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Project Summary

Emissions of Metals and Organics from Municipal Wastewater Sludge Incinerators

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In order to provide data for a sludge regulations development effort, emissions of metals and organics from a series of four wastewater sludge incinerators were measured. Three multiple hearth units and one fluidized bed combustor were tested. Emissions were controlled with a combination of venturi and/or tray impingement scrubbers. One site incorporated an afterburner as well. Flue gas testing was conducted at the inlet and outlet to the air pollution control devices at two of the plants. Feed sludge was also extensively tested for moisture, metals, and organics, as well as overall feed rate and heating value. Testing operating conditions were categorized as short-term versus normal or long-term conditions, which include transients, start-up, feed interruptions, etc.

All test results are fully documented in individual site reports. Emission test results for particulate matter/metals sampling are separated into short-term versus long-term tests. Gas concentrations, mass emissions rates, metals-to-particulate ratios, and emission factors are presented. Results are given for chromium VI sampling efforts. Metals concentrations in the various process streams (sludge feed, scrubber water, and bottom ash) are also given.

Volatile and semivolatile test results are also presented for flue gas samples as well as sludge feed samples. Certain compounds were detected at higher mass rates in the flue gas than in the sludge, designating them as products of incomplete combustion (PICs).

All other test results including CEM data, PSD data, CDD/CDF data, and operating data are all presented in the report volumes.

This Project Summary was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in the reports listed at the end of this summary. (See Project Report ordering information at back.)

Introduction

The U.S. Environmental Protection Agency (EPA) has drafted regulations for air emissions from municipal wastewater sludge incinerators that are based on cancer risk by inhalation of various metals and organics. The regulations were authorized under Section 405d of the Clean Water Act. A proposal soliciting public comments was published in the *Federal Register* on February 6, 1989. Final regulations are scheduled for publication in the *Federal Register* in January 1992.

To provide data for these regulations, Radian Corporation performed emissions stack testing. These tests were performed at four operating municipal wastewater sludge incinerators from April to October 1987. The project was jointly funded by EPA's Risk Reduction Engineering Laboratory (RREL) and its Office of Water Regulations and Standards (OWRS).

During the project, metals and organics data were collected to determine:

- Long-term stack emissions over a range of operating conditions;

- Long-term and short-term stack emission rates as related to sludge composition;
- If short-term stack emissions data taken during periods of best operation can approximate long-term stack emissions;
- The efficiency of wet scrubbers in removing metal and organic stack emissions; and
- Cause and effect relationships between incinerator operation and emissions (including the use of an afterburner).

Test Methods

At Sites 1 and 3, emissions testing was performed only at the control device outlet (exhaust stack). At Sites 2 and 4, emissions were measured at both the control device inlet and outlet. Also, at all four sites, samples of the sludge feed, scrubber water, and bottom ash were collected. Analyses of particle size distribution (PSD) were performed for Sites 2 and 4 and analyses of chlorinated dibenzo-*p*-dioxins and dibenzofurans (CDD/CDF) were performed for Site 4.

Particulate matter (PM) and metals sampling was conducted at the scrubber inlet/outlet according to EPA Reference Method 12 (Alternate). After gravimetric analysis of the filters, the particulate was digested in nitric acid and combined with the impinger solutions for analysis. Atomic adsorption (AA) analysis was used for the determination of arsenic and lead. The determination of beryllium, cadmium, chromium, and nickel was performed using the inductively coupled argon plasma (ICAP) technique.

Flue gas sampling for volatile organics was performed using the most recently developed method by EPA. This method, using the volatile organic sampling train (VOST) (SW-846, Method 0030 for sampling and Method 5040 for analysis), is designed to collect volatile organic compounds with boiling points between 30°C and 100°C. The organics are collected on two resin traps in series containing Tenax resin and charcoal. The sample is collected at 1 L/min for 20 min for each pair of traps. Four pairs of traps are collected per test run. The resin traps are analyzed by the purge and trap techniques followed by gas chromatography/mass spectrometry (GC/MS).

Semivolatile samples of the flue gas were collected according to the semi-VOST method developed by EPA. The method is basically a modification of EPA Reference Method 5 with a condenser and adsorbent module added after the filter and before the impinger train to collect semivolatile organics. The particulate filter, resin trap and impinger solutions are extracted with organic solvent, concentrated, and analyzed by GC/MS.

Grab samples of the process samples, which included feed sludge, bottom ash, and scrubber influent and effluent water, were collected at regular intervals during flue gas sampling. The sludge feed was sampled from the feed conveyor after dewatering. Bottom ash was collected from an intermediate point on the conveyor system prior to combination with other ashes. Scrubber water was collected from taps in the pipes. Hourly or 30 min grab samples were combined at the end of a test run and analyzed following similar analytical schemes used for the flue gas samples.

Continuous emissions monitoring was also conducted at all four test sites. Gases such as O_2, CO_2, CO, SO_2, NO_x and total hydrocarbons (THC) were continuously monitored daily. All results are tabulated and graphically presented in the individual site reports.

The key operating parameters that were monitored include incinerator operating parameters, sludge feed characteristics, and wet scrubber system operating data.

Results

The metals found in greatest concentrations in the sludge were lead, chromium, and nickel. The highest metal emission rates (Table 1) were of lead and cadmium. Chromium, arsenic, and nickel were the metals most effectively removed by the scrubbers (Table 2). Lead emissions appeared to increase with increasing maximum hearth temperature.

Testing for organics, in terms of volatile species (B.P. 30°C - 100°C) (Table 3) and semivolatile species (Table 4), took place. For the volatile species, toluene had the highest concentration in the sludge and acrylonitrile, benzene, toluene, chloroform, and vinyl chloride had the highest emission rates. Certain compounds were detected in higher amounts at the stack when compared to the sludge indicating that they were PICs (Table 5). Certain species also appeared to be stripped from the primary and secondary treatment effluent used in the scrubbers.

Few of the target semivolatile compounds were detected in either the sludge feed or at the stack. Bis(2-ethylhexyl) phthalate had the highest concentration in the sludge whereas phenol, naphthalene, and dichlorobenzene had the highest emission rates