PILOT-SCALE TREATABILITY TESTING OF WASTE-PIT LIQUID FROM THE LOWRY LANDFILL SUPERFUND SITE

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ABSTRACT

This paper presents the results of treatability testing conducted to remove organics, metals, radionuclides, and other inorganic contaminants from a complex liquid matrix (waste-pit liquid). The waste-pit liquid that was used in the pilot-scale treatability study program was collected from wells installed in a landfill formerly used for codisposal of municipal and liquid industrial waste. The waste-pit liquid has a high organic content (as quantified by biochemical oxygen demand [BOD], chemical oxygen demand [COD], and total organic carbon [TOC], which were measured at 4080 milligrams per liter, 6200 mg/l and 524 mg/l, respectively), a high total dissolved solids (TDS) content (greater than 19,000 milligrams per liter), and contains metals and low levels of radionuclides. The unit processes evaluated for treatment of the waste-pit liquid include (1) gravity phase separation, (2) lime-soda softening, and (3) Powdered Activated Carbon Treatment (PACT®) biological treatment. As a result of these treatment processes, target analytes were effectively removed.

INTRODUCTION

This paper presents the results of pilot-scale treatability studies conducted to assess the effectiveness of selected physical and chemical unit treatment processes for treatment of a complex liquid matrix. The liquid matrix used for this study was collected from the Lowry Landfill Superfund site in Arapahoe County, southeast of Denver, Colorado. A site map of the Lowry Landfill is provided as Fig. 1.

The Lowry Landfill formerly accepted municipal refuse, liquid industrial waste (including some hazardous substances), and municipal sewage sludge. The disposal procedure used was known as codisposal. Codisposal consisted of excavating waste pits, filling them approximately three-quarters full with liquid, and then filling them with municipal refuse. Additional municipal refuse was mounded several feet above the waste pits.

Environmental investigations began at Lowry Landfill in the mid-1970s and currently continue. The U.S. Environmental Protection Agency (EPA) became actively involved in monitoring activities in 1981, when Lowry Landfill was first considered for the National Priorities List (NPL). Lowry Landfill was placed on the NPL in 1984 and was divided into operable units (OUs). The OUs are as follows: Shallow Groundwater and Subsurface Liquids (OU 1), Landfill Solids (OU 2), Landfill Gas (OU 3), Soils (OU 4), Surface Water and Sediment (OU 5), and Deep Groundwater (OU 6).

The treatability study program for waste-pit liquid was conducted under the Administrative Order on Consent (AO) (1) for the remedial investigation and feasibility study (RI/FS) for OUs 1 and 6. In accordance with the AO, three stages of treatability testing were conducted. The first two stages were conducted to fulfill identified data needs for potentially applicable treatment technologies. The third stage of treatability testing consisted of pilot-scale testing of an entire train of representative process options. This paper focuses on the pilot-scale testing of the waste-pit liquid matrix.

The waste-pit liquid collected for the treatability study has a high organic content, as *quantified* by BOD, COD, and TOC, which were measured at 4080 mg/l, 6200 mg/l, and 524 mg/l, respectively. The organic fraction of the waste-pit liquid includes volatile organic compounds, semivolatile organic compounds, pesticides, herbicides, dioxins, and furans. Radionuclides, metals, and a high total dissolved solids content have also been detected in the waste-pit liquid. A summary of the analytes detected in the waste-pit liquid is presented in Table I.

Previous treatability testing (2) demonstrated that biological treatment could effectively reduce the organic contamination present in the waste-pit liquid. However, because of the presence of metals, radionuclides, and other inorganics in the waste-pit liquid as reported during the RI (3), a pretreatment step was implemented before biological treatment to (1) remove metals, radionuclides, and other inorganics to meet potential effluent requirements and (2) to concentrate metals and radionuclides in a residual stream before biological treatment. Therefore, the treatment train evaluated during pilot-scale testing included gravity phase separation and lime-soda softening before the biological treatment step.

OBJECTIVES

The objective of this paper is to present the results of treatability testing conducted to evaluate the effectiveness of the overall process treatment train for treatment of waste-pit liquid from the Lowry Landfill Superfund site as well as the effectiveness of the selected physical and chemical treatment processes. The criteria that were used to evaluate effectiveness during the treatability study program are as follows:

- Removal of target organic analytes to yield acceptable concentrations in the final treated effluent
- Removal of inorganics, including calcium and magnesium, and radionuclides to prevent *potential interference* with the downstream biological processes

EXPERIMENTAL PROCEDURES

The waste-pit liquid samples that were used for treatability testing were collected from several waste-pit wells at the site. During waste-pit liquid sample collection, the waste-pit liquid was stored in 15-gallon, polyethylene U.S. Department of Transportation (DOT) containers and the container headspace was minimized.

