000
CTT3-1	7.95	23.8	N/A	8.11	17.6	1.95%*	8.58	16	N/A	8.69	18	1.23%*	8.64	11.5	N/A	8.85	8.9	N/A	8.66	30.6	2200
CTT3-2	7.53	23.4	N/A	8.09	17.7	1.23%*	6.50	16	N/A	8.83	18.7	9100	8.74	11.1	N/A	8.99	8.9	N/A	8.68	33.8	1500
CTT3-3	7.63	23.4	N/A	8.06	17.8	2.05%*	6.50	17	N/A	8.70	18.9	1.48%*	8.73	11.2	N/A	8.92	9	N/A	8.74	28.4	2000
CTT5-1	7.32	23.2	N/A	8.14	17.8	200	6.50	16	N/A	7.67	17.4	5000	8.82	10	N/A	8.77	8.6	N/A	8.69	29.8	6700
CTT5-2	7.40	23.3	N/A	8.18	17.9	2.67%*	6.50	16	N/A	7.95	17.2	2.0%*	8.87	10.9	N/A	8.85	8.7	N/A	8.72	30.2	8700
CTT5-3	7.10	23.3	N/A	8.05	17.7	4.47%*	6.50	16	N/A	8.37	16.4	1.8%*	8.53	10.4	N/A	8.91	8.8	N/A	8.74	29.8	3000
CTT6-1	8.16	23.5	N/A	8.13	17.3	200	6.50	16	N/A	8.67	16.4	800	8.76	9.2	N/A	8.99	8.2	N/A	8.6	27.2	300
CTT6-2	7.42	23.3	N/A	8.36	17.1	200	6.50	15	N/A	8.55	16.5	300	8.85	9.3	N/A	8.98	8.4	N/A	8.66	30.6	300
CTT6-3	7.66	22.8	N/A	8.35	17.0	-	6.50	15	N/A	8.78	17.2	1.3	8.67	9.4	N/A	8.71	8.5	N/A	8.71	29.6	-

* Instrument reads in % volume when readings exceed 20,000ppm