



Project Summary

Pilot-Scale Incineration of Contaminated Soils from the Drake Chemical Superfund Site

C. King, J.W. Lee, and L.R. Waterland

A series of pilot-scale incineration tests was performed at the U.S. Environmental Protection Agency's (EPA's) Incineration Research Facility (IRF) to evaluate the potential of incineration as an option to treat contaminated soils from the Drake Chemical Superfund site in Lock Haven, PA. The soils at the Drake site are reported to be contaminated to varying degrees with various organic constituents and several hazardous constituent trace metals. The purpose of the test program was to evaluate the incinerability of selected site soils in terms of the destruction of contaminant organic constituents and the fate of contaminant trace metals. All tests were conducted in the rotary kiln incineration system (RKS) at the IRF.

Test results show that destruction and removal efficiencies (DRE) of greater than 99.995% can be achieved for the principal organic hazardous constituents (POHC) at kiln exit gas temperatures of nominally 816°C (1,500°F) and 538°C (1,000°F). Complete soil decontamination of semivolatile organics was achieved; however, kiln ash levels of three volatile organic constituents remained comparable to soil levels.

Kiln ash accounted for the predominant fraction of all contaminant trace metals with the exception of mercury, which appeared to be entirely in the flue gas discharge. The flue gas discharge from the venturi/packed-column scrubber air pollution control system (APCS) accounted for a minor fraction of all contaminant trace metals, with

the exception of mercury, cadmium, and, possibly, arsenic. The scrubber liquor accounted for less than 10% of the contaminant metals, with the exception of copper and chromium, and, in one case, nickel. Kiln temperature in the range tested, as above, did not affect overall metal distributions in incinerator discharges.

None of the soils tested, nor the kiln ash resulting from their incineration, would be considered a toxicity characteristic (TC) hazardous waste because of their leachable trace metal contents. Further, no test scrubber liquor would be considered a TC hazardous waste because of trace metal concentrations. Lead concentrations in test scrubber liquors were, however, at levels near 50% of the toxicity characteristic leaching procedure (TCLP) regulatory level in some cases. This suggests that the scrubber liquor discharge from a wet scrubber APCS could become a TC hazardous waste in the incineration of "hot spot" lead-containing soils or under scrubber operation at minimum blowdown. The flyash collected at the afterburner exit (upstream of the wet scrubber APCS) would be a TC hazardous waste because of leachable chromium and lead concentrations and, in one case, arsenic and cadmium concentrations. This suggests that the collected particulate from a dry APCS (such as a fabric filter) would be a TC hazardous waste.

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 EPA's IRF is to support regional offices in evaluations of the potential of incineration as a treatment option for contaminated soils and sediments at Superfund sites. One priority Superfund site is the Drake Chemical site, in Lock Haven, PA. EPA Region 3 requested that test burns be conducted at the IRF to support evaluations of the suitability of incineration as a treatment technology for the contaminated soils and sediments at the site.

The Drake Chemical site, covering approximately 12.5 acres, was a chemical manufacturing facility from 1951 to 1982. According to site investigation data, as a result of these activities, the soils at the Drake site are contaminated to varying degrees with various organic constituents and several hazardous constituent metals. With respect to incinerability evaluation, the primary objective was to determine whether treatment of the soils by incineration would generate a residue environmentally suitable for redeposit, without further treatment, at the site during full-scale remediation. Therefore, one primary concern was whether incineration could effectively destroy the organic contaminants in the soils. Equally important was what the fate of the trace metals in the soils would be when the soils were subjected to incineration.

This test program was designed to evaluate the effectiveness of varying incinerator operating conditions on organic contaminant destruction and the effects of these varied conditions on the distributions of the trace metals in the discharge streams. Specific questions answered in this test program were

- Can rotary kiln incineration effectively destroy the organic contaminants in the site soils?
- Will incineration-treated site soils have characteristics that will allow it to be backfilled (redeposited), without further treatment, at the site?
- Can site soils be incinerated in compliance with the hazardous waste incinerator performance standards?
- What is the fate of the contaminant trace metals in the incineration of the site soils?
- What are the effects of incineration temperature on contaminant metal fate and kiln ash characteristics?

This test program, as originally conceived, was to have consisted of an initial

phase of nine tests and an optional phase of four additional tests. The results from the initial-phase testing, specifically the toxicity characteristics exhibited by the incinerator residuals, were to guide the decision as to whether the optional testing would be needed. A subset of the initial-phase incineration testing was conducted at the IRF in January and February 1991. The TCs of all test program samples were below regulatory threshold levels. These results led to the conclusion that several of the originally conceived initial-phase tests and the optional testing would not be necessary to meet the stated program objectives.