In preparation for the gravity phase separation step, the waste-pit liquid samples from individual waste-pit wells were composited in a 1000-gallon tank and completely mixed. To effect gravity phase separation, the composited liquid was

TABLE I
Treatability Study Summary of Percent Removals Achieved for Analytes Detected in Waste-Pit Liquid

	Waste-Pit Liquid					
		Lime-Soda Softening		PACT® Biological Treatment		
Analyte	Gravity-phase Separation Effluent Concentration[a]	Effluent Concentration[b]	Percent Removal	Influent Concentration[c]	Effluent Concentration[d]	Percent Removal
Volatile Organic Compounds (μg/l)						
Vinyl chloride	481 D	348	28	120	<2.00	>98
Chloroethane	110	89.1	19	27.9	<5.00	>82
Methylene chloride	1860 D	1980	15	571	22.5 JB	96
Acetone	61,100 D	51,400	16	37,810	<3500	>95
Carbon disulfide	6.60 J	<10.0	-	<10.0	NA	-
1,1-Dichloroethene	18.0	16.4	9	<10.0	<7.00	-
1,1-Dichloroethane	3510 D	3000	15	845	<0.500	>99
1,2-Dichloroethene (total)	520	403	23	132	<70.0	>46
Methyl ethyl ketone	16,900 D	13,100	22	12,200	<1750 R	>85
Chloroform	56.1	44.3	21	11.3	<5.70	>49
1,2-Dichloroethane	27,200 D	22,500	17	11,200	<5.60	>99
1,1,1-Trichloroethane	551 D	428	22	120	<200	-
Trichloroethene	61.8	39.6	36	12.2	<5.00	-
Benzene	193	163	16	45.6	<5.00	-
4-Methyl-2-pentanone	2725 D	2110	23	1840	<2.00	>99
2-Hexanone	152	128	16	112	<2.00	>98
Tetrachloroethene	60.7	38.2	37	<10.0	<10.0	-
Toluene	9540 D	6550	31	1860	<2420	-
Chlorobenzene	86.7	59.2	32	18.3	<300	-
Ethylbenzene	138	99.9	27	22.1	<680	-
Total xylenes	722	545	25	136	<440	-
Semivolatile Organic Compounds (μg/l)						
Phenol	851 D	1200	-	1488	<1.0	>99
2,4-Dimethylphenol	176 D	130	26	<100	<1.0	-
bis(2-Ethylhexyl)phthalate	19.3 JB	<10	>48	<1.0	<1.0	-
2-Methylphenol	71.8 JB	50.7	29	<100	<1.0	-
4-Methylphenol	3750 JD	2730	27	2360	<1.0	>99
Pesticides/PCBs (μg/l)						
Heptachlor epoxide	0.09 JB	<0.05	-	<0.05	<0.03	-
Dieldrin	0.33 J	<0.10	-	<0.10	<0.05	-
4,4′-DDE	0.06 JB	0.02 JP	66	<0.10	<0.05	-
Endrin	0.18 J	<0.10	-	<0.10	<0.05	-
Arcolor 1260	4.4 J	4.4 JS	-	<1.00	<0.50	-
Herbicides (μg/l)						
2,4,5-TP	1.3 J	<0.10	>92	<0.10	<0.10	-
Metals (μg/l)						
Aluminum	1390 D	401	71	283	138	51
Antimony	5.00 J	<4.10 JB	>18	5.70	6.60	-
Arsenic	27.8	<10.0	>64	22.5	6.00	73
Barium	1010	392	61	351	515	-
Boron	10,700 JD	<8720 JB	>18	9710	11,200	-
Cadmium	0.86 J	<5.00	-	430	1.30	70
Calcium	224,000 D	<27,700 JB	>87	13,600	69,000	-
Chromium	52.3 J	58.2	-	40.1	29.1	27
Cobalt	18.5 J	15.1	>18	17.0	77.6	-
Copper	36.3 J	139	-	32.1	35.3	-
Metals (μg/l) (continued)						
Iron	48,700 D	1701	>96	1610	439	73
Lead	34.8	3.60 JB	89	7.0	2.90	58
Magnesium	211,000 D	61,000	71	83,700	71,500	14
Manganese	1260 JE	45.5	96	50.9	332	-
Nickel	260 J	196	24	237	287	-
Potassium	431,000 D	483,000	-	424,000	387,000	8.7
Silver	0.43 JS	<10.0	-	2.30	2.80	-
Sodium	5,760,000 D	7,030,000	-	6,940,000	6,980,000	-
Vanadium	11.9 J	35.1	-	23.0	9.10	60
Zinc	184 JS	61.2	66	68.3	306	-
Radionuclides (pCi/l)						
Gross beta	650±60 J	510±50	21	570±60	220±30	61
Tritium	980±130 J	1200±100	-	990±16	500±60	49
Potassium-40	406±48	<60	85	366±47	298±36	18

