United States Environmental Protection Agency
Research and Development

Risk Reduction Engineering Laboratory
Cincinnati OH 45268

EPA/600/S2-91/058 May 1992

EPA

Project Summary

Pilot-Scale Incineration of Contaminated Soil from the Purity Oil Sales and McColl Superfund Sites

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An incineration test program was conducted at the U.S. Environmental Protection Agency's (EPA) Incineration Research Facility (IRF) to evaluate the potential of incineration as an option to treat contaminated soils at the Purity Oil Sales Superfund site in Fresno, CA, and the McColl Superfund site in Fullerton, CA. The soils at these sites are contaminated with up to several percent levels of sulfur and, to a lesser extent, with hazardous organic constituents. In addition, the Purity soils are contaminated with lead. The purpose of these tests was to evaluate the incinerability of these soils in terms of the destruction of organic contaminants and, for the Purity soils, the fate of lead during the incineration process. Three Purity soils, with lead concentrations ranging from 760 to 10,200 mg/kg and two McColl site materials were tested in a pilot-scale rotary kiln incineration system with a single-stage ionizing wet scrubber for particulate and acid gas control. Incineration conditions were nominally the same for all tests with kiln and afterburner temperatures at approximately 871°C and 982°C, respectively.

Test results suggest that incineration would be an acceptable treatment option for the McColl soils. In these tests, organic contaminant destruction was effective, particulate emissions were below the federal hazardous waste incinerator performance standard, and SO_2/SO_3 emissions were low.

Incineration could be considered applicable to the treatment of the Purity soils based on effective organic decontamination, acceptable (in meeting federal standards) particulate emissions, and low SO_2/SO_3 emissions. These test results, however, suggest that the resulting kiln ash would be a "characteristic" hazardous waste that would require further treatment to stabilize or remove leachable lead levels before redeposition at the site. Furthermore, if a wet scrubber of the type in place for these tests is used for air pollution control, the acceptability of lead air emission levels would need to be evaluated and the scrubber blowdown could also be a characteristic hazardous waste for the highly lead-contaminated soil areas.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

One of the primary missions of the IRF is to support EPA's Regional offices in evaluating the potential of incineration as a treatment option for wastes resulting from remedial actions taken at Superfund sites. Several types of hazardous wastes exist at two priority sites in Region 9. EPA Region 9 requested test burns at the IRF of five contaminated soils from these sites to support evaluations of the suitability of incineration as a treatment technology for these wastes.

The Purity site is an abandoned oil- recycling facility. The results of a soil stratigraphy investigation of the site indicated that four contaminated subsurface layers are present in the waste pit area at the site. The top layer is primarily composed of construction rubble, sand, and gravel. The second layer, tar sludge, underlies the construction debris and is mixed, to some extent, with soil and rubble. The third layer is composed of contaminated silty sand. The fourth layer is uncontaminated-to-slightly-contaminated silty sand. The materials tested in this program were from the first (A layer), second (B layer), and third (C layer) subsurface layers. The materials are contaminated to varying degrees with organic contaminants and lead. Concentrations of both are highest in the B layer.

The McColl site is an abandoned refinery waste disposal area. The major soil contaminants here are organic constituents and sulfur. The soil borings excavated from the site during the remedial investigation/feasibility study efforts were stored in drums at the site. The physical characteristics of the materials do not vary significantly from drum to drum. Two drums, one containing a high-sulfur-content material and a second containing a low-sulfur-content material, were selected for testing in this test program.

The overall objective of the test program was to determine whether treatment by incineration would result in a treated soil residue suitable for redepositing at each site during full-scale remediation. Specific technical objectives were as follows:

- to determine the distribution of lead present in the Purity soils among the incinerator discharges,
- to determine the concentrations of semivolatile organic hazardous constituent contaminants in the flue gas emission and incineration residuals to verify the suitability of incineration for treating the materials,
- to evaluate the effectiveness of the ionizing wet scrubber air pollution control system (APCS) for removing lead (Purity site), SO_2 and SO_3, and
- to demonstrate compliance with the federal hazardous waste incinerator performance standards for particulate emissions.

