United States
Environmental Protection
Agency

Solid Waste and
Emergency Response
(OS-305)

EPA/530-SW-90-029B
March 1990

EPA

Characterization of Municipal Waste Combustion Ash, Ash Extracts, and Leachates

Executive Summary

EXECUTIVE SUMMARY

This report has been prepared for the United States Environmental Protection Agency (EPA) and the Coalition on Resource Recovery and the Environment (CORRE). EPA and CORRE have cosponsored this study, conducted by NUS Corporation, to enhance the data base on the characteristics of Municipal Waste Combustion (MWC) ashes, laboratory extracts of MWC ashes, and leachates from MWC ash disposal facilities.

The Coalition on Resource Recovery and the Environment (CORRE) was established to provide credible information about resource recovery and associated environmental issues to the public and to public officials. In providing information, CORRE takes no position as to the appropriateness of one technology compared to others. CORRE recognizes that successful waste management is an integrated utilization of many technologies which taken as a whole, are best selected by an informed public and informed public officials.

Incineration of municipal solid waste (MSW) has become an important waste disposal alternative because it provides an effective means of reducing the volume of MSW as well as an important source of energy recovery. Currently, 10 percent of MSW is incinerated. Based on the number of municipal waste combustion (MWC) facilities being planned across the country, this percentage is expected to increase to roughly 16-25 percent by the year 2000.

As incineration has grown in popularity, so has concern over the management of increasing volumes of ash. Ashes from MWC facilities have, on occasion, exhibited a hazardous waste characteristic as determined by the EP Toxicity Test. The debate regarding the regulatory status of ash and the representativeness and validity of the EP test continues. Congress is considering several legislative initiatives that would give EPA clear authority to develop special management standards for ash under Subtitle D of RCRA.

To conduct this study, NUS collected combined bottom and fly ash samples from five mass-burn MWC facilities and leachate samples from the companion ash disposal facilities.

The facilities sampled were selected by CORRE to meet the following criteria:

- The facilities were to be state-of-the-art facilities equipped with a variety of pollution control equipment.
- The facilities were to be located in different regions of the United States.
- The companion ash disposal facilities were to be equipped with leachate collection systems or some means of collecting leachate samples.

The identities of the facilities are being held in confidence.

The ash and leachate samples collected were analyzed for the Appendix IX semivolatile compounds, polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDDs/PCDFs), metals for which Federal primary and secondary drinking water standards exist, and several miscellaneous conventional compounds. In addition, the ash samples were analyzed for major components in the form of oxides. The ash samples were also subjected to six laboratory extraction procedures and the extracts were then analyzed for the same compounds as the ash samples. The following six extraction procedures were used during this study:

- Acid Number 1 (EP-TOX).
- Acid Number 2 (TCLP Fluid No. 1).
- Acid Number 3 (TCLP Fluid No. 2).
- Deionized Water (Method SW-924), also known as the Monofill Waste Extraction Procedure (MWEP).
- CO_2 saturated deionized water.
- Simulated acid rain.

These extraction procedures have been used separately by a variety of researchers on MWC ashes but never have all six procedures been used on the same MWC ashes. This study was designed to compare the analytical results of the extracts from all six procedures with each other and with leachate collected from the ash disposal facilities used by the MWC facilities.

All sampling, laboratory preparation, and laboratory analysis followed stringent EPA quality assurance/quality control (QA/QC) procedures. The work was performed in accordance with the Work Plan (Appendix A) prepared by NUS for this project and with a QA/QC Plan prepared by NUS and approved by EPA. A detailed listing of the positive results is presented in a data base which is included in this Report as Appendix B (Ash), Appendix C (Leachate), and Appendix D (Ash Extracts). The results in the data base are presented as reported by the laboratories, complete with the laboratory's qualifications. Summaries of the results are presented in Sections 2.0 through 7.0. These summaries include the laboratory's qualifiers and also qualifiers placed on the data as a result of data validation.