TABLE I

***Treatability* Study Summary of Percent Removals Achieved for Analytes Detected in Waste-Pit Liquid, Cont'd**

	Waste-Pit Liquid					
		Lime-Soda Softening		PACT® Biological Treatment		
Analyte	Gravity-phase Separation Effluent Concentration[a]	Effluent Concentration[b]	Percent Removal	Influent Concentration[c]	Effluent Concentration[d]	Percent Removal
Dioxins (pg/l)						
123678-HxCDD	93.9	<5.0	-	86.8 JB	<3.00	>96
123789-HxCDD	11.8	<6.6	>44	69.2 JB	<3.90	>94
1234678-HpCDD	2470 JB	<96.8 JB	>96	3010 JB	37.6 JB	98
OCDD	19,960 JB	<672 JB	>96	15,100 JB	<157 JB	>98
2378-TCDF	17.1 J	<3.7	>78	<5.80 JB	2.10	-
12378-PeCDF	9.0	<5.0	>44	2.80	<3.00	-
23478-PeCDF	6.8	<4.9	>28	<1.60	<3.00	-
123478-HxCDF	70.7	<4.6	>93	18.2	<2.80	>84
123678-HxCDF	9.8 JB	<3.5	>64	<3.50 JB	<2.10	-
234678-HxCDF	22.3	<4.9	>78	6.00 BJP	4.40	26
1234678-HpCDF	389	10.0 EMPC	97	19.3	<2.10	>89
1234789-HpCDF	56.7	<7.1	>87	<4.00	<4.00	-
OCDF	2300	40.0	98	38.9	<5.10	>86
Total PeCDD	28.4 JP	<6.9	>76	<237 JB	<4.50	-
Total HxCDD	383	9.7	97	<1030 JB	5.00 J	-
Total HpCDD	4550 JB	170 JB	96	<5910 JB	<64.6 JB	-
Total PeCDF	85.3 J	<5.0	>94	34.5	<3.00	>91
Total HxCDF	616	<10.4 JB	>98	74.6 JB	4.10	94
Total HpCDF	1860	39.9	98	89.4 JB	<2.80	>96
Inorganic Parameters (mg/l)						
Ammonia	595	675	-	1010	1.11	99
Boron	5.39	8.40	-	9.32	9.60	-
Fluoride	123	132	-	1120	<2.50	799
Sulfate	68.4 D	48.8	29	45.4	84.5	-
Chloride	7950	7930	0	7120	8090	-
Alkalinity (as $CaCO_3$)	4740 J	4740	0	5360	299	94
TOC	524	2150	-	1800	149	92
TOX	54.90 J	48.2	12	0.9	1.16	-
COD	6200	5800	6	6190	832	86
BOD	4080	3210	21	3350	105	97
TSS	420	254	40	202	182	10
TDS	19,200	20,100	-	25,300	20,300	20
Corrosivity	0.26	NR	-	0.096	1.32	-
pH	7.20	10.65	-	9.56	6.51	32
Specific conductance (μmhos/cm)	28,000	25,300	10	26,000	26,500	-
Oil and grease	81.1	64.7	20	145	1.47	99
Turbidity (NTU)	8.10	NR	-	31.5	6	81
TPH	162	161	1	4.7	3.0	36
TKN	683	610	11	488	8.6	98

[a]The sample designation for the data presented is GPS-APL.
[b]The sample designation for the data presented is LSS-APL.
[c]The sample designation for the data presented is BIO-APLA.
[d]The sample designation for the data presented is BIO-APLB.