The tests were completed during January and February 1990. An outline of the test program and test results are given in the following sections.

Test Program

The test program consisted of five tests, one each with the three Purity soils and the two McColl soils. All tests were performed in the rotary kiln system (RKS) at the IRF with a single-stage ionizing wet scrubber APCS. A schematic of the RKS is given in Figure 1, and the design characteristics of the system are given in Table 1.

Soil was shipped to the IRF in 55-gal drums, 200 kg (440 lb) of each material was nominally shipped. Before testing, each drum of soil was packaged into 1.5-gal fiberpack containers at the IRF for feeding to the RKS via the ram feeder system. The fiberpack drums were nominally filled with 4.1 kg (9 lb) of test material. During the tests, the material was fed to the kiln at a rate of 12 fiberpack drums per hr (1 drum every 5 min). Thus, test material feedrate was about 49 kg/hr (108 lb/hr). All tests lasted about 4 hr, and each set of incinerator operating conditions was similar. These conditions are listed in Table 2. The kiln rotation speed, noted in Table 2, corresponds to a solids residence time in the kiln of about 1 hr.

Figure 2 identifies the sampling location for the tests and summarizes the sampling protocols employed.

Test Results

Throughout the test program, CO levels at the scrubber exit and the stack were, at most, a few parts per million. Total unburned hydrocarbon levels were similarly low at the afterburner and scrubber exits and in the stack. Average NO_x concentrations at the stack ranged from 20 to 38 ppm, levels typical for the RKS. Average SO_2 levels, measured with the use of a continuous SO_2 emission monitor, at the stack, were <1 ppm for the Purity site soil tests, and 4 to 7 ppm for the McColl site sulfur-contaminated soil tests.

Flue gas particulate levels at the scrubber exit (corrected to 7% O_2) ranged from 6 mg/dscm for the Purity C layer material test to 126 mg/dscm for the McColl high-sulfur-material test. In the stack, after the flue gas passed through with a secondary APCS consisting of a carbon bed absorber and a high-efficiency particulate air (HEPA) filter, particulate levels ranged from 7 mg/dscm for the Purity C layer material test to about 70 mg/dscm for both the Purity B layer and McColl high-sulfur-material tests. All levels fell well below the federal hazardous-waste incinerator performance standard of 180 mg/dscm.

Table 3 summarizes the ultimate analysis data for the soil samples from each test drum. Table 3 also shows the carbon content of the kiln ash resulting from the incineration of each test soil. The data suggest that incineration was quite effective in destroying the overall organic content (as indicated by total carbon content) of the Purity site A and C layer soils. The kiln ash resulting from the incineration of the Purity B layer soil and the McColl site soils, however, still had significant carbon content.

Table 4 summarizes the results of the semivolatile organic hazardous constituent analysis for each soil. As shown, of the semivolatile organic hazardous constituents, naphthalene was found in four of the five soils, and bis-(2-ethylhexyl)-phthalate was found in three of the five. Kiln ash from all tests contained no detectable semivolatile constituents at detection limits of 1 to 2 mg/kg, and the scrubber blowdown contained no detectable semivolatile constituents at detection limits of 0.02 to 0.04 mg/L. Semivolatiles were specifically not detected in the McColl soil kiln ashes despite their significant residual carbon content. Evidently the kiln ash carbon content consisted of fixed carbon or organic compounds not classified as semivolatile hazardous constituents. Kiln ash and scrubber blowdown leachate samples from the toxicity characteristic leaching procedure (TCLP) contained no detectable semivolatiles at detection limits of 0.02 to 0.04 mg/L.

Scrubber exit and stack flue gas concentrations of semivolatile organic constituents were at less-than-detectable limits of 4 to 12 µg/dscm except bis-(2-ethylhexyl)-phthalate. The phthalate concentrations of 8 to 80 µg/dscm for these tests are ascribed to commonly encountered laboratory contamination by this compound.