Results of the test program are discussed in the subsections that follow.

Test Program

Test Facility

A process schematic of the RKS is shown in Figure 1. The IRF RKS consists of a primary combustion chamber, a transition section, and a fired afterburner chamber. After exiting the afterburner, flue gas flows through a quench section followed by a primary APCS. The primary APCS for these tests consisted of a venturi scrubber followed by a packed-column scrubber. Downstream of the primary APCS, a backup secondary APCS, composed of a demister, an activated-carbon adsorber, and a high-efficiency particulate (HEPA) filter, is in place.

Test Waste Description

The Phase III record of decision (ROD) document for the Drake Chemical site indicates that about 252,000 yd³ of contaminated soils and sediments will be excavated and decontaminated onsite by a transportable rotary kiln incinerator. The ROD further indicates that these materials are contaminated with varying levels of organic compounds and several hazardous constituent trace metals, including arsenic, barium, cadmium, chromium, lead, and mercury.

For the test program, seventeen 55-gal drums of the contaminated site soils were excavated and shipped to the IRF for possible testing. Only a subset of these drums was actually used in the test program, however.

Test Conditions

As noted above, the objective of the proposed test program was to evaluate the suitability of incineration as a treatment technology for the contaminated soils and sediments at the Drake Chemical site. The rescoped test program consisted of five tests. The test numbering of the origi-

nally conceived test program was retained, however. Of the five conditions tested, three (Tests 1, 2, 3a, and 3b) were designed to study the fate of the inorganic contaminants (trace metals). Tests 1 and 2 studied the distribution of the trace metal contaminants throughout the incinerator system. These tests also provided information on the concentrations of trace metals in the kiln ash and flue gas flyash TCLP leachates. Tests 3a and 3b determined the effects of kiln temperature on the trace metal concentrations in the kiln ash and scrubber liquor streams. All of these tests were conducted with the soils in their original, as-received form. Tests 6 and 7 were designed to study the destruction of the organic contaminants. Because the as-received soils contained low levels of organic contamination, the Test 6 and Test 7 soils were spiked with naphthalene and 1,4-dichlorobenzene at 3,000 and 130 mg/kg, respectively. The destruction of the spiked POHCs became the principal indicator of the effectiveness of incineration under these test conditions.

The five tests were conducted from January 30, 1991, through February 7, 1991. Tests 3a and 3b were performed in one day, with sufficient time allowed in between subtests to achieve steady-state operation at the target kiln temperature of 816°C (1,500°F) for Test 3a and 538°C (1,000°F) for Test 3b. Test soils were fed to the kiln via the fiberpack drum ram feeder system. Each fiberpack contained 4.5 kg (10 lb) of soil. One fiberpack was charged into the kiln every 5 min, resulting in soil feedrates of nominally 55 kg/hr (120 lb/hr).

Table 1 compares the target and actual test operating conditions for each test. As shown, the average kiln temperatures were within about 15°C (25°F) of the target temperatures for all of the tests. Afterburner temperatures were maintained within 3°C (5°F) of the 1,093°C (2,000°F) target for all tests. O₂ levels in the flue gas exiting both the kiln and afterburner were somewhat higher than target levels for all tests, however, because the rotating kiln seals could not be tightly secured and excessive air leaked into the kiln. Nevertheless, based on the IRF's past experience, the results would not have been different had the flue gas O₂ levels been on target.

Table 2 summarizes the total amount of soil fed to the RKS for each test and the corresponding weight of ash collected for each test. As shown, except for Test 7, the weight of ash discharged was generally about 70% of the weight of soil fed to the kiln.

