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Project Summary

Characterization of Hazardous Waste Incineration Residuals

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The Office of Solid Waste and Emergency Response (OSWER-EPA) is considering establishment of a criterion for land disposal of waste or residue. This criterion is based on the achievement of residue quality equivalent to that from effective incineration. The purpose of this study was to provide data on the quantities and characteristics of solid and liquid discharges from hazardous waste incineration facilities. A total of 10 facilities were sampled comprising major incineration designs and flue gas treatment devices. All inlet and outlet liquid and solid streams were sampled and subjected to extensive analyses for organic and inorganic pollutant concentrations. Laboratory analyses for solid discharge streams also included leachate evaluations using standard EPA toxicity tests for metals and a draft Toxicity Characteristic Leaching Procedure (TCLP) for volatile and semivolatile organics and metals. Monitored data on incinerator facility operation was then used to determine the discharge rates of detected pollutants.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research 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

Under the 1985 amendments to the Resource Conservation and Recovery Act (RCRA), the Environmental Protection Agency (EPA) is required to ban the land disposal of many hazardous wastes unless their safe disposal can be demonstrated. The Office of Solid Waste and Emergency Response (OSWER) is considering the establishment of a criterion to require residue quality equivalent to that from effective incineration before residue land disposal of waste or residue. EPA's Office of Research and Development (ORD) characterized stack gas emissions from incinerators under a field testing program in support of OSWER's regulation development process. This testing, conducted at eight full-scale operating incinerators, assessed the incinerator's achievement of a required destruction and removal efficiency (DRE) of 99.99 percent(1). Previously, some analysis of bottom ash, flyash, and scrubber discharge liquid was conducted. The latter effort, described herein, was undertaken to achieve a more comprehensive characterization of incinerator bottom ash and flyash from a greater number of hazardous waste incineration facilities. In addition to meeting OSWER's quality criterion for residues, the Office of Water's (OW) pretreatment discharge standards will apply to facilities that treat, store, or dispose of hazardous wastes (TSDs). There exists, therefore, a need to characterize any wastewater discharged from an incinerator burning hazardous wastes.

Approach

Criteria for candidate test site selection were based on site availability, operational status and types of wastes incinerated. Preference was given to those facilities incinerating solid wastes, generating ash and employing air pollution control devices and to those previously tested for air emissions and thermal destruction. Ten sites were selected, representing a broad range of design and operating practice. Six employed rotary kilns; three, fixed

hearths; and one, a fluidized bed. The six rotary kilns burned liquid wastes downstream of rotary combustors. Air pollution control equipment (APCE) ranged from uncontrolled to primarily wet controls. Two sites had no control equipment. All except those two had a quench system and a scrubber. Two sites had wet scrubbers and also employed wet electrostatic precipitators. Table 1 summarizes the ten incineration configurations.

During the site visits, the wastes fired were typical of those normally incinerated. In two cases, solid hazardous wastes were selected to provide a more uniform feed to promote production of a more representative sample. The wastes were not spiked as is usual in source testing operations. Table 2 summarizes the sampled input and output streams and the analyses performed. The typical test involved sampling non-gaseous incinerator inlet and outlet streams during a 2- to 4-hour period of operation. At Sites 2, 7, and 8, not all streams were sampled due to safety and/or proprietary concerns. Wastes not sampled included lab packs, hospital wastes, nitriles magnesium scrap, and, at one site, all drummed wastes. Concurrent with sampling, system operating information was also obtained to substantiate normal operation.

The samples were analyzed for volatile and semivolatile organics and priority pollutant metals in accordance with EPA/OSWER procedures (2). Ash samples were also analyzed for leachate organics and metals. Two extraction procedure (EP) toxicity test methods were used, namely Method 1310 in SW-846, the EP Toxicity Test Procedure, and a draft TCLP using the EPA draft protocol (3). Extracts from the former were analyzed for priority pollutant metals. Extracts from the latter were analyzed for priority pollutant metals and semivolatile organics, and for volatile organics, using a zero-head extraction vessel (ZHEV).