Test results with respect to lead distributions for the Purity soil are summarized in Table 5. The table shows lead concentrations measured in each sample of soil feed analyzed: kiln ash, scrubber blowdown, flue gas, and the extraction procedure (EP) toxicity and TCLP leachate for soil feed, kiln ash and scrubber blowdown. Table 5 also shows the corresponding lead feedrates and residual stream discharge rates for each test.

As shown in Table 5, lead concentrations in resulting kiln ash from the incineration treatment of all soils were all roughly twice the parent soil concentrations. This results in part from the volume reduction of the material during incineration and in part from mass balances achieved.

The toxicity characteristic (TC) threshold concentration for lead is 5 mg/L. Thus, no Purity soil would be considered a characteristic hazardous waste for lead based on the EP toxicity test, but all three would be considered so based on the TCLP test. (The EP toxicity test has been replaced by TCLP).

Despite the fact that the kiln ash resulting from the incineration treatment of the Purity soils contained roughly twice the lead concentrations of the parent soil, their EP toxicity leachate concentrations were lower. TCLP leachate lead concentrations for the kiln ash of all three soils were significantly greater than corresponding EP toxicity leachate concentrations and greater than the parent soil TCLP leachate concentrations for two of the three Purity soils. As was the case with the soils, these tests suggest that the kiln ash resulting from incineration

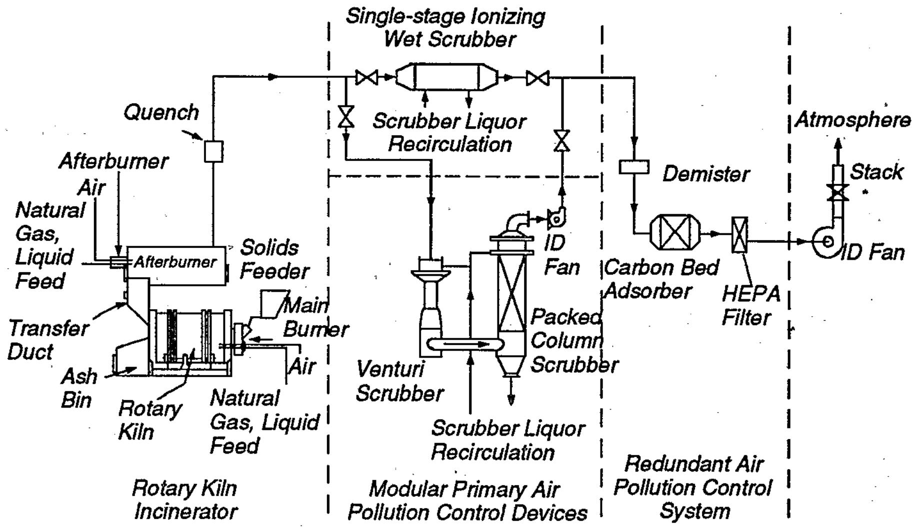


Figure 1. *Schematic of the IRF rotary kiln incinerator system.*

treatment of the soils would not be considered a characteristic hazardous waste for lead based on the EP toxicity test, but the ash would be considered so, and thus banned from landfill disposal without further treatment, based on the TCLP test.

Both the EP toxicity and TCLP leachate lead concentrations of the scrubber blowdown from all three Purity soils were comparable and were lower than the parent scrubber blowdown concentration. For the Purity materials, scrubber blowdown EP toxicity and TCLP leachate concentrations were half or less than half of the concentrations of the parent blowdown sample. This is understandable. Both the EP toxicity and TCLP methods for liquid samples specify filtering the blowdown sample, then weighing the solid residue. If the solid residue accounts for less than 0.5% of the original blowdown sample (as was the case for these tests), the solid residue is discarded and the resulting filtrate is defined to be the corresponding leachate. The fact that scrubber blowdown EP toxicity and TCLP leachate concentrations were similar for all Purity materials is to be expected, therefore, since the procedures result in analyzing essentially the same sample (scrubber blowdown filtrate). The fact that leachate (i.e., filtrate) samples contained less lead than the unfiltered blowdown sample merely confirms that some of the blowdown lead was contained as insoluble lead in the blowdown suspended soils (i.e., collected particulate) fraction.