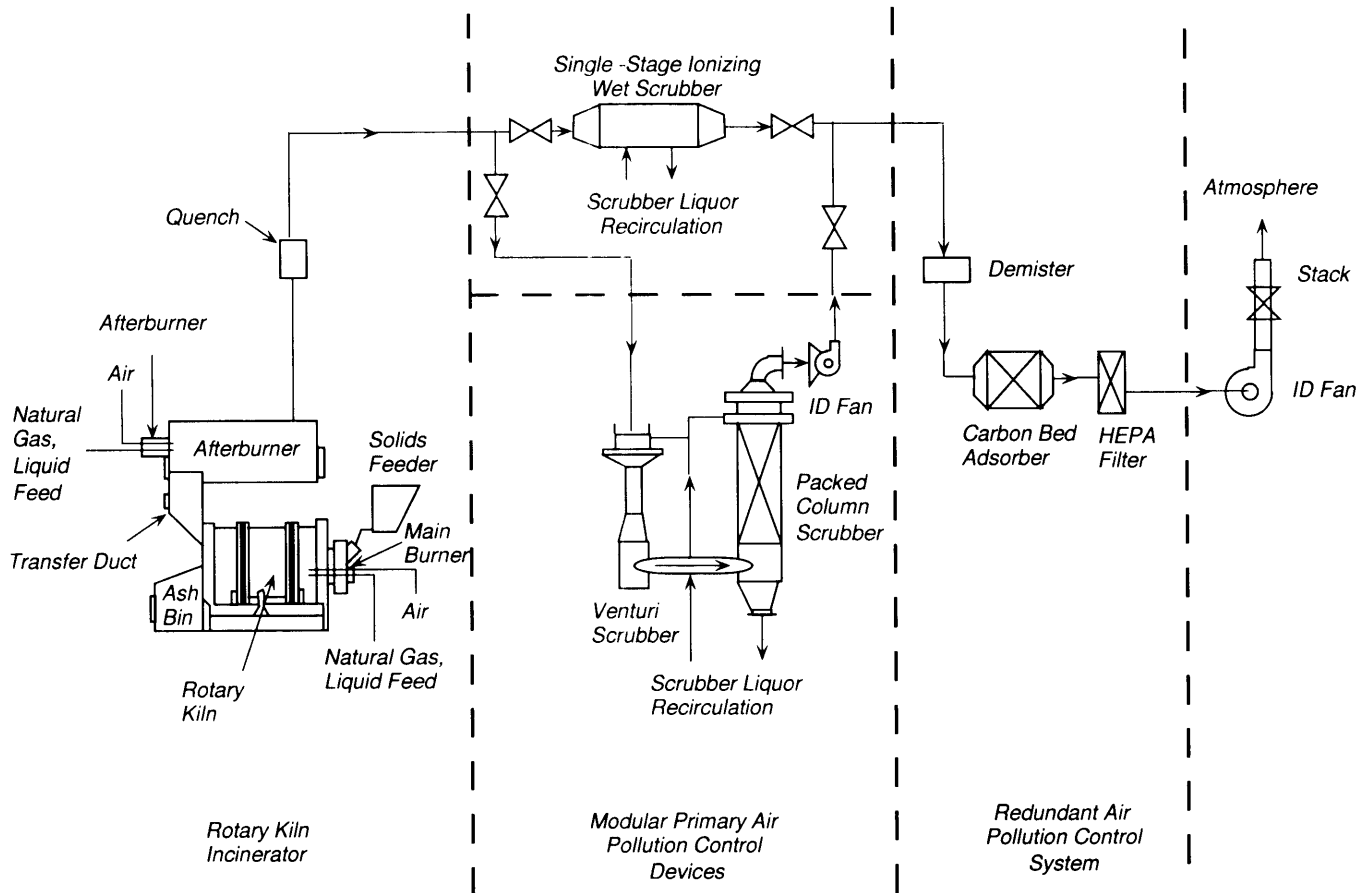


Figure 1. Schematic of the IRF rotary kiln incineration system.

Sampling and Analysis Procedures

Because the objectives of Tests 1, 2, 3a, and 3b were different from those of Tests 6 and 7, different sampling and analysis procedures were employed for each test group. Several procedures were, however, performed for all tests:

- obtaining a composite sample for the soil feed from each drum before the soil was packaged into fiberpack containers,
- collecting a composite kiln ash sample,
- collecting a composite scrubber liquor sample,
- continuously measuring O₂ concentrations at the kiln exit; O₂, CO, CO₂, and total unburned hydrocarbon (TUHC) at the afterburner exit; O₂, CO₂, and NO_x at the scrubber exit; and CO and TUHC at the stack, and

- sampling the flue gas at the stack for HCl and particulate, by using a Method 5¹ sampling train.

The above were the only sampling procedures employed for Tests 3a and 3b. In addition to the above, the following were performed for Tests 1 and 2:

- sampling the flue gas at the afterburner exit (i.e., upstream of the scrubber) for particulate load and for trace metals (excluding mercury), by using a Method 17¹ sampling train, modified with multiple metals train impingers,
- determining the particle size distribution of the afterburner exit flue gas particulate, by using an Anderson cascade impactor train,
- sampling the flue gas upstream and downstream of the scrubber for mercury, by using a Method 101A² train at each location, and

- sampling the flue gas downstream of the scrubber system for particulate and trace metals (excluding mercury), by using the EPA multiple metals train.³

In addition to the sampling performed for all tests noted above, the flue gas downstream of the scrubber system was sampled for semivolatile POHCs, by using a Method 0010⁴ sampling train, in Tests 6 and 7.

In addition to analyzing flue gas sampling trains for their sampled analyte set, the following were performed for Tests 1, 2, 3a, and 3b.