When the laboratories did not report a positive value for a compound (i.e., the compound was not present above laboratory detection limits), the compound was reported as not detected (ND) in the tables in the text. The laboratory detection limits are the method detection limits for each specific method, unless interferences were encountered during the analysis. When interferences occurred, the laboratory adjusted the method detection limits by an appropriate dilution factor. The analytical methods used in this study were selected so that the method detection limits were well below present levels of human, environmental, or regulatory concerns.

The EPA publication "Interim Procedures for Estimating Risk Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-Dioxins and Dibenzofurans (CDDs and CDFs)" was used to evaluate the dioxin data. These procedures use Toxicity Equivalency Factors (TEFs) to express the concentrations of the different isomers and homologs as an equivalent amount of 2,3,7,8-Tetrachloro Dibenzo-p-Dioxin (2,3,7,8-TCDD). The Toxicity Equivalents, as calculated by using the TEFs, are then totaled and compared to the Centers for Disease Control (CDC) recommended upper level of 2,3,7,8-TCDD Toxicity Equivalency of 1 part per billion in residential soil (Kimbrough, 1984).

The major features of the five MWC facilities are provided in Table ES-1, and the major features of the MWC Ash Disposal Facilities are provided in Table ES-2. Pertinent information regarding the operating conditions of the MWC facilities, as well as information about the air pollution control equipment used by the facilities, is also provided in Table ES-1.

TABLE ES-1

MAJOR FEATURES OF MWC FACILITIES

Operational Features	Facilities				
	ZA	ZB	ZC	ZD	ZE
Facility Type	Energy recovery, continuous feed, reverse-reciprocating grate.	Energy recovery, continuous feed, reciprocating grate.	Energy recovery, continuous feed, reverse-reciprocating grate.	Energy recovery, continuous feed, reciprocating grate.	Energy recovery, continuous feed, reciprocating grate.
Startup Date	May 1986	Early 1987	January 1987	1975	September 1987
Capacity	275 tons/day/boiler 2 boilers	75 - 100 tons/day/boiler 2 boilers	400 tons/day/boiler 3 boilers	750 tons/day/boiler 2 boilers	750 tons/day/boiler 2 boilers
Combustion Temperature	1,800-2,000°F at stoker	1,800°F	1,750-1,800°F	1500-1700°F flue gas as it enters superheater	1,800°F at the grate
Temperature of air entering the boiler	Under fire: 250°F Over fire: ambient	Under fire: ambient Over fire: ambient	Under fire: 380°F Over fire: ambient	Under fire: ambient Over fire: ambient	Under fire: ambient Over fire: ambient
Volume of air entering boiler	Under fire: 70,000-90,000 lb/hour Over fire: 41,000 lb/hour	Under fire: 10,890 cu ft/min Over fire: 5,900 cu ft/min	Under fire: 34,000 ft^3/min Over fire: 11,000 ft^3/min	Under fire: 48,000 ft^3/min Over fire: 32,000 ft^3/min	
Source of ash quench water	Floor drains, rain water.	Cooling tower and boiler blowdowns, septic system discharge, floor drains.	Tertiary effluent from neighboring sewage treatment plant.	Cooling tower and boiler blowdowns.	Wastewater from plant processes.
Air pollution control equipment	Lime slurry is injected into flue gas after economizer, fabric filter baghouses.	Dry lime is injected into flue gas after economizer, fabric filter baghouses. Fly ash has phosphoric acid added to it and is agglomerated before being mixed with bottom ash.	Electrostatic precipitators.	Electrostatic precipitators	Lime slurry is injected into flue gas after economizer, electrostatic precipitators. Fly ash has water added to it and is agglomerated before being mixed with bottom ash.
Approximate waste composition	Residential: 40% Commercial/ Light Industrial: 60%	Residential: 80% Commercial/ Light Industrial: 20%	Residential: 60% Commercial/ Light Industrial: 40%	Residential: 90% Commercial/ Light Industrial: 10%	Residential: 65% Commercial/ Light Industrial: 35%