Table 6 summarizes the lead discharge distributions measured in each Purity Oil Sales site soil test on a percent of feed basis. Entries in Table 6 correspond to the fraction (in percent) of lead fed that is accounted for by each of the incineration system discharge streams: kiln ash, scrubber liquor, and scrubber exit flue gas. These fractions were calculated from the measured lead concentrations in the analyzed samples of Table 5 and the appropriate stream flowrate (i.e., soil feedrate, flue gas flowrate, and kiln ash discharge rate). Also shown in Table 6 is the total ash fraction for each test. This represents the ratio of the total weight of kiln ash discharged in a test to the total weight of soil fed (expressed as a percentage). The ash fractions measured from the RKS generally compare favorably with the ultimate analysis results for soil feed samples noted in Table 3.

The data in Table 6 show that total closure for the Purity tests was 126% to 169%. This level of closure for lead is considered acceptable when viewed in light of past experience in achieving trace metal mass balance closure from a variety of combustion sources, incinerators included. Typical mass balance closure results from this past experience have been in the 30% to 200% range.

Conclusions

Test results include:

- The semivolatile organic contaminants in all five test soils were effectively destroyed based on the analytical methods used to measure contaminant concentrations. Semivolatile organic constituents were not detected in the kiln ash, scrubber blowdown, or flue gas resulting from the incineration of any of the five tested contaminated soils, with the exception of bis-(2-ethylhexyl)-phthalate (a common laboratory contaminant) in flue gas samples.
- Particulate emissions at the exit of the single-stage ionizing wet scrubber employed for particulate and acid gas control ranged from 6 to 126 mg/dscm (at 7% O_2). All measured levels were below the federal hazardous waste incinerator performance standard of 180 mg/dscm (at 7% O_2).
- For the Purity Oil Sales site soil tests, kiln ash lead concentrations were roughly double that of the parent soil concentrations. Scrubber blowdown lead concentrations were about 3 mg/L for the two low-lead-concentration Purity soils (on the order of 800 mg/kg lead contamination). Scrubber exit flue gas concentrations were 1 to 1.6 mg/dscm for these soils. For the high-lead-concentration Purity soil (10,200 mg/

