Cost and Performance Summary Report
Thermal Desorption at the Sand Creek Industrial Superfund Site, OU 5
Commerce City, Colorado

Summary Information [1, 2, 4, 7, 10, 11]

The Sand Creek Industrial Superfund Site (Sand Creek), located in Commerce City, Colorado (a suburb of Denver), is a former industrial property that was used for the manufacture of agricultural chemicals, the production of petroleum, and the storage and distribution of chemicals. The Colorado Organic Chemical (COC) Company manufactured pesticides and insecticides at the site in the 1960s and 1970s. During this time, improper storage of pesticides, as well as fires at the site in 1968 and 1977, resulted in contamination of soil and groundwater. During the 1970s and 1980s, several administrative and enforcement actions were taken by the State of Colorado and EPA. COC removed portions of contaminated soil from the site in 1978 and removed drummed waste, excess product, and additional contaminated soil in 1984. The site was placed on the National Priorities List in September 1983. Several site investigations were conducted in the 1980s, including a remedial investigation (RI) in 1988, and a feasibility study (FS) in 1989.

Sand Creek was divided into six operable units for remediation. This report focuses on Operable Unit 5 (OU 5). OU 5 covered approximately 17 acres and consisted of shallow surface soils (1-5 feet below grade) contaminated with pesticides and heavy metals.

A Record of Decision (ROD), signed in September 1990, selected soil washing to remediate 14,000 cubic yards (yd^3) of soil at an estimated cost of $5 million. The volume of soil requiring remediation, as specified in the ROD, was based on the results of 17 soil samples taken at the site.

In 1992, a pilot-scale soil washing treatability study revealed that a more accurate cost of remediation using soil washing was $13 million. It was further determined that soil washing would not meet the action levels for dieldrin and heptachlor, two of the pesticides at this site. As a result of this study, more extensive sampling was conducted in 1992 and 1993 as part of the remedial design (RD) to better characterize the extent of the contamination at OU 5.

The samples were taken in two areas of OU 5: 1) the railroad area, and 2) the pesticide production/storage area. Phase 1 sampling (July 1992) included 11 samples collected to determine the range of pesticide contamination across the site. Phase 2 sampling, an evaluation of field soil immunoassay tests, was canceled due to lack of available test kits. Phase 3 sampling (November 1992) included the analysis of 332 samples out of approximately 500 collected from three soil depths. A statistical strategy called the "decision tree" methodology was used, which eliminated the need for analysis of 159 samples. (For more information on Phase 3 sampling activities/strategies, refer to reference #11.)

The results of Phase 3 sampling, presented in Table 2, showed pesticide concentrations as high as 419 milligrams per kilogram (mg/kg) for toxaphene, and metals as high as 131 mg/kg for arsenic. Maximum concentrations for DDD and DDT were 28.8 mg/kg and 184 mg/kg, respectively.

The ROD was amended in September 1993 to change the remedy to on-site low temperature thermal desorption (LTTD). The cost estimate in the amended ROD for cleanup using LTTD was $5.4 million. LTTD system operations were conducted from June 28 - July 29, 1994. A total of 8,254 yd^3 (approximately 13,000 tons) of soil were treated during this application.

CERCLIS ID Number:	COD980717953
Lead:	Federal Lead/Fund-Financed

Timeline [2, 4]

September 28, 1990	ROD for OU 5 issued, selecting soil washing as the remedy
July - November 1992	Phase 1 & 3 RD soil sampling conducted
September 8, 1993	Amendment to 1990 ROD issued, changing selected remedy to on-site low temperature thermal desorption
March 25, 1994	Pilot-scale treatment tests conducted

June 15 - June 20, 1994	Full-scale performance demonstration conducted (assess mechanical and thermal operations; demonstrate removal of pesticides to below soil action levels)
June 28 - July 29, 1994	Full-time system operation (24 hours per day, 5 days per week) with ongoing soil confirmation sampling
August 19 - September 14, 1994	System decontamination & demobilization, backfilling activities, regrading and revegetation completed

Factors That Affected Cost or Performance of Treatment [2, 3, 12]

The OU 5 site lies within the Sand Creek flood plain where surficial soils consist of alluvial deposits ranging in thickness from less than 30 feet to approximately 90 feet. The deposits are unconsolidated and consist primarily of interbedded gravel, sand, silt, clay with minor amounts of cobbles, and pebbles. Permeability in the sand and gravel components is generally high.

Listed below are the key matrix characteristics that affected the cost or performance of this technology.