Results

Volatiles and Semivolatile Organics

A total of 19 volatile organics and 24 semivolatile organics were detected in the ash residual samples. Those present in the highest concentrations were toluene (120 ppm), 2-butanone (34 ppm), 4-methyl-2-pentanone (29 ppm), and tetrachloroethane (16 ppm). Even the low volatiles concentrations reported in the ash would generally not be expected. However, these levels might be due to the ash adsorbing volatiles from quench water (Sites 1, 2, 3, 7, 8, and 9), flue gas, or air; products of in-

Table 1. *Hazardous Waste Incinerator Configurations and Waste IDs*

Site No. Incinerator type	*1 Rotary kiln with secondary combustor in parallel with a liquid waste-fired boiler*	*2 Rotary kiln with secondary combustor in parallel with a liquid injection combustor*	*3 Rotary kiln with secondary combustor*	*4 Fluidized bed incinerator*	*5 Fixed hearth (2 separate incineration systems)*	*6 Fixed hearth*	*7 Fixed hearth with secondary combustor*	*8 Rotary kiln with (secondary) liquid injection combustor. Drums also conveyed through combustor*	*9 Rotary kiln with secondary combustor*	*10 Rotary kiln with secondary combustor*
EPA Waste identification no.	*D001 F001 F002 F003 F005*	*D001 D008*	*D001 F001 F002 F003 F005*	*None*	*D001 F001 F002 F003 F005*	*D001 F003 F005*	*D001 F001 F002 F003 F005*	*D001 D002 D006 D007 D008 D009 F001 F002 F003 F005 U002*	*D001 F001 F002 F003 F005*	*D001 F001 F002 F003 F005*
Incinerator ash quench	X	X	X				X	X (rotary kiln only)	X	X (But no ash during testing)
Secondary combustion chamber with liquid waste injection							X		X	X
Hot-gas cyclones	X			X						
Quench	X	X	X	X			X	X	X	X
Scrubber + demister	X	X	X	X			X	X	X	X
Acid absorbers		X								X
Waste heat recovery boiler	X (liquid-waste fired)		X							
Wet ESP's			X					X		
No control device (Constraints on fuel and firing rates)					X	X				
Selective material reburning							X	X (drums and residue)		

Table 2. *Summary of Samples Collected and Analyses Performed for 10 Hazardous Waste Incineration Facilities*

Stream description	Site numbers	Analyses					
		Volatiles	Semivolatiles	Priority pollutant metals	EP II procedure	Draft TCLP	PCB identity[a]
Input Streams							
APCE aqueous supply	8	X	X	X			
Aqueous or low-Btu waste	1 and 5	X	X	X			
Coating waste solids	7	X	X	X			
Chloroprene catalyst sludge	2	X	X	X			
CS tear gas powder	4	X	X	X			
DCB coke solids	2	X	X	X			
Drum feed liquids	3	X	X	X			
Drum feed solids	3 and 9	X	X	X			
Lacquer chips	6	X	X	X			
Lacquered cardboard waste	5	X	X	X			
Latex coagulum solids	7	X	X	X			
Liquid injected waste fuels	1, 3, 5 to 10	X	X	X			
PCB-contaminated dirt	1	X	X	X			
PCB liquid waste	1	X	X	X			X
Unused automotive paint	2	X	X	X			
Vacuum filter solids	2	X	X	X			
Output Streams							
APCE aqueous effluent	1 to 4, 7 to 10	X	X	X			X
Boiler tube soot blowdown	3	X	X	X	X	X	
Cyclone ash	1 and 4	X	X	X	X	X	
Incinerator bottom ash	5 to 8	X	X	X	X	X	
Wastewater treatment facility belt filter cake residue	3 and 7	X	X	X	X	X	
Rotary kiln ash	1 to 3, 8, 9	X	X	X	X	X	X
Stack condensate	4						

[a]*Site 1 only.*
APCE = Air polution control equipment
CS = O-chlorobenzalmalonitrile
DCB = 1,4-Dichlorobutene-2

complete combustion (PICs) (especially possible with Site 4) or early ash quenching before completed ash burnout (possible with Sites 3 and 8). Except for Site 4, where the feed material was a relatively pure chemical, o-chlorobenzalmalononitrile (CS), the volatile organics found also appear in the waste feed. The cyclone ash from Site 4 shows several compounds that appear to be PICs. Because the cyclone ash was periodically emptied, and allowed to fall freely during the cyclone draining procedures, it was likely that the volatiles observed were adsorbed while the ash was in the cyclone and/or during the free fall upon draining.