Table 1. Design Characteristics of the IRF Rotary Kiln System

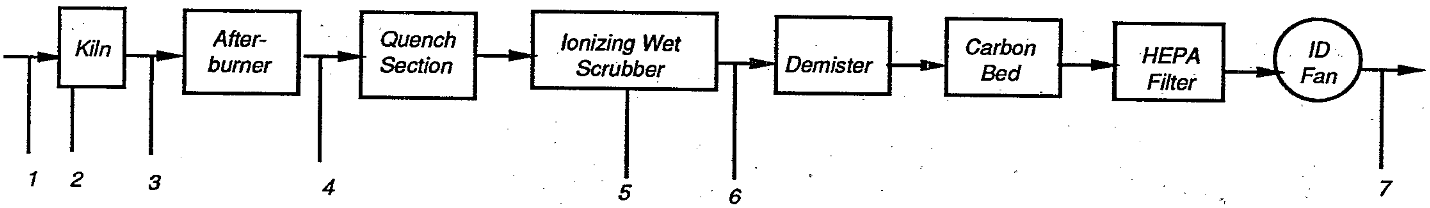
Characteristics of the Kiln Main Chamber	
Length	*2.49 m (8 ft-2 in)*
Diameter, outside	*1.37 m (4 ft-6 in)*
Diameter, inside	*Nominal 1.00 m (3 ft-3.5 in)*
Chamber volume	*1.90 m³ (67.3 ft³)*
Construction	*0.95 cm (0.375 in) thick cold-rolled steel*
Refractory	*18.7 cm (7.375 in) thick high alumina castable refractory, variable depth to produce a frustroconical effect for moving solids*
Rotation	*Clockwise or counterclockwise, 0.2 to 1.5 rpm*
Solids retention time	*1 hr (at 0.2 rpm)*
Burner	*North American burner rated at 800 kW (2.7 MMBtu/hr) with liquid feed capability*
Primary fuel	*Natural gas*
Feed system:	
Liquids	*Positive displacement pump via water-cooled lance*
Sludges	*Moyno pump via front face, water-cooled lance*
Solids	*Metered twin-auger screw feeder or fiberpack ram feeder*
Temperature (max)	*1010°C (1850°F)*
Characteristics of the Afterburner Chamber	
Length	*3.05 m (10 ft)*
Diameter, outside	*1.22 m (4 ft)*
Diameter, inside	*0.91 m (3 ft)*
Chamber volume	*1.80 m³ (63.6 ft³)*
Construction	*0.63 cm (0.25 in) thick cold-rolled steel*
Refractory	*15.2 cm (6 in) thick high alumina castable refractory*
Gas residence time	*0.8 to 2.5 s depending on temperature and excess air*
Burner	*North American Burner rated at 800 kW (2.7 MMBtu/hr) with liquid feed capability*
Primary fuel	*Natural gas*
Temperature (max)	*1200°C (2200°F)*
Characteristics of the Ionizing Wet Scrubber APCS	
System capacity, inlet gas glow	*85 m³/min (3000 acfm) at 78°C (172°F) and 101 kPa (14.7 psia)*
Pressure drop	*1.5 kPa (6 in W.C.)*
Liquid flow	*230 L/min (60 gpm) at 345 kPa (50 psig)*
pH control	*Feedback control by NaOH solution addition*
Characteristics of the Venturi/Packed Column Scrubber APCS	
System capacity, inlet gas flow	*107 m³/min (3773 acfm) at 1200°C (2200°F) and 101 kPa (14.7 psia)*
Pressure Drop	
Venturi scrubber	*7.5 kPa (30 in W.C.)*
Packed column	*1.0 kPa (4 in W.C.)*
Liquid flow	
Venturi scrubber	*77.2 L/min (20.4 gpm) at 60 kPa (10 psig)*
Packed column	*116 L/min (30.6 gpm) at 69 kPa (10 psig)*
pH control	*Feedback control by NaOH solution addition*

kg lead), scrubber blowdown and exit flue gas concentrations were increased to 45 mg/L and 24 mg/dscm, respectively. Lead concentrations in the scrubber blowdown, TCLP leachates of scrubber blowdown, and EP toxicity leachates of the soil feed, kiln ash, and scrubber blowdown were less than the TC threshold, which defines a "characteristic" hazardous waste for the two low-lead-concentration Purity soils. Lead concentrations in TCLP leachates of the soil feed and kiln ash, however, exceeded the TC threshold for these soils.

These test results suggest that incineration would be an acceptable treatment option for the McColl site materials. Based on these results, organic contaminant destruction is effective, particulate emissions comply with the federal hazardous-waste incinerator performance standards, and SO_2 emissions are low.

Incineration could be considered applicable to the treatment of the Purity soils based on effective organic decontamination acceptable particulate emissions and low SO_2 emissions. These test results do, however, suggest that the resulting kiln ash would require further treatment to stabilize or remove leachable lead levels and that the scrubber blowdown from the incineration of the high-lead-concentration soil could become a characteristically hazardous waste if an ionizing wet scrubber were used for air pollution control. Furthermore, the acceptability of lead emission levels from a wet scrubber control device would require further evaluation.

The full report was submitted in fulfillment of Contract 68-C9-0038 by Acurex Corporation under the sponsorship of the U.S. Environmental Protection Agency.



Sampling point	Waste feed	Kiln ash	Ionizing wet scrubber blowdown	Continuous flue gas monitoring	Method 0010 (semivolatile organics)	Method 12 (lead)	Method 5/8 (particulate SO_2, SO_3)
1	X						
2		X					
3				X			
4				X			
5			X				
6				X	X	X	X
7				X	X	X	X

Figure 2. *Sampling matrix.*

Table 2. *Incinerator System Operating Conditions for Purity Oil Sales and McColl Site Soil Incineration Tests*

Total waste/soil feedrate	49 kg/hr (108 lb/hr)
Kiln temperature	871°C (1600°F)
Kiln exit flue gas O_2	11% to 13%
Afterburner	982°C (1800°F)
Afterburner exit flue gas O_2	9% to 11%
Kiln rotation speed	0.2 rpm
Scrubber blowdown flowrate	1.9 L/min (0.5 gpm)
Scrubber liquor flowrate	150 L/min (40 gpm)
Scrubber pressure drop	1.5 kPa (6 in W.C.)