- analyzing the soil feed and kiln ash samples for trace metals (arsenic,

¹40 CFR 60, Appendix A

²40 CFR 61, Appendix B

³40 CFR 266, Appendix IX

⁴SW-846

Table 1. Target Versus Actual Operating Conditions for the Drake Chemical Soil Tests

Test no.	Kiln				Afterburner	
	Target temperature, °C (°F)	Actual average temperature, °C (°F)	Target O ₂ , %	Actual average O ₂ , %	Target O ₂ , %	Actual average O ₂ , %
1	816 (1,500)	826 (1,519)	11.0	13.3	7.0	8.7
2	816 (1,500)	823 (1,513)	11.0	13.1	7.0	9.2
3a	816 (1,500)	829 (1,524)	11.0	13.8	7.0	9.2
3b	538 (1,000)	546 (1,015)	11.0	17.0	7.0	11.8
6	816 (1,500)	822 (1,512)	11.0	12.7	7.0	9.3
7	538 (1,000)	553 (1,027)	11.0	15.4	7.0	9.9

Table 2. Soil Feed and Ash Collected

Test	Test soil	Total soil fed, kg (lb)	Total ash collected	
			Weight, kg (lb)	Fraction of soil fed, %
1	(1/30/91) M-2	240 (529)	173 (381)	72
2	(2/5/91) M-5D	232 (512)	177 (390)	76
3a	(1/31/91) O-1	112 (246)	74 (163)	66
3b	(1/31/91) O-1	113 (249)	83 (183)	73
6	(2/6/91) L-2	240 (529)	187 (411)	78
7	(2/7/91) O-2	209 (460)	183 (404)	88

barium, cadmium, chromium, copper, mercury, nickel, lead, selenium, silver, and zinc),

- analyzing the soil and kiln ash TCLP leachates for trace metals, and
- analyzing the scrubber liquor samples for trace metals.

In addition, for Tests 1 and 2, an aliquot of the afterburner exit particulate collected with the Method 17 sampling train was extracted by the TCLP and the resulting leachate analyzed for trace metals. For Tests 6 and 7, the analysis protocol included analyzing the soil feed, kiln ash, and scrubber liquor samples for volatile and semivolatile organic contaminants.

Test Results

Inorganic-Contaminated-Soil Tests

Table 3 provides a complete summary of the trace metal analysis results for all test samples taken for trace metal analysis. The data in Table 3 show that soil feed and resulting kiln ash metal concentrations were generally comparable for all metals. The concentrations of metals in the afterburner exit particulate were, however, significantly greater than corresponding soil feed and kiln ash concentrations for all metals in the two tests for which afterburner exit particulate was collected

for analysis. Flue gas particulate at the afterburner exit was analyzed as an analog to the flyash collected by dry APCSS. The data in Table 3 suggest that the flyash collected by a fabric filter APCSS, for example, will likely contain significantly higher levels of all test program trace metals (except mercury) than does the parent soil incinerated.

Tests 1, 2, and 3a were performed at a kiln temperature of nominally 824°C (1,515°C). Test 3b was performed at a lower kiln temperature of 546°C (1,015°F) to evaluate whether variations in kiln temperature in this range affected resulting kiln ash trace metal contents. The data in Table 3 show no significant differences in the trace metal contents of the kiln ash from Test 3a compared to Test 3b.

The data in Table 3 show that kiln ash TCLP leachates were quite similar in metal content to the corresponding soil leachates, with the exception that the Test 2 leachate had a significantly lower zinc concentration than its corresponding soil. Still, no soil or kiln ash resulting from its incineration in these tests had TCLP leachate trace metal concentrations even approaching the TCLP regulatory levels. Thus, the kiln ashes resulting from the incineration of site soils would not be TC hazardous wastes based on these test data.

In contrast, the concentrations of metals in leachates of the afterburner exit flue gas particulate were significantly higher than corresponding soil and resulting kiln ash leachate concentrations. In fact, the particulate leachate concentrations of chromium and lead exceeded their corresponding TCLP regulatory levels for both Tests 1 and 2; and the Test 2 particulate leachate was at or over the regulatory levels for arsenic and cadmium. Because the afterburner exit flue gas particulate was collected as an analog for dry APCSS (e.g., fabric filter) collected flyash, the data in Table 3 suggest that the collected flyash from the incineration of soil highly contaminated by trace metals would be a TC hazardous waste, not suitable for land disposal without further treatment.

The scrubber liquor trace metal data show that no scrubber liquor contained trace metal concentrations exceeding TCLP regulatory levels. In two of three cases, however, lead concentrations in test scrubber liquor were nearly 50% of the regulatory level for lead. This suggests that the scrubber liquor discharge from a wet APCSS, generated in the incineration of "hot spot" lead-containing soils or under scrubber operation at minimum blowdown, could be a TC hazardous waste.