In general, most organic compounds were detected at less than 10 ppm. Since most sites quench ash with water, especially if a rotary kiln discharges solid waste feed too quickly, it is possible for some of the organics to not be subjected to high enough temperatures for complete destruction (thus, the appearance of the organics in the ash). Also, the quench water is often recycled plant wastewater which may experience a buildup of these organic compounds and contaminate the ash (c.f., wet and dry ash from Site 8).

The total organic content in each ash stream, calculated by adding the concentrations of all hazardous organic compounds (RCRA, Appendix VIII) detected, indicated that kiln and bottom ash have similar semivolatile organic content with average concentrations measured approximately 100 mg/kg. Average volatile organic content was higher for the kiln ash. The bottom ash average would be increased, however, if values were deleted for Site 5's large incinerator (since that incinerator burned only liquid waste) and Site 8's bottom ash (since that ash was predominantly generated from liquid waste). Average leachable volatiles and semivolatile organics for each type of ash were less than 1 mg/L or 1 ppm. RCRA organics with the highest concentration in the TCLP leachates were toluene (1.7 ppm), phenol (1.8 ppm), methylene chloride and dimethyl phthalate (each at about 0.6 ppm), and MEK (0.3 ppm).

Volatile and semivolatile organics, detected in various APCE effluents, indicate that the highest concentrations of volatile organics were in the APCE effluent at Site 5. Since the cyclone ash sample at this site also contained volatile organics, these compounds may be attributed to byproduct emissions from the incinerator. Site 1 and 8 practice extensive water recirculation in comparison to the other sites which practice only some APCE effluent recirculation prior to discharge to an onsite wastewater treatment facility. Because of this higher recirculation, Site 1 and 8 APCE effluents are expected to have higher than average organic content in agreement with results of this study.

Priority Pollutant Metals

Analytical results for metals concentrations in all ash residual samples are

summarized in Table 3. Figures 1 and 2 show the ranges in total priority pollutant metals experienced in ash and ash leachate samples. The kiln ash indicates an average priority pollutant metal concentration of about 1 percent (10,000 ppm). The same average is lower for the bottom ash. Boiler ash from Site 3 has the highest concentration of metals, as indicated in Table 3. The small ash particle size at this site resulted in a high surface-to-mass ratio which favors metals condensation.

EP and TCLP metal analysis results illustrated in Figure 1 indicate that leachate concentrations are highest for boiler ash. Kiln ash leachate would be expected to have more metals than bottom ash leachate, but one very low zinc concentration apparently substantially skewed the EP toxicity kiln ash data.

Table 4 shows the highest metals concentrations experienced in all leachate test samples. EP leachate concentrations are also compared with applicable EP toxicity limits (standards set forth in Table 4 of 40 CFR 261.24). The results indicate that only 1 metals measurement of the EP leachate, out of 84 measurements performed for the whole study, exceeded the maximum concentration of contaminants for characteristics of EP toxicity. Hence, only the boiler ash at Site 3 (see Table 3), with a cadmium content of 8.6 mg/L versus an allowable standard of 1 mg/L, would be considered a hazardous waste for metals not already listed in 40 CFR Subpart D. The TCLP leachate, if subjected to the same standards, would have 3 measurements out of 84 exceeding an allowable concentration. Site 3 boiler ash would exceed the standards for cadmium at 6.7 mg/L, and selenium at 1.4 mg/L versus an allowable standard of 1 mg/L. Site 6 ash would exceed the standard for lead at 12 mg/L versus an allowable 5 mg/L. In general, the results from the two different extraction procedures were within a factor of three.