- = Percent removal was negative or could not be calculated because the influent was less than the specified quantitation limit.
< = The analyte was not detected at or above the specified quantitation limit.
> = greater than
BOD = biochemical oxygen demand
$CaCO_3$ = calcium carbonate
COD = chemical oxygen demand
Data qualifiers
B = blank contamination
D = diluted sample
J = estimated value
mg/l = milligrams per liter
NTU = nephlometric turbidity units
PACT® = Powdered Activated Carbon Treatment
pCi/l = picocuries per liter
pg/l = picograms per liter
TDS = total dissolved solids
TKN = total Kjeldahl nitrogen
TOC = total organic carbon
TOX = total organic halogens
TPH = total petroleum hydrocarbons
TSS = total suspended solids
μg/l = micrograms per liter

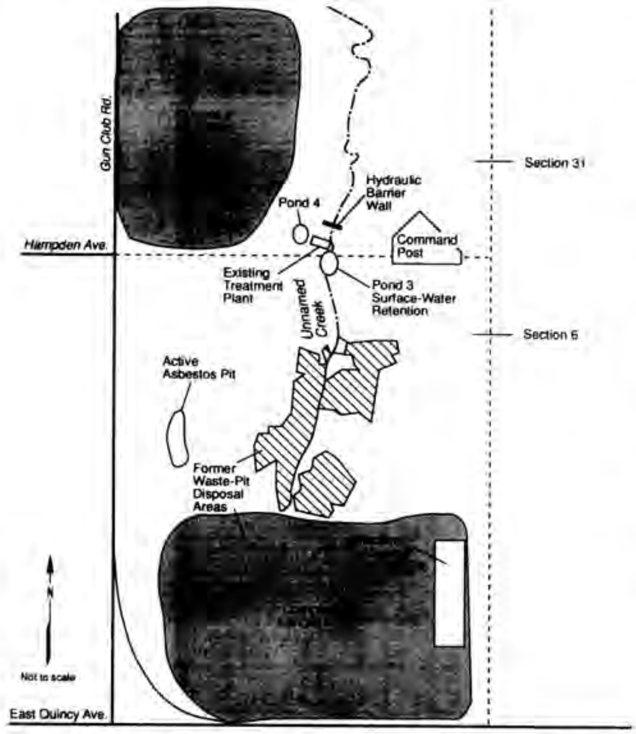

Fig. 1. Site map, Lowry Landfill, Arapahoe County, Colorado.

initially allowed to stand for approximately two to four hours. Samples of dense nonaqueous-phase liquid (DNAPL) and light nonaqueous-phase liquid (LNAPL) were then to be collected for subsequent characterization. However, because of the lack of observed DNAPL and LNAPL, the composited waste-pit liquid was allowed to stand for an additional 16 hours. The resulting aqueous-phase liquid was used for subsequent pilot-scale treatability testing.

Lime-soda softening treatment was evaluated for effectiveness in removing metals and hardness from the waste-pit liquid before biological treatment. The lime-soda softening tests were conducted using hydrated lime and soda ash. Based on previous treatability testing, an optimum pH of 11.2 was selected for the lime-soda softening process to obtain effluent calcium and magnesium concentrations between 30 and 100 mg/l (as calcium carbonate). Soda ash also was added to reduce the noncarbonate portion of the hardness. Several polymers were evaluated to select the polymer that provided the most improvement in the settling characteristics of the floc.

The PACT® biological treatment process was included in the treatment train to remove organics, including volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, herbicides, and dioxins.

A schematic flow diagram of the PACT® pilot-scale system is illustrated in Fig. 2. The PACT®® system operated in a continuous flow mode, treating approximately 9 gallons per week of the filtrate from hydroxide precipitation. A two-stage PACT® system was used during the 60-day study to 1) obtain improved removals of organics and 2) provide denitrification. The PACT® system was initially seeded with activated sludge from a municipal wastewater treatment plant, and powdered activated carbon (PAC) was added to the aeration tanks before feed flow was initiated. The system operated for 60 days at ambient temperature. Phosphorus and micronutrients, including cobalt, copper, and manganese, were added to the influent to the PACT® system during the entire study.