Table 3. *Ultimate Analysis of the Test Soils and Resulting Kiln Ashes*

Parameter (wt %)	Soil				
	Purity A layer (Test 1)	Purity C layer (Test 2)	Purity B layer (Test 3)	McColl low sulfur (Test 4)	McColl high sulfur (Test 5)
C	2.14	1.63	24.83	15.64	19.88
H	0.99	<0.5	4.64	3.36	3.65
O	5.27	2.75	17.50	17.13	20.83
N	<0.5	<0.5	<0.5	<0.5	<0.5
S	0.58	0.43	2.43	3.58	8.13
Cl	<0.18	<0.21	<0.27	<0.58	<0.28
Ash	86.09	86.15	58.39	57.29	41.40
Total organic carbon	1.74	1.61	24.83	15.60	19.88
	Kiln ash				
C	0.19	0.12	3.39	4.18	6.65

Table 4. *Semivolatile Organic Hazardous Constituents in Test Soils*

Constituent	Concentration (mg/kg)				
	Purity A layer (Test 1)	Purity C layer (Test 2)	Purity B layer (Test 3)	McColl low sulfur (Test 4)	McColl high sulfur (Test 5)
Naphthalene	ND[a]	35	90	96	340
Bis(2-ethylhexyl)-phthalate	ND	77	41	ND	43
All other semivolatiles analyzed	<25	<25	<25	<25	<25

[a]ND - not detected at detection limits of 25 mg/kg for base-neutrals and 50 mg/kg for acids.

Table 5. *Lead Distributions for the Purity Oil Sales Site Soil Tests*

Parameter	Test 1 (1/19/90) Purity A layer	Test 2 (1/23/90) Purity C layer	Test 3 (1/31/90) Purity B layer
Lead concentration			
Soil feed, mg/kg	860	780	10,200
Kiln ash, mg/kg	1,620	1,830	23,800
Scrubber blowdown, mg/L	2.8	3.2	45
Scrubber exit flue gas, mg/dscm	1.6	1.0	24
Stack gas, mg/dscm	1.2	0.47	21
Lead flowrate, g/hr			
Soil feed	42	39	510
Kiln ash	61	64	588
Scrubber exit flue gas	3.3	1.9	46
Stack gas	2.8	1.0	45
Soil feed leachate			
EP toxicity concentration, mg/L	2.1	2.6	2.6
Fraction leachable, %	4.9	2.8	0.5
TCLP concentration, mg/L	5.7	18	21
Fraction leachable, %	13	46	4.1
Kiln ash leachate			
EP toxicity concentration, mg/L	<0.07	0.23	0.33
Fraction leachable, %	<0.1	0.25	0.03
TCLP concentration, mg/L	10	15	110
Fraction leachable, %	12	16	9.2
Scrubber blowdown leachate			
EP toxicity concentration, mg/L	1.4	1.2	19
TCLP concentration, mg/L	1.4	1.2	17

Table 6. *Lead Discharge Distributions for the Purity Oil Sales Site Soil Tests*

Parameter	Test 1 Purity A Layer	Test 2 Purity C layer	Test 3 Purity B layer
Total kiln ash discharge (% of soil weight fed)	77	69	49
Lead distribution (% of lead fed)			
Kiln ash	146	163	115
Scrubber liquor	1	1	2
Scrubber exit flue gas	8	5	9
Total	155	169	126

☆U.S. GOVERNMENT PRINTING OFFICE: 1992 - 648-080/40252

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The complete report, entitled "Pilot-Scale Incineration of Contaminated Soil from the Purity Oil Sales and McColl Superfund Sites," (Order No. PB92-105 857/AS; Cost: $19.00, subject to change) will be available only from:

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