For leachate analysis, approximately 20 units of acidic water are used for each unit of ash. Thus, leachate concentrations (in mg/L) are expected to be about 20 times less than reported ash values (in mg/kg) for 100 percent soluble metals. Although several metals in ash concentrations are at less than detectable limits and cannot be further evaluated, solubility generally ranged from 1 to 10 percent. Metal concentrations greater than 1000 mg/kg of ash, included chromium (Site 3), copper

Table 3. *Concentration of Priority Pollutant Metals in Incinerator Residuals*

Site number	1	2	3	3	4	5
Stream description	Kiln ash	Kiln ash	Kiln ash	Boiler ash	Cyclone ash	Large incinerator bottom ash
	Concentration[a]					
	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)
Antimony	2 / <0.05 / 0.04	6 / <0.01 / <0.01	18 / 0.06 / <0.01	190 / <0.01 / <0.01	<1 / <0.01 / <0.01	3 / <0.01 / <0.01
Arsenic	4 / 0.23 / <0.01	2 / <0.01 / <0.01	3 / <0.01 / <0.01	14 / <0.01 / <0.01	<1 / <0.01 / <0.01	9 / 0.12 / 0.10
Beryllium	<1 / <0.01 / <0.01	<2 / <0.01 / <0.01	<7 / <0.01 / <0.01	6 / <0.01 / 0.08	<2 / <0.01 / <0.01	<2 / <0.01 / <0.01
Cadmium	<2 / <0.01 / <0.01	<1 / <0.01 / <0.01	<1 / <0.01 / <0.01	61 / 8.6 / 6.7	<1 / <0.01 / <0.01	2 / <0.01 / <0.01
Chromium	120 / 0.10 / 0.22	110 / 0.09 / 0.10	660 / 0.03 / 0.06	1800 / 0.03 / 0.36	7 / 0.03 / 0.03	520 / 098 / 0.20
Copper	6900 / 8.6 / 16	840 / 3.7 / 7.9	400 / 0.02 / 0.09	780 / 31 / 21	<4 / <0.01 / 0.02	500 / <0.01 / 0.11
Lead	220 / 2.3 / 3.5	100 / <0.01 / <0.01	610 / 0.04 / <0.01	5000 / 4.4 / 4.5	<1 / <0.01 / <0.01	1800 / <0.01 / <0.01
Mercury	<0.05 / <0.001 / <0.001	1.5 / <0.001 / <0.001	<0.1 / <0.001 / <0.001	0.2 / <0.001 / <0.001	<0.1 / <0.001 / <0.001	<0.1 / <0.001 / <0.001
Nickel	190 / 0.49 / 0.45	7300 / 6.9 / 6	240 / 0.79 / 13	4700 / 20 / 13	25 / 0.18 / 0.22	34 / 0.03 / 0.02
Selenium	<1 / <0.05 / 0.02	6 / 0.02 / 0.05	13 / 0.17 / 1.4	13 / <1 / 1.4	<1 / <0.01 / <0.01	8 / <0.01 / 0.03
Silver	11 / <0.01 / <0.01	8 / 0.05 / <0.01	4 / 0.02 / 0.05	190 / 0.09 / 0.05	120 / <0.01 / <0.01	16 / <0.01 / <0.01
Thallium	<1 / <0.01 / <0.02	<1 / <0.01 / <0.02	7 / <0.01 / <0.02	9 / 0.7[b] / <0.02	<1 / <0.01 / <0.02	<1 / <0.01 / <0.02
Zinc	160 / 0.14 / 0.42	640 / 1.8 / 2	21000 / 27 / 300	32000 / 1400 / 1200	200 / 2.2 / 2.6	1300 / 0.14 / 0.17
Comments						
Wet or Dry Ash	Wet	Wet	Wet	Wet	Dry	Dry