TABLE ES-1
MAJOR FEATURES OF MWC FACILITIES
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Operational Features	Facilities				
	ZA	ZB	ZC	ZD	ZE
Amount of electricity generated	13.1 megawatts/hour	4.5 megawatts/hour	29 megawatts/hour	35 megawatts/hour	45 megawatts/hour
Amount of electricity used internally by facility	1.7 megawatts/hour	0.63 megawatts/hour	2.5 megawatts/hour	2.5 to 3.5 megawatts/hour	7 megawatts/hour
Material removed from incoming refuse	Large appliances, other unacceptable material diverted to demolition landfill.	Large appliances, material that will not pass through the boilers.	Large appliances, material that will not pass through the boilers.	Large appliances, material that will not pass through the boilers.	Large appliances, material that will not pass through the boilers.
Material removed from ash	Ferrous metal removed from ash at the MWC facility.	None.	Ferrous metal removed from ash at the MWC facility.	Ferrous metal removed from ash at the MWC facility.	Items greater than 10 inches in diameter.

TABLE ES-2

MAJOR FEATURES OF MWC ASH DISPOSAL FACILITIES

Operational Features	Facilities				
	ZA	ZB	ZC	ZD	ZE
Facility Type	Monofill - single clay liner	Monofill - double liner (HDPE and compacted till soil)	Codisposed facility - bottom-clay liner synthetic sidewall liners	Monofill - unlined. Ash is placed over trash deposited before 1975	Monofill - double liner (HDPE and clay)
Startup Date	1986	October 1988	Landfill - 1984 Ash Disposal - 1985	1975	1987
Disposal Capacity	83,400 cubic yards	90,000-100,000 tons	Total capacity 9 million tons	Remaining capacity - 990,000 tons (6 years)	Permitted for 20 years, approximately 3.8 million tons
Amount of Ash Disposed	150 tons/day	60 tons/day	400,000 tons/year. 40% ash (2/3 of ash from ZC MWC facility).	450 tons/day	525 tons/day
Materials other than Ash disposed of	None	None	Non-burnable materials from 2 MWC facilities. Overflow from 2nd MWC facility.	None	None
Leachate Collection System	Perforated PVC pipe in a coarse aggregate envelope	Slotted HDPE	Main header - PVC collection trenches - gravel with fabric filter	None - leachate samples were collected from well points installed in the ash	Slotted HDPE
Cover	Final cover - soil and HDPE	Daily cover - sand. Non working face covered by plastic to limit leachate generation	Daily - native soil and shredded tires. Intermediate - native soils. Final - native soils.	Daily cover - soil. Intermediate - soil compacted to 10^{-6} permeability. Final - clay or HDPE.	Daily cover - soil. Intermediate - soil compacted to 10^{-6} permeability. Final - clay of HDPE.
Compaction of Ash	Only as bulldozer spreads ash in ash fill.	Bulldozer spreads and compacts ash in 8-12 inch lifts.	Track mounted compactor.	Only as bulldozer spreads ash in ash fill.	Vibrating roller.

The major findings of the ash sampling and analyses during this study are described in the following paragraphs.

Of the five ash samples (one from each facility) analyzed for the Appendix IX semivolatile compounds, four samples contained bis(2-ethylhexyl)phthalate, three contained di-n-butyl phthalate, and one contained di-n-octyl phthalate. Two PAHs, phenanthrene and fluoranthene, were detected in only one of the five ash samples. These semi-volatile compounds were detected in the parts per billion (ppb) range.

The results for the five ash samples (one from each facility) analyzed for PCDDs/PCDFs are presented in Table ES-3. This table also includes the calculated Toxicity Equivalents (TE) for each homolog of PCDD/PCDF. These TEs were calculated using EPA's methodology (EPA, March 1987). The data in this table indicate that PCDDs/PCDFs were found at extremely low levels in each ash sample. The Total TE for each ash sample was below the Centers for Disease Control (CDC) recommended 2,3,7,8-TCDD Toxicity Equivalency limit of 1 part per billion in residential soil (Kimbrough, 1984).