The test sample concentration data from Table 3 can be combined with waste feedrate and kiln ash discharge rates and flue gas flowrate data to calculate the distribution of trace metals among the various incinerator discharges of the tests. Table 4 summarizes these trace metal distributions among the incinerator discharge streams, expressed as fractions (in percent) of the amount of each metal fed to the incinerator in each test. Thus, the values in the table represent the fraction of the metal fed to the kiln accounted for by the noted discharge. The rows labeled "Total" represent the total amount of metal fed accounted for by the sum of the discharges analyzed. Thus, these rows represent the degree of mass balance closure achieved for each metal for each test.

The data in Table 4 show that the kiln ash fraction contained the predominant amount of all metals, except mercury, for both Tests 1 and 2. Scrubber exit flue gas fractions were generally quite low for all metals except for mercury, cadmium, and possibly arsenic for both tests. The flue gas accounted for all measured mercury for both tests. The scrubber liquor accounted for less than about 10% of the amount of metal fed for all metals except

Table 3. Test Sample Trace Metal Concentrations

Sample	As	Ba	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Test 1 (1/30/91)											
Soil feed (M-2), mg/kg	16	167	1.1	18	49	439	0.1	17	<10	<2	302
Soil feed TCLP leachate, mg/L	<0.1	0.44	<0.01	<0.03	<0.01	<0.06	<0.002	<0.03	<0.1	<0.02	0.05
Kiln ash, mg/kg	13	211	1.1	22	41	403	<0.1	22	<10	<2	234
Kiln ash TCLP leachate, mg/L	<0.1	<0.01	<0.01	<0.03	<0.01	<0.06	<0.002	<0.03	<0.1	<0.02	<0.02
Scrubber liquor, mg/L	<0.1	1.4	<0.01	0.57	1.7	2.7	<0.002	0.47	<0.1	<0.02	1.2
Afterburner exit flue gas, µg/dscm	3.2-13.8	105	2.2	54	7.6	74	3.9-4.2	59	<2.7	0.9-3.1	78
Afterburner exit flue gas particulate, mg/kg	50	590	9.5	168	117	570	NA ^a	178	<25	15	684
Afterburner exit flue gas particulate TCLP leachate, mg/L	<3	11	0.4	5.8	3.4	12	NA	4.9	<3	<0.5	15
Scrubber exit flue gas, µg/dscm	6.2-46	1.4-4.2	2.3-6.3	7.7-16.8	8.3-11.1	132-150	9.2-9.3	<9.1	3.0-7.0	2.7-8.9	15
Test 2 (2/5/91)											
Soil feed (M-5D), mg/kg	62	57	2.0	12	43	77	0.3	15	<10	<2	251
Soil feed TCLP leachate, mg/L	<0.1	<0.01	0.015	<0.03	<0.01	<0.06	<0.002	<0.03	<0.1	<0.02	1.5
Kiln ash, mg/kg	16	48	1.7	9.8	21	38	<0.1	8.7	<10	<2	115
Kiln ash TCLP leachate, mg/L	0.14	<0.01	<0.01	<0.03	<0.01	<0.06	<0.002	<0.03	<0.1	<0.02	<0.02
Scrubber liquor, mg/L	0.66	0.74	0.021	0.18	1.3	1.3	<0.002	0.13	<0.1	<0.02	1.2
Afterburner exit flue gas, µg/dscm	108	57	5.2	94	18	88	5.7-5.9	76	<1.6	<1.9	158
Afterburner exit flue gas particulate, mg/kg	462	223	20	209	160	554	NA	110	<10	<2	777
Afterburner exit flue gas particulate TCLP leachate, mg/L	31	9.6	1.0	11	7.2	20	NA	5.9	<3	<0.5	28
Scrubber exit flue gas, µg/dscm	43-84	2.4-5.5	6.5-10.6	3.7-12.9	14-17	74-93	15	<9.2	<7.3	4.7-11.4	36
Test 3 (a and b) (1/31/91)											
Soil feed (O-1), mg/kg	11	194	<1.0	20	35	443	0.2	12	<10	<2	272
Soil feed TCLP leachate, mg/L	<0.1	<0.01	<0.01	<0.03	<0.01	0.06	<0.002	<0.03	<0.1	<0.02	0.07
Scrubber liquor, mg/L	<0.1	1.1	0.015	0.24	1.4	2.3	<0.002	0.17	<0.1	<0.02	1.3
Test 3a (829°C [1,524°F])											
Kiln ash, mg/kg	<10	199	1.4	24	39	345	<0.1	23	<10	<2	192
Kiln ash TCLP leachate, mg/L	<0.1	<0.01	<0.01	<0.03	<0.01	<0.06	<0.002	0.032	<0.1	<0.02	0.35
Test 3b (546°C [1,015°F])											
Kiln ash, mg/kg	<10	184	<1.0	18	42	410	<0.1	18	<10	<2	299
Kiln ash TCLP leachate, mg/L	<0.1	<0.01	<0.01	<0.03	<0.01	<0.06	<0.02	<0.03	<0.1	<0.02	<0.02
TCLP regulatory level, mg/L	5.0	100	1.0	5.0	^b	5.0	0.2	—	1.0	5.0	—

^aNA = Not analyzed

^b- = Not a TCLP metal

chromium, copper, and nickel in Test 1, and copper in Test 2.