Site number	5	6	7	8	8	9
Stream description	Small incinerator bottom ash	Incinerator bottom ash	Incinerator bottom ash	Kiln ash	Incinerator bottom ash	Kiln ash
	Concentration[a]					
	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)	(mg/kg) / (mg/L) / (mg/L)
Antimony	<1 / <0.01 / 0.10	<1 / 0.07 / 0.06	49 / <0.01 / 0.02	240 / 0.49 / 0.36	32 / <0.05 / <0.01	<0.8 / <0.01 / 0.02
Arsenic	<1 / 0.12 / 0.54	8 / <0.01 / <0.01	12 / <0.06 / <0.01	11 / <0.06 / 0.02	27 / 0.22 / <0.01	2 / <0.06 / <0.01
Beryllium	<2 / <0.01 / <0.01	<2 / <0.01 / <0.01	<1 / <0.01 / <0.01	<1 / <0.01 / <0.01	<1 / <0.01 / <0.01	<1 / <0.01 / <0.01
Cadmium	<1 / <0.01 / <0.01	<1 / 0.04 / <0.01	<1 / <0.01 / <0.01	36 / 0.12 / 0.19	3 / 0.03 / <0.01	<1 / <0.01 / <0.01
Chromium	100 / 0.03 / 2.7	110 / 0.03 / <0.02	120 / <0.03 / <0.02	250 / <0.03 / <0.02	110 / 0.63 / 0.28	29 / 0.08 / <0.02
Copper	40 / 0.02 / 0.07	120 / 1.9 / 0.64	2000 / 13 / 11	2900 / 0.33 / 1.8	14 / 0.09 / 0.05	120 / <0.02 / 0.67
Lead	<1 / <0.01 / <0.01	1300 / 3.3 / 12	160 / 0.11 / 0.50	1600 / 0.11 / <0.01	280 / <0.07 / <0.01	490 / <0.07 / <0.50
Mercury	<0.1 / <0.001 / <0.001	<0.1 / <0.001 / <0.001	0.25 / <0.001 / <0.001	0.1 / <0.001 / <0.001	<0.05 / <0.001 / <0.001	<0.05 / <0.001 / <0.001
Nickel	3 / 0.04 / 0.27	22 / 0.33 / 0.49	650 / 13 / 4.0	100 / 0.42 / 0.71	15 / <0.03 / <0.01	21 / 2 / 0.49
Selenium	<1 / <0.1 / 0.12	12 / 0.03 / 0.02	19 / <0.05 / 0.02	<40 / <0.05 / 0.04	8 / <0.05 / <0.01	<4 / <0.05 / <0.01
Silver	54 / <0.01 / <0.01	21 / <0.01 / <0.01	9 / <0.01 / <0.01	3 / <0.01 / <0.01	<1 / <0.01 / <0.01	9 / 0.09 / <0.01
Thallium	6 / <0.01 / <0.02	<1 / 0.05 / <0.02	4 / <0.01 / <0.02	3 / <0.01 / 0.18	4 / <0.01 / <0.02	6 / <0.01 / <0.02
Zinc	200 / 0.31 / 0.17	810 / 16 / 9.5	850 / 65 / 98	2500 / 12 / 35	2200 / 8.5 / 20	44 / 0.67 / 1.9
Comments						
Wet or Dry Ash	Dry	Dry	Wet	Wet	Dry	Wet

[a] *Sample concentration / EP leachate concentration / TCLP leachate concentration.*
[b] *Thallium EP leachate concentration for Site 3 boiler ash measured as 0.7 but probably less due to interference.*