All 25 of the ash samples (five daily composites from each facility) were analyzed for the metals on the primary and secondary drinking water standards lists as well as for the oxides of five major ash components. Although, the results from these analyses indicate that the ash is heterogeneous, this heterogenicity appears to have been reduced by the care taken when compositing the ash samples during this study. Comparison of the results of this study with results reported in the literature (EPA, October 1987) indicates that the variability of results for each compound appears to have been reduced in this study.

Metals showing the widest range of concentrations among samples collected at each facility included barium (ZB); cadmium (ZB); chromium (ZD, ZE); copper (ZA, ZB, ZC); lead (ZD); manganese (ZA, ZC); mercury (ZE); zinc (ZB, ZD, ZE); and silicon dioxide (ZA).

Metals showing the widest variation of concentrations between the facilities included barium (results for Facility ZC are lower than the results for the other facilities); iron (results for each facility vary from all of the other facilities); lead (results for Facility ZD are higher than the results for the other facilities); mercury (results for Facilities ZC and ZD are lower than the results for the other facilities);

TABLE ES-3

ASH DIOXIN RESULTS

Compound	Toxicity Equivalency Factor (TEF)(1)	Samples (pg/g or ppt)									
		ZA-AH-003		ZB-AH-001		ZC-AH-003		ZD-AH-003		ZE-AH-003	
		Value	Toxicity Equivalents	Value	Toxicity Equivalents	Value	Toxicity Equivalents	Value	Toxicity Equivalents	Value	Toxicity Equivalents
2,3,7,8-TCDD	1	10	10	24	24	16	16	35	35	10	10
Other TCDD	0.01	206	2.06	351	3.51	281	2.81	541	5.41	120	1.2
2,3,7,8-TCDF	0.1	263	26.3	617	61.7	236	23.6	626	62.6	176	17.6
Other TCDF	0.001	1,688	1.69	3,721	3.72	1,208	1.21	2,633	2.63	1,136	1.14
1,2,3,7,8-PeCDD	0.5	33	16.5	118	59	71	35.5	ND	0	35	17.5
Other PeCDD	0.005	317	1.59	759	3.80	1,051	5.26	1,910	9.55	248	1.24
1,2,3,7,8-PeCDF	0.1	61	6.1	194	19.4	64	6.4	151	15.1	52	5.2
2,3,4,7,8-PeCDF	0.1	46	4.6	162	16.2	56	5.6	171	17.1	43	4.3
Other PeCDF	0.001	484	0.484	1,527	1.53	607	0.607	1,736	1.74	448	0.448
1,2,3,4,7,8-H_XCDD	0.04	12	0.48	40	1.6	66	2.64	86	3.44	11	0.44
1,2,3,6,7,8-H_XCDD	0.04	17	0.68	34	1.36	90	3.6	148	5.92	11	0.44
1,2,3,7,8,9-H_XCDD	0.04	28	1.12	79	3.16	120	4.8	194	7.76	22	0.88
Other H_XCDD	0.0004	154	0.062	342	0.137	925	0.37	853	0.34	104	0.042
1,2,3,4,7,8-H_XCDF	0.01	74	0.74	336	3.36	218	2.18	654	6.54	95	0.95
1,2,3,6,7,8-H_XCDF	0.01	131	1.31	524	5.24	279	2.79	660	6.60	134	1.34
1,2,3,7,8,9-H_XCDF	0.01	36	0.36	127	1.27	193	1.93	479	4.79	45	0.45
2,3,4,3,7,8-H_XCDF	0.01	5	0.05	54	0.54	70	0.70	124	1.24	20	0.20
Other H_XCDF	0.0001	281	0.0281	939	0.0939	635	0.0635	1,686	0.169	280	0.028
1,2,3,4,6,7,8-H_PCDD	0.001	159	0.159	319	0.319	1,849	1.85	1,555	1.56	122	0.122
Other H_PCDD	0.00001	140	0.0014	288	0.00288	1,511	0.0151	1,384	0.0138	0	0
1,2,3,4,6,7,8-H_PCDF	0.001	139	0.139	539	0.539	653	0.653	1,842	1.84	155	0.155
1,2,3,4,7,8,9-H_PCDF	0.001	8	0.008	48	0.048	83	0.083	119	0.119	16	0.016
Other H_PCDF	0.00001	51	0.00051	197	0 00197	254	0 00254	384	0.00384	44	0.00044
OCDD	0	313	0	544	0	6,906	0	4,519	0	294	0
OCDF	0	66	0	243	0	563	0	893	0	59	0
TOTAL TEs			74.5		211		119		189		63.7

(1) Toxicity Equivalency Factors are EPA's current recommended Factors, (EPA, March 1987).