The metal distribution data for Tests 3a and 3b generally support the observations from Tests 1 and 2 discussed above. The kiln ash discharge again accounted for the predominant fraction of each metal except mercury, which was not found in the kiln ash of either Test 3a or 3b. Again, the scrubber liquor accounted for less than about 10% of the amount of metal fed for all metals except copper. Comparing the kiln ash fraction data of Test 3a and Test 3b shows that decreasing the kiln temperature from 829°C (1,524°F) to 546°C (1,015°F) had no effect on kiln ash metal fractions, with the possible exception of increased kiln ash zinc with decreased temperature.

Scrubber collection efficiencies for each of the metals measured in the flue gas streams for Tests 1 and 2 can be calculated from measured concentrations in the afterburner exit flue gas and the scrubber exit flue gas. The IRF's experience, however, has been that flue gas metal con-

centrations measured at this location are generally lower than expected. Thus, calculated scrubber collection efficiencies using measured metal concentrations in afterburner exit flue gas are often quite poor. Based on past experience, a better estimate of the flowrate of metals at the scrubber inlet has been obtained by summing the flows in the two scrubber discharge streams: the scrubber exit flue gas and the scrubber liquor. This allows an apparent scrubber collection efficiency to be calculated as (scrubber liquor fraction)/(scrubber liquor fraction plus scrubber exit flue gas fraction).

Table 5 summarizes the apparent scrubber collection efficiencies calculated for each metal measured in the test program for Tests 1 and 2. The data in Table 5 show that the collection efficiencies of the venturi/packed-column scrubber system were greater than about 90% for barium, chromium, copper, nickel, and zinc in Test 1, and possibly chromium and nickel in Test 2. Cadmium collection efficiencies were less than 30% to 40%, and mercury

collection efficiencies less than 5% for both tests. Lead collection efficiencies were nominally 80% for both tests. Arsenic collection efficiencies were between 64% and 78% for Test 2 but less than 36% for Test 1.

Organic-Contaminated-Soil Tests

Table 6 summarizes the results of the organic analyses of the organic-contaminated test soils. As shown in the table, fenac was present in the L-2 test soil at 70 mg/kg. Fenac was not detected in the O-2 test soil. The results in Table 6 also indicate that both test soils contained low levels of several volatile organics and that the O-2 soil contained low levels of several semivolatile organics.

Because the organic test soils contained very low levels of organic contamination, they were spiked with naphthalene and 1,4-dichlorobenzene to the 3,000 mg/kg and 130 mg/kg levels, respectively. These two semivolatile compounds became surrogate test POHCs. Measured naphtha-

Table 4. Trace Metal Distributions

Sample	Distribution, % of metal fed								
	As	Ba	Cd	Cr	Cu	Pb	Hg	Ni	Zn
Test 1 (1/30/91), Soil M-2									
Kiln temperature: 826°C (1,519°F)									
Kiln ash	56	90	71	88	61	66	<71	91	55
Afterburner exit flue gas	0.7-3	2	7	11	0.6	0.6	150-160	12	0.9
Total	57-59	92	78	99	62	67	150-231	103	56
Kiln ash	56	90	71	88	61	66	<71	91	55
Scrubber exit flue gas	2-11	<0.1	8-22	2-4	1	1	350	<2	0.2
Scrubber liquor	<6	8	<9	32	34	6	<20	27	4
Total	58-73	98	79-102	122-124	96	73	350-441	118-120	59
Test 2 (2/5/91), Soil M-5D									
Kiln temperature: 823°C (1,513°F)									
Kiln ash	20	65	65	61	37	38	<2.5	45	35
Afterburner exit flue gas	6	4	9	28	2	4	68-71	19	2
Total	26	69	74	89	39	42	68-96	64	37
Kiln ash	20	65	65	61	37	38	<2.5	45	35
Scrubber exit flue gas	3-5	0.2-0.4	12-20	1-4	1	4-5	195-198	<2	0.6
Scrubber liquor	9	11	9	13	26	14	<6	8	4
Total	32-34	76	86-94	75-78	64	56-57	195-229	53-55	40
Test 3a (1/31/91), Soil O-1									
Kiln temperature: 829°C (1,524°F)									
Kiln ash	(a)	69	(b)	83	75	52	<31	129	48
Test 3b (1/31/91), Soil O-1									
Kiln temperature: 546°C (1,015°F)									
Kiln ash	(a)	70	(b)	69	88	68	<35	108	81
Total Test 3									
Kiln ash	(a)	70	(b)	76	82	61	<35	118	65
Scrubber liquor	(a)	3	(b)	7	22	3	<6	8	3