Based on the results of the process chemical analyses conducted during the first week of operation, *additional* nitrogen was not required because the ammonia nitrogen concentration in the feed was sufficient for microbial growth. The influent pH was adjusted twice daily to assure that a stable pH range for *nitrosomonas* and *nitrobacter* organisms was maintained for denitrification. Ten percent sulfuric acid was used to adjust the pH in each aeration tank. The target pH was between 7.8 and 8.2.

Mixed liquor was removed directly from each aeration basin daily to maintain the desired solids retention time (SRT). Virgin PAC was added to the second stage of the PACT®® system daily.

A granular media filter using silica sand was used after the second stage clarifier to further reduce the amount of solids in the effluent from the second stage clarifier. Alum and polymer were added to the second stage supernatant before media filtration to 1) coagulate colloidal solids and 2) improve solids removal performance by filtration.

Operation of the PACT® system included daily monitoring of feed and effluent volumes, solids wasting rate, mixed liquor pH, temperature, dissolved oxygen, and oxygen uptake rates. The mixed liquor microorganism population and yield were also evaluated. Samples of the influent, first- and second-stage effluents, filtered effluent, and mixed liquors were withdrawn several times per week and analyzed for various target parameters, including five-day BOD, COD, purgeable organic carbon, nonpurgeable organic carbon, suspended solids, total Kjeldahl nitrogen, ammonia nitrogen, nitrate nitrogen, and nitrite nitrogen.

Table II provides a summary of the operating conditions evaluated for each technology.

TABLE II

Summary of Process Operating Conditions for Pilot-scale Treatability Study Program

Process	Value
Gravity Phase Separation	
Reactor type	Batch
Sample volume	750 gallons
Detention time	16 hours
Lime-Soda Softening	
Reactor type	Batch
Sample volume	750 gallons
Lime added	26 pounds
Soda ash added	15 pounds
pH	11.2
Sludge generated	69 gallons
Sludge solids content (weight basis)	10 percent
Powdered Activated Carbon Treatment	
Reactor type	Continuously stirred tank reactor
Flow rate	35 liters/day
Number of stages	2

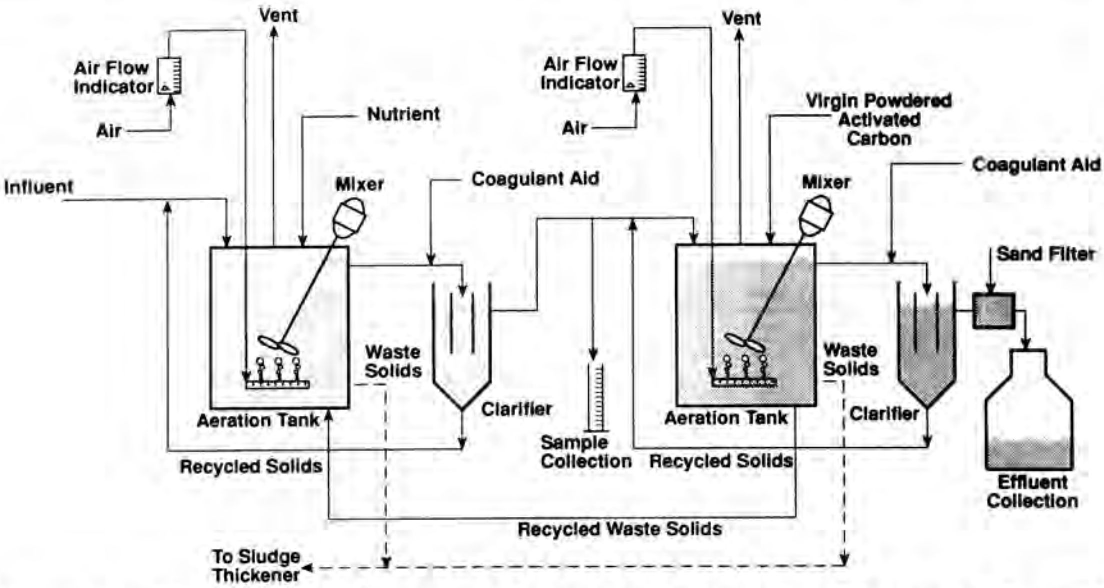

Fig. 2. Schematic flow diagram of PACT® two-stage pilot-scale system-Lowry Landfill, Arapahoe County, Colorado.