ND Not detected below 221 pg/g.

sodium (results for Facilities ZD and ZE are lower than the results for the other facilities); calcium oxide (the results for Facilities ZA and ZB are higher than the results for the other facilities); and silicon dioxide (the results for Facility ZC are higher than the results for the other facilities).

Some additional findings of the ash sampling and analyses are as follows:

- The ashes are alkaline with the pH ranging from 10.36 to 11.85.
- The ashes are rich in chlorides and sulfates. The total soluble solids in the ashes varied from 6,440 to 65,800 ppm.
- The ashes contained unburnt total organic carbon (TOC) ranging from 4,060 ppm (0.4 percent) to 53,200 ppm (5.32 percent).

The major findings of the leachate sampling and analysis during this study are summarized in the following paragraphs.

Only four Appendix IX semivolatile compounds were found in the leachates from the ash disposal facilities. Benzoic acid was found in both leachate samples collected at one of the five ash disposal facilities. Phenol, 3-methylphenol, and 4-methylphenol were found in some of the leachate samples from one of the other facilities. All of these compounds were detected at very low levels (2-73 ppb).

PCDDs/PCDFs were only found in the leachate from one facility. The homologs found are the more highly chlorinated homologs. The data obtained during this study appears to indicate that PCDDs/PCDFs do not readily leach out of the ash in the ash disposal facilities. The low levels found in the leachates of the one facility probably originated from the solids found within the leachate samples because these samples were not filtered nor centrifuged prior to analysis.

None of the leachate samples exceeded the EP Toxicity Maximum Allowable Limits established for the eight metals in Section 261.24 of 40 CFR 261. In addition, the data from this study indicate that although the leachates are not used for drinking purposes, they are close to being acceptable for drinking water use, as far as the metals are concerned.

Some other findings of the leachate sampling and analyses are as follows:

- Sulfate values ranged from 14.4 mg/L to 5,080 mg/L, while Total Dissolved Solids (TDS) ranged from 924 mg/L to 41,000 mg/L.

- The field pH values ranged from 5.2 to 7.4.

- Ammonia (4.18-77.4 mg/L) and nitrate (0.01-0.45 mg/L) were present in almost all leachate samples.

- Total Organic Carbon values ranged from 10.6 to 420 ppm.

The major findings from the analysis of the ash extracts during this study are summarized as follows:

- Of the five composite samples of the deionized water (SW-924) extracts analyzed for the Appendix IX semivolatile compounds (one from each facility), only one sample contained low levels of benzoic acid (0.130 ppm).

- None of the extracts contained PCDDs/PCDFs. These data confirm the findings of the actual field leachate samples that PCDDs/PCDFs are not readily leached from the ash.

The data obtained during the metals analyses of the ash extracts indicate that, in general, the extracts from the EP Toxicity, the TCLP 1, and the TCLP 2 extraction procedures have higher metals content than the extracts from the deionized water (SW-924), the CO_2, and the Simulated Acid Rain (SAR) extraction procedures. The EP Toxicity Maximum Allowable Limits for lead and cadmium were frequently exceeded by the extracts from the EP Toxicity, TCLP 1, and TCLP 2 extraction procedures. One of the extracts from the EP Toxicity extraction procedure also exceeded the EP Toxicity Maximum Allowable Limit for mercury.