^aArsenic present in Test 3 soil just at the practical quantitation limit (PQL), not detected in any residual sample.
^bCadmium not detected in Test 3 soil.

lene DRE was greater than 99.995% for both tests. No 1,4-dichlorobenzene was detected in the scrubber exit flue gas, with a DRE corresponding to the quantitation limit for 1,4-dichlorobenzene of greater than 99.89%. The spiking level for 1,4-dichlorobenzene, mistakenly chosen to be 130 mg/kg, combined with the flue gas sampling and analysis method PQL, was too low to allow establishing a higher DRE. The lower kiln temperature for Test 7, 553°C (1,027°F), when compared with the Test 6 kiln temperature of 822°C (1,512°F), did not result in a measurable decrease in DRE.

Neither fenac nor any other semivolatile organic was detected in any other organic-contaminated soil test sample.

The volatile organic constituent analysis results for kiln ash and scrubber liquor are summarized in Table 7. As shown in the table, both tests' (Tests 6 and 7) scrubber liquor contained toluene. The Test 7 scrubber liquor also contained 2-butanone. Both tests' kiln ash contained 2-butanone

and toluene. In addition, the Test 7 kiln ash contained xylenes. Comparing the kiln ash 2-butanone, toluene, and xylene concentrations with the corresponding feed concentrations noted in Table 6 shows that they are comparable in all cases. Evidently, incineration at both kiln temperatures was ineffective in decontaminating the test soils of these three volatile organics. The authors can offer no explanation for this observation.

Particulate and HCl Emissions Data

Flue gas particulate load measurements were made at various sampled locations for different tests. Particulate levels in the afterburner exit flue gas were in the nominal range of 100 to 300 mg/dscm at 7% O₂ for Tests 1, 2, 6, and 7. Scrubber exit particulate levels were reduced to the nominal range of 10 to 20 mg/dscm at 7% O₂ for the two tests (Tests 1 and 2) during which this location was sampled. The reduction corresponds to a scrubber effi-

ciency in the 90% to 95% range, typical for a venturi scrubber. Both scrubber exit levels measured were below the 180 mg/dscm at 7% O₂ hazardous waste incinerator performance standard.

Flue gas HCl levels were also measured at the afterburner exit and in the stack during the test program. Afterburner exit flue gas HCl was 13 ppm for Test 6 (L-2 soil) and 201 ppm for Test 7 (O-2 soil). All levels were below detection limits at the stack for all tests. Corresponding system HCl collection efficiencies were greater than 98.5% for Test 6, and greater than 99.8% for Test 7.

Conclusions

Test conclusions are as follows:

- Organic contaminants in the test soils can be destroyed to greater than 99.99% DRE. Naphthalene, spiked into test soils at 3,000 mg/kg for the two organic destruction tests, was destroyed at a DRE of greater than 99.995%. 1,4-Dichlorobenzene,

Table 5. Apparent Scrubber Collection Efficiencies

Metal	Apparent scrubber collection efficiency, %	
	Test 1 (1/30/91)	Test 2 (2/5/91)
Arsenic	<36	64-78
Barium	98.8-99.6	97-99
Cadmium	<29	31-43
Chromium	90-95	76-91
Copper	98	94-95
Lead	82-84	76-79
Mercury	<5	<3
Nickel	>93	>76
Zinc	94	88

spiked into the test soils at 130 mg/kg for the same two tests, was not detected in incineration flue gas; detection limits corresponded to a DRE of greater than 99.89%. These DRE levels were attained at both kiln temperatures tested, 822°C (1,512°F) and 553°C (1,027°F), although the afterburner was operated at 1,096°C (2,005°F) for both tests. No native soil semivolatile POHCs were detected in combustion flue gas.