Matrix Characteristics

Parameter	Value
Soil Classification:	Sandy loam
Clay Content and/or Particle Size Distribution:	Approximately 35% clay
Moisture Content:	Not available
pH:	7-10
Total Petroleum Hydrocarbons:	Not available

Geotechnical testing (including particle size analysis and moisture content) was performed by ATEC Associates, Inc.; however, detailed testing results were not provided.

Treatment Technology Description [1, 4, 6, 10, 11, 12]

The RUST/Triton LTTD system used at OU 5 consisted of a rotary kiln, a burner with a maximum firing rate of 400 million British Thermal Units (BTU)/hour, two sulfur-impregnated vapor-phase carbon units (20,000 pounds (lb) each) in parallel, four liquid-phase carbon units (1,000 lb each), cyclones, a baghouse, and a packed bed scrubber.

Prior to operation, a full-scale performance demonstration was conducted using clean soil from an off-site location and contaminated soil from OU 5. The results of the performance test were used to establish parameters for full-scale operation, which began on June 28, 1994.

Contaminated soil from a stockpile was passed through a bar screen to remove oversize particles. The screened soil was then fed into the rotary kiln and heated to 500°F for 6.5 minutes by a hot air stream drawn through the kiln. Off-gases were treated using cyclones and a baghouse to remove particulates and a scrubber to treat acid gases. The off-gases were then passed through vapor-phase carbon units prior to discharge to the atmosphere. The liquid stream was passed through liquid-phase carbon units, then sent to a pugmill where it was mixed with treated soil to reduce fugitive emissions.

Particulates from the cyclones and baghouses were collected and mixed with the treated soil. The spent vapor-phase carbon units were shipped off site for destruction.

Operations were conducted 24 hours per day, 5 days per week, except during maintenance periods.

Listed below are the key operating parameters that affected the cost or performance of this technology and the values measured for each.

Operating Parameters

Parameter	Value
Residence Time:	6.5 minutes
System Throughput:	35-40 tons/hour
Soil Temperature:	500°F

Performance Information [1, 4, 5, 9, 12, 13]

The ROD identified the following action levels for soil and stack gas emissions:

Table 1. Soil & Stack Gas Emission Action Levels [1, 9]

Contaminant	Soil Action Level (mg/kg)	Stack Gas Emission Action Level (mg/m^3)*
Aldrin	1.45	0.006
α-BHC	3.91	0.0119
β-BHC	13.7	0.0119
γ-BHC	18.9	0.0119
Chlordane	18.9	0.0019
DDD	104	0.0238
DDE	73.2	0.0238
DDT	72.4	0.0238
Dieldrin	1.54	0.006
Heptachlor	5.47	0.0019
Heptachlor E	2.71	0.0119
Toxaphene	22.4	0.0119
Arsenic	12.7	0.0048
Chromium	56.2	0.0012

* Action level = threshold limit value/42

Excluding chromium, the soil action levels presented in Table 1 were developed based on an evaluation of risk to public health using carcinogenic effects. These effects were assessed using the cancer potency factors developed by EPA, a cancer risk of less than 1×10^{-5}, and a residential land use scenario. The action level for chromium was assessed using the hazard index approach based on a comparison of a non-carcinogenic oral reference dose (RfD) and a non-carcinogenic health-based concentration (HBC) of approximately 5,319 mg/kg, and using a hazard index of less than 1.

Contaminated soil was treated on a batch basis, with each batch containing approximately 100 yd^3. At least one confirmation sample was taken from each batch to test for compliance with action levels.

The results of confirmation sampling (June 28 - July 29, 1994), presented in Table 3, showed that the action levels for pesticides and chromium were achieved. Only two soil batches did not achieve action levels for pesticides (specific pesticides not identified) after a single pass through the treatment unit. These batches were retreated and met the action levels for these contaminants. According to EPA, the LTTD system at OU 5 had a 99% removal efficiency for pesticides.

The average arsenic concentration for all confirmation samples was 25 mg/kg, with concentrations ranging from ND to 55 mg/kg. Arsenic levels in treated soil batches exceeded the residential land use action level of 12.7 mg/kg in the majority of samples (75 of 89). During treatment, EPA determined that the residential land use action level for arsenic could not be met using the LTTD system at OU 5.