None of the extracts from the deionized water (SW-924), the CO_2, and the Simulated Acid Rain (SAR) extraction procedures exceeded the EP Toxicity Maximum Allowable Limits. In addition, the majority of the extracts from these three extraction procedures also met the Primary and Secondary Drinking Water Standards for metals

Table ES-4 compares the range of concentrations of the metals analyses of the ash extracts with the range of concentrations for leachate as reported in the literature (EPA, October 1987) and the range of concentrations for the leachates as determined in this study. For the facilities sampled during this study, the data in Table ES-4 indicate that the extracts from the deionized water (SW-924), the CO_2, and the SAR extraction procedures simulated the concentrations for lead and cadmium in the field leachates better than the extracts from the other three extraction procedures.

TABLE ES-4

COMPARISON OF ASH EXTRACT METAL ANALYSES RESULTS WITH LEACHATE METAL ANALYSES RESULTS

Parameter	Samples (µg/L)							
	EP TOX Extracts	TCLP 1 Extracts	TCLP 2 Extracts	CO_2 Extracts	DI H_2O Extracts	SAR Extracts	Leachate (Literature)(1)	Leachate (CORRE)
Arsenic	ND-31	ND	ND-60	ND-53	ND-45	ND	5-218	ND-400
Barium	23-455	161-1,850	12-809	126-530	139-3,050	129-3,960	1,000	ND-9,220
Cadmium	25-1,200	ND-1,150	ND-1,560	ND-354	ND-7.6	ND-6.0	ND-44	ND-4
Chromium	ND-86	ND-8.0	ND-799	ND-9.8	ND-16	ND-10	6-1,530	ND-32
Copper	24-5,170	5-858	5.4-1,400	8.8-620	12-534	8.5-610	22-24,000	ND-12
Iron	ND-82,000	ND-7,220	ND-162,000	ND-304	ND-115	ND-97	168-121,000	108-10,500
Lead	ND-19,700	ND-10,500	ND-26,400	ND-504	ND-3,410	ND-3,940	12-2,920	ND-54
Manganese	250-8,540	ND-5,170	3.8-7,370	ND-2,390	ND-20	ND-6.4	103-4,570	310-18,500
Mercury	ND-203	ND-3.8	ND-4.6	ND-155	ND-0.96	ND-1.1	1-8	ND
Selenium	ND	ND	ND	ND	ND	ND-23	2.5-37	ND-340
Silver	ND	ND	ND	ND-16	ND	ND	70	ND
Sodium	33,600-225,000	1,380,000-1,640,000	38,700-228,000	24,800-168,000	24,100-209,000	24,200-201,000	200,000-4,000,000	188,000-3,800,000
Zinc	67-95,600	9.7-79,500	26-164,000	5-127,000	5.4-1,340	12-1,290	ND-3,300	5.2-370

TABLE ES-4
COMPARISON OF ASH EXTRACT METAL ANALYSES RESULTS
WITH LEACHATE METAL ANALYSES RESULTS
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Parameter	Samples (µg/L)							
	EP TOX Extracts	TCLP 1 Extracts	TCLP 2 Extracts	CO_2 Extracts	DI H_2O Extracts	SAR Extracts	Leachate (Literature)(1)	Leachate (CORRE)
Aluminum Oxide*	ND-150,000	ND-62,800	ND-152,000	ND-90,700	ND-203,000	ND-118,000	NR	ND-920
Calcium Oxide*	592,000-4,810,000	666,000-2,750,000	692,000-3,640,000	398,000-1,920,000	141,000-1,740,000	142,000-1,800,000	21,000	64,600-8,390,000
Magnesium Oxide*	27,300-130,000	55-375,000	623-137,000	207-59,300	21-379	12-430	NR	14,800-367,000
Potassium Monoxide*	10,100-189,000	14,600-210,000	15,100-1,110,00	12,300-155,000	13,100-189,000	14,500-181,000	21,500	79,700-1,620,000
Silicon Dioxide*	5,090-98,700	379-51,700	820-143,000	418-71,800	402-3,990	364-3,770	NR	470-15,300

ND Not Detected.
NR Not Reported in the literature.
(1) EPA, October 1987.
* The ash extracts were analyzed as ions for these compounds and reported as oxides. The leachates were analyzed and are reported as ions for these compounds.