- The treated soil (kiln ash) contained no detectable semivolatile organic soil contaminant; this indicated effective decontamination for this class of contaminants at both kiln temperatures. The levels of three volatile organic soil contaminants, 2-butanone, toluene, and xylene, in kiln ash were, however, comparable to parent soil concentrations at both kiln temperatures; this suggested poor decontamination effectiveness for these constituents.
- None of the soils tested, nor the kiln ash resulting from their incineration, would be considered a TC hazardous waste because of their leachable trace metal content.
- No test scrubber liquor would be considered a TC hazardous waste because of trace metal concentrations. Lead concentrations in test scrubber liquors were, however, at levels near 50% of the TCLP regulatory level in some cases. This suggests that the scrubber liquor discharge from a wet scrubber APCS could become a TC hazardous waste in the incineration of "hot spot" lead-containing soils or under scrubber operation at minimum blowdown.
- The flyash collected at the afterburner exit (upstream of the wet scrubber APCS) would be a TC

Table 6. Organic Analysis Results for Feed Samples

Compound	Concentration, mg/kg	
	Test 6 (2/6/91) Soil L-2	Test 7 (2/7/91) Soil O-2
Semivolatile organics:		
Benzo(a)pyrene	ND ^a	11
Fluoranthene	ND	44
Indeno(1,2,3-cd)pyrene	ND	24
Phenanthrene	ND	58
Pyrene	ND	43
1,2,4-Trichlorobenzene	ND	43
All other semivolatile organics	ND	ND
Volatile organics:		
2-Butanone	20	20
Chlorobenzene	5.7	2.9
Trichloroethene	< 0.63	4.5
Toluene	0.69	4.7
Xylenes (total)	<0.63	3.0
All other volatile organics	ND	ND
Fenac	70	<10

^aND = Not detected.

hazardous waste because of leachable chromium and lead concentrations in both metal-contaminated soils tested in the full evaluation tests and, additionally, because of leachable arsenic and cadmium in one soil. This suggests that the collected particulate from a dry APCS, such as a fabric filter, would be a TC hazardous waste and could not be backfilled at the site without further treatment or stabilization.

- Particulate levels in the flue gas at the exit of the venturi/packed-column scrubber APCS were less than 20 mg/dscm (0.1 grains/dscf) at 7% O₂, in

compliance with the hazardous waste incinerator performance standard of 180 mg/dscm (0.08 grains/dscf) at 7% O₂. HCl emissions were not detectable downstream of the scrubber. Thus, the hazardous waste incinerator performance standard for these constituents can be met.

- The kiln ash discharge accounted for the predominant fraction of all trace metals introduced in the soil feed with the exception of mercury, which appeared to be completely accounted for in the flue gas discharges. The scrubber exit flue gas accounted for a minor fraction of the trace metals fed with the exception of mercury, cadmium, and possibly arsenic. The scrubber liquor accounted for less than 10% of the trace metals fed with the exception of copper and of chromium and nickel for one soil feed.
- Kiln ash trace metal concentrations were generally comparable to the corresponding soil feed concentrations. Afterburner exit flue gas particulate metal concentrations, however, were significantly greater.
- Varying kiln temperature in the range of 546°C (1,015°F) to 829°C (1,524°F) generally had no effect on contaminant metal fate or kiln ash characteristics
- Venturi/packed-column scrubber collection efficiencies were 90% to 95% for overall particulate. Apparent collection efficiencies were greater than about 90% for barium, chromium, copper, nickel, and zinc; about 80% for lead; less than 30% to 40% for cadmium; and variable, between 36% and 78%, for arsenic.

The full report was submitted in fulfillment of Contract No. 68-C9-0038 by Acurex Environmental Corporation under the sponsorship of the U.S. Environmental Protection Agency.

Table 7. Volatile Organic Constituent Concentrations in Kiln Ash and Scrubber Liquor Samples

Test:	Kiln ash concentration, mg/kg		Scrubber liquor concentration, µg/L	
	6	7	6	7
Date:	2/6/91	2/7/91	2/6/91	2/7/91
Feed:	Soil L-2	Soil O-2	Soil L-2	Soil O-2
Kiln temperature, °C:	822	553	822	553
Volatile organics:				
2-butanone	26	16	<100	190
Toluene	0.84	8.4	5	6
Xylenes (total)	<0.62	0.86	<50	<50

C. King, J.W. Lee, and L.R. Waterland are with Acurex Environmental Corporation, Jeferson, AR 72079.

R.C. Thurnau is the EPA Project Officer (see below).

R.E. Mournighan was the EPA Technical Project Monitor.

The complete report, entitled "Pilot-Scale Incineration of Contaminated Soils from the Drake Chemical Superfund Site," (Order No. PB93-163004; Cost: \$36.50, subject to change) will be available only from:

National Technical Information Service

5285 Port Royal Road

Springfield, VA 22161

Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Risk Reduction Engineering Laboratory

U.S. Environmental Protection Agency

Cincinnati, OH 45268

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

Official Business
Penalty for Private Use
\$300

EPA/600/SR-93/047

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35