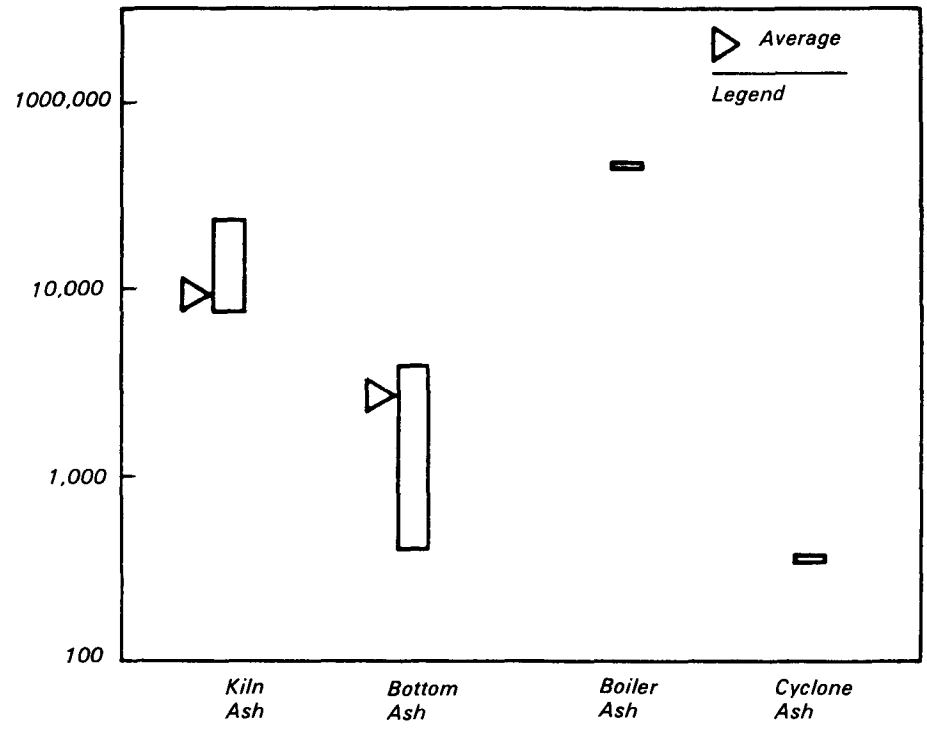

Figure 1. Total and average priority pollutant metals concentrations in ash.

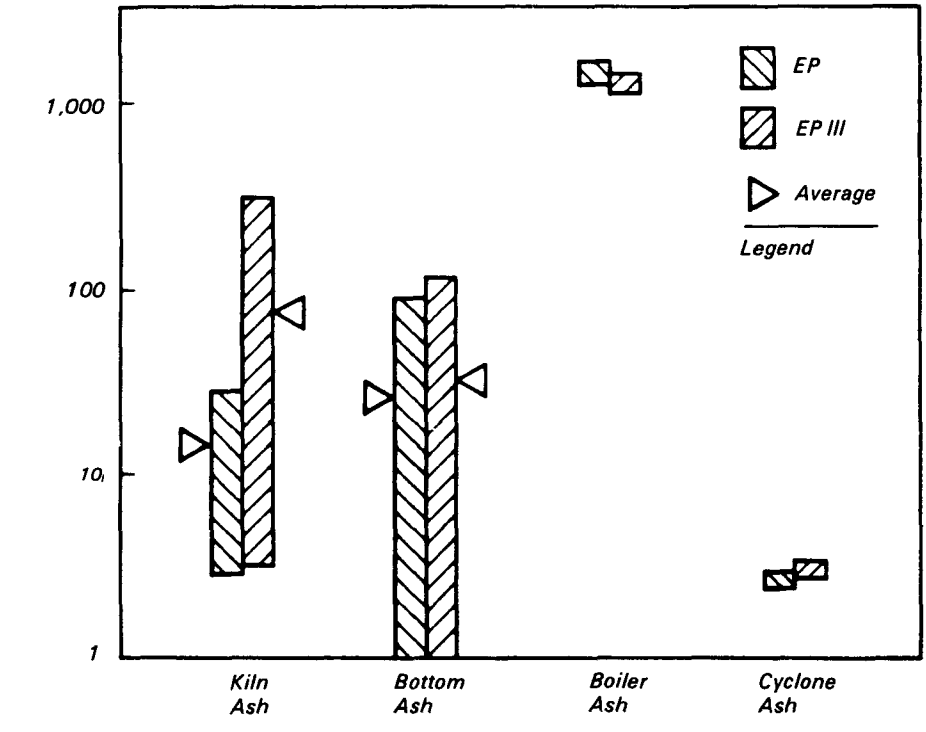

Figure 2. Total and average metals concentrations in ash leachate.

(Sites 1, 7, and 8) lead (Sites 3, 5, 6, and 8), nickel (Sites 2 and 3), and zinc (Sites 3 and 8). Most of the leachate measurements for antimony, arsenic, beryllium, cadmium, lead, selenium, silver, and thallium yielded values less than the detectable limits nominal of 0.01 to 0.05 mg/L of leachate. Mercury leachate measurements were all less than 0.001 mg/L of leachate.

These high concentrations in the ash did not always yield a good mass balance. Most notably, the calculated discharge rate for chromium (Site 3), copper (Site 1), and lead (Site 6), exceeded the calculated feedrate to the incinerator by a factor of 10. Copper (Site 7) showed a discharge rate 100 times the feedrate accountable by the waste feed samples. There are several possible reasons for these results. First, process data were not available for Site 5, and all streams were not sampled for Sites 7 and 8; thus these mass balances cannot be accurately made for those sites. In general, to improve representativeness of the samples, and to better close a metals mass balance, would have required more sampling (and analysis) of input and output streams over a longer test period.