RESULTS AND DISCUSSION

This section presents the results of the pilot-scale testing program conducted for waste-pit liquid collected from the Lowry Landfill Superfund site. The results of the pilot scale testing program were evaluated to assess the effectiveness of the waste-pit liquid treatment train for removal of organics (VOCs, SVOCs, pesticides/PCBs, and herbicides), inorganics, and radionuclides. The effectiveness of the overall treatment train for the waste-pit liquid as well as the effectiveness of the individual physical and chemical unit treatment processes within the treatment train were evaluated by assessing the percent removals of target analytes using EPA Contract Laboratory Program (CLP) procedures (4, 5). During operation, process effectiveness was monitored using selected process indicator parameters.

Organics Removal

LNAPL and DNAPL were not observed during the gravity phase separation process. The resulting aqueous phase waste-pit liquid had a high organic content as quantified by BOD, COD, and total and TOC. As expected, the BOD, COD, and TOC concentrations were not significantly reduced by the lime-soda softening process. A significant amount of VOCs (ranging from 3 to greater than 74 percent depending on the analyte) were lost to volatilization on a mass basis during lime-soda softening indicating that a vapor phase treatment technology may be required to treat the offgas generated during this process.

The PACT® system effectively removed organic compounds from the lime-soda softened waste-pit liquid. A summary of the PACT® effluent detected analyte concentrations is presented in Table I. The percent reductions of BOD, COD, and TOC by the PACT® system were 97, 86, and 93 percent, respectively.

The PACT® system also effectively removed the target VOC and SVOC organic compounds. VOCs and SVOCs detected in the influent waste-pit liquid to PACT® were reduced to detection limits with the exception of bis(2-ethylhexyl)phthalate, which was reduced to .15 μg/l. The mass of VOCs lost in the offgas during PACT® treatment accounted for less than 20 percent of the total mass of VOCs treated by the PACT® system.

Inorganics Removal

The concentrations of several metals and inorganics present in the influent waste-pit liquid, including calcium, lead, iron, and manganese were reduced more than 80 percent by the lime-soda softening process. However, sodium increased as the result of the addition of soda ash. The metals including chloride, copper, potassium, and vanadium were not reduced by the lime-soda softening process. TDS, total suspended solids (TSS), ammonia, and alkalinity (as $CACO_3$) removals were 10, 43, 52, and 94 percent, respectively.

The concentrations of inorganics in the PACT® influent and effluent streams were analyzed during the pilot scale testing program. In general, the PACT® process is not designed for removal of metals from contaminated water; however, the concentrations of some metals including aluminum, arsenic, lead, and silver decreased during the PACT® treatment. Other metals such as manganese and cobalt increased in concentration. These increases probably resulted from the micronutrient addition of metals to the PACT® influent.

Reductions in other inorganic parameters include ammonia (99 percent), (TSS) (10 percent), and TDS (20 percent). Concentrations of nitrate and nitrite increased during PACT® treatment as the result of nitrification and the addition of nitric acid for pH control.

Radionuclide Removal

Removal of individual radionuclides from the waste-pit liquid was inconclusive because of analytical variability. Gross alpha was not detected in either the influent or effluent waste-pit liquid. Gross beta was reduced by 66 percent through PACT® treatment.

CONCLUSIONS

The removal of metals, radionuclides, and organic compounds from waste-pit liquid collected from the Lowry Landfill Superfund site was evaluated using physical, chemical, and biological treatment technologies. Conclusions from this evaluation are as follows:

- Distinct separate phases were not observed in effluent from the phase separation process. Therefore, it is unlikely that a phase separation step will be needed in a full-scale treatment system for waste-pit liquid.
- The pilot-scale testing demonstrated that the lime-soda softening process is an effective pretreatment step before biological treatment because it will: 1) reduce hardness that can cause scaling in process equipment and piping, 2) reduce the concentrations of metals that can be toxic to biological treatment systems (e.g., aluminum, zinc), and 3) reduce TSS.
- The PACT® system generally reduced waste-pit liquid concentrations of VOCs and SVOCs to analytical detection limits indicating that the PACT® system would be an effective full-scale treatment process for removal of organics. The PACT® system did not effectively remove TSS indicating that a polishing step such as rapid sand filtration may be required for removal of TSS. Ammonia was also effectively reduced during PACT® treatment; however, nitrate and nitrite increased indicating that adjustments to the PACT® system or a denitrification step may be necessary.
- The treatment train used during this pilot-scale testing program was effective in removing organic and inorganic contaminants to *acceptable levels*.

REFERENCES

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