Based on an evaluation of the health risks posed by arsenic at this site, EPA decided that an industrial land use action level of 25 mg/kg could be used instead of the residential land use action level. According to EPA, the evaluation included a few "hot spot" locations in excess of the industrial action level and analyses of exposure to both a child trespasser and an on-site industrial worker. EPA permitted the backfilling of all treated soil batches on site as long as the arsenic concentration of all surface soils (0-1 ft bgs) was below the 25 mg/kg industrial land use action level. Therefore, treated soil batches with arsenic concentrations exceeding 25 mg/kg were backfilled in the 1-5 ft depth range of the excavation.

Although chromium is generally considered to be a non-volatile metal, concentrations of chromium in the soil were reduced to below action levels following treatment in the LTTD unit. According to EPA, this was due, in part, to blending of soils with higher and lower chromium concentrations during the treatment process.

Stack gas emissions from the LTTD system were periodically monitored for pesticides and other compounds. Initial stack tests were conducted during the performance demonstration from June 16 - June 20, 1994, to verify that emissions were below action levels. According to EPA's ARCS contractor, URS Consultants, Inc. (URS), greater than 99% removal of pesticides from the LTTD stack gas was demonstrated by the emissions testing, and emissions were below action levels.

In a change order issued to the RA subcontractor, Rust Remedial Services, Inc., the scope of the RA subcontract was modified to include the removal of approximately 2,000 yd^3 of hydrocarbon-contaminated soil visible in the southeast corner of OU 5. The surface contamination was excavated in August 1994 and disposed at a Subtitle D landfill. The excavated area was backfilled with treated soil from the LTTD process.

Performance Data Quality [4]

Soil samples were analyzed by Core Laboratories for Rust Remedial Services, Inc. using EPA-approved methods. EPA analyzed split samples on a frequency of 10% for pesticides and 5% for metals as an independent QA check for the analysis of confirmation soil samples. URS stated that results for the split sample analyses were substantially consistent with results from primary analyses of confirmation soil samples.

Table 2. Phase 3 Sampling Data [1]

Contaminant	Number of Samples Analyzed				Soil Action Level (mg/kg)	Maximum Soil Concentration (mg/kg)				Average Soil Concentration (mg/kg)			
	Pesticide Production/ Storage Area			Railroad Area		Pesticide Production/ Storage Area			Railroad Area	Pesticide Production/ Storage Area			Railroad Area
	0-1' bgs	1-3' bgs	3-5' bgs	0-1' bgs		0-1' bgs	1-3' bgs	3-5' bgs	0-1' bgs	0-1' bgs	1-3' bgs	3-5' bgs	0-1' bgs
Aldrin	11	12	8	3	1.45	6.64	73.7	4.28	0.87	0.40	1.87	0.47	0.28
α-BHC	6	11	4	4	3.91	0.27	58.0	17.9	0.48	0.25	1.66	1.06	0.26
β-BHC	14	15	7	6	13.7	0.37	11.9	32.3	1.10	0.26	0.55	0.39	0.27
Chlordane	44	35	20	37	18.9	55.0	139	213	12.4	4.55	4.63	1.74	1.74
DDD	42	32	22	29	104	5.76	5.46	28.8	2.61	1.55	0.92	1.25	1.12
DDT	45	44	27	41	72.4	65.7	184	21.7	20.1	10.4	9.35	2.99	3.59
Dieldrin	45	40	20	36	1.54	110	46.7	24.5	38.4	4.29	2.39	2.19	1.42
Heptachlor	29	32	15	16	5.47	84.8	249	364	9.75	3.81	8.75	11.3	0.38
Heptachlor E	22	9	5	5	2.71	4.21	13.4	1.66	2.40	0.50	0.76	0.33	0.37
Toxaphene	26	26	6	28	22.4	419	134	26.2	144	17.8	11.0	2.55	13.7
Arsenic	24	22	22	48	12.7	131	58.1	20.4	83.7	16.3	5.50	3.10	8.60
Chromium	24	22	22	48	56.2	37.5	20.9	48.9	118	12.8	10.7	12.1	14.8

Table 3. Treatment Performance Data [4, 5]

Contaminant	Number of Samples Analyzed	Number of Samples Below Action Level	Soil Action Level (mg/kg)	Soil Concentrations After Treatment (mg/kg)		
				Average*	Median*	Range
4,4'-DDE	179	179	73.2	6.8	5.6	2.6 - 15
α-chlordane	96	96	18.9[a]	0.53	ND	ND - 3.9
γ-chlordane	104	104	18.9[a]	1.3	0.5	ND - 13
All other pesticides[1]	79	77[b]	NA	ND[c]	ND[c]	ND[c]
Arsenic	89	14	12.7	25	24	ND - 55
Chromium	89	89	56.2	10	10	5 - 55