APCE water effluents were also analyzed for priority pollutant metals. The results are summarized in Table 5. Two sites which most effectively limit discharging a wastewater effluent (through high recirculation), Sites 1 and 8, have the highest concentration of metals, 2,475 and 51 mg/L, respectively. The wastewater effluents for these sites were also found to contain higher than average organic levels. A comparison of these metals concentrations with EP toxicity limits reveals that the Site 1 effluents would be considered toxic for cadmium (3.5 mg/L), chromium (11 mg/L), and lead (860 mg/L), while the effluent from Site 8 would be considered hazardous for cadmium (2.8 mg/L), lead (31 mg/L), and selenium (2.1 mg/L). Sites with an apparent low effluent recirculation rate, such as Site 9, appear to have low metals concentration in the APCE effluent (2.3 mg/L).

Recommendations

On the basis of the data presented above, Acurex recommends that more sampling and analysis of hazardous waste incinerator residues be undertaken. Specifically, we recommend:

- Retesting, intermittently over a period of perhaps 4 to 6 months, two or three of the sites already tested.

This will allow EPA to evaluate the variations in residue quality over time at one site.

- Testing incinerator sites which have dry APCE systems in place. Two of the sites already tested will have their wet systems removed, and dry systems installed. The "dry sites" could also be new incinerator facilities.
- Testing sites which typically burn more chlorinated wastes,
- Testing some younger (in age) incinerators and those with more state-of-the-art equipment and controls
- Testing enough new incinerator sites to increase the data base to at least 20.

References

1. Trenholm, A., P. Gorman, and G. Jungclaus. *Performance Evaluation of Full-Scale Hazardous Waste Incinerators*. Midwest Research Institute, Kansas City, Missouri.
2. "Test Methods for Evaluating Solid-Waste-Physical/Chemical Methods," SW 846 Second Edition, U.S. EPA, April 1984.
3. "Toxicity Characteristic Leaching Procedure (TCLP)," U.S. EPA draft revised, December 20, 1985.

Table 4. *Highest Metals Concentrations in Ash Leachate in mg/L*

	EP		
	Toxicity limit	Concentration	TCLP Concentratic
Antimony	—	0.49	0.36
Arsenic	5	0.23	0.54
Beryllium	—	<0.01	0.08
Cadmium	1	8.6	6.7
Chromium	5	0.98	0.36
Copper	—	31	21
Lead	5	4.4	12
Mercury	0.2	<0.001	<0.001
Nickel	—	20	13
Selenium	1	0.17	1.4
Silver	5	0.09	0.05
Thallium	—	0.05	0.18
Zinc	—	1400	1200

Table 5. *Concentrations of Priority Pollutant Metals in APCE Aqueous Effluents, in mg/L*

Site number	1	2	3	4	7	8[a]	9	10
Antimony	0.1	<0.01	0.61	<0.01	1.7	4.1	<0.03	0.1
Arsenic	0.2	<0.01	<0.01	<0.01	0.06	0.4	<0.1	<0.1
Beryllium	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.0
Cadmium	3.5	<0.01	0.04	<0.01	0.08	2.8	<0.01	<0.0
Chromium	11	<0.05	0.1	0.06	0.28	3.8	0.27	0.2
Copper	550	<0.04	0.26	<0.04	0.64	2.2	0.46	0.0
Lead	860	<0.01	2.6	<0.01	2.6	31	0.38	0.1
Mercury	0.06	0.013	0.013	<0.001	<0.005	<0.005	<0.005	<0.0
Nickel	<0.02	23	0.17	0.05	0.75	1.5	0.07	0.4
Selenium	0.09	<0.01	<0.01	<0.01	0.6	2.1	<0.1	0.2
Silver	<0.01	<0.02	0.04	<0.02	0.05	0.15	0.61	<0.0
Thallium	<0.01	1.3	16	0.02	0.16	1.6	0.31	0.0
Zinc	950	0.02	16	0.27	6.7	1.6	0.16	0.1
Total	2380	24.3	35.7	0.4	13.6	51.3	2.26	1.3

[a]*Highest values used for aqueous effluent recirculated from two cooling ponds.*

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The complete report, entitled "Characterization of Hazardous Waste Incineration Residuals," (Order No. PB 87-168 159/AS; Cost: $18.95, 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:

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