[1] = Includes aldrin, α-BHC, β-BHC, γ-BHC, DDD, DDT, dieldrin, heptachlor, heptachlor E and toxaphene.
[a] = Action level for chlordane is for total chlordane.
[b] = The two treated soil batches that were sampled and determined to exceed action levels were retreated in order to achieve compliance.
[c] = Result for all other pesticides[1] was ND for all samples except: Aldrin = 0.48, 0.38; α-BHC = 0.29;γ-BHC = 1.3; DDT = 0.65, 0.80.
** = Value of zero was used in calculating average and mean values where result was below detection or quantitation limit.*
NA = Not applicable.
ND = Result below detection limit (detection limits not provided).
Note: Some pesticide sample results are estimates because concentrations exceeded the calibration range of the instrument used. Other results are estimates because compounds were determined to be present based on mass spectral data but at lower concentrations than the practical quantitation limit of the method. Core Laboratories indicated that data in this table should be used with caution as some have not been verified under QA/QC procedures.
With a few exceptions, results for all other pesticides[1] was ND for all samples. Because of this, only contaminants with detectable concentrations are presented in this table.

Cost Information [8]

Actual cost data was provided by EPA for this application, as shown below in Table 4. The total cost of $1,995,481 (capital + O&M) corresponds to a unit cost of $230 per cubic yard for 8,254 yd^3 of soil treated, or $150 per ton for approximately 13,000 tons of soil treated.

Table 4. Actual Project Costs ($ in 1995)

Type of Cost	Technology Cost	Cost for Calculating Unit Cost
1. Capital		
Technology, mobilization, setup, and demobilization	Included with equipment and appurtenances	
Planning and preparation	65,720	
Site work	Included with equipment and appurtenances	
Equipment and appurtenances - LTTD pool subcontract	1,738,617	
Startup and testing	Included with equipment and appurtenances	
Total capital costs		1,804,337
2. Operation and Maintenance		
Labor	191,144	
Materials	Included with capital costs	
Utilities and fuel	Included with capital costs	
Equipment ownership, rental, or lease	0	
Performance testing and analysis	Included with capital costs	
Other	0	
Total operation and maintenance costs		191,144
3. Other Technology-specific Costs		
Compliance testing and analysis	44,542	
Soil, sludge, and debris excavation collection and control	85,019	
Disposal of residues	22,351	
4. Other Project Costs	0	
Total technology cost	2,147,393	
Total cost for calculating unit cost		1,995,481
Quantity treated		8,254 cubic yards soil (approximately 13,000 tons)
Calculated unit cost		$230 per cubic yard of soil treated ($150/ton)

Observations and Lessons Learned [4, 11, 12]

In less than five weeks, the LTTD system at OU 5 treated approximately 8,000 yd^3 (13,000 tons) of soil contaminated with pesticides and chromium to below action levels.

The action level of 12.7 mg/kg for arsenic was not achieved in most treated soil batches. EPA established an industrial land use action level of 25 mg/kg for arsenic at OU 5 and approved backfilling of all treated soil batches as long as the surface soils (0-1 ft bgs) were below the industrial action level.

According to the RPM:

- Use of the "decision tree" methodology as a sampling strategy during Phase 3 sampling eliminated the need for analysis of 159 samples, which resulted in a cost savings of approximately $330,000. EPA stated that this methodology can be readily applied at other sites where substantial sampling appears necessary.

- The additional field sampling at OU 5 in 1992 and 1993 better characterized the extent of contamination, reduced the volume of soil requiring remediation by 25%, and reduced the time and cost of treatment.

- The total project cost of $2,147,393 was less than half of the cost estimate in the amended OU 5 ROD. The lower actual cost was due, in part, to the high level of competition for the RA subcontract.

According to the vendor, costs were also lower than expected because of several reductions in the scope of work and because certain services contemplated in the RA subcontract were determined not to be necessary. For example, soil stabilization was not needed, resulting in a reduction in cost of approximately $146,000. Also, the volume of soil requiring excavation and treatment was reduced by approximately 15% due to the presence of subsurface concrete monoliths and other debris.

The vendor reported finding elevated concentrations of mercury in the spent activated carbon that had been used to treat both liquid- and vapor-phase streams in the LTTD system. Mercury in the excavated soil would be expected to desorb from the soil during LTTD treatment, resulting in elevated concentrations in spent activated carbon. However, no previous occurrences of mercury contamination in soils were documented at the OU 5 site.

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Acknowledgments

This report was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Tetra Tech EM Inc. under EPA Contract No. 68-W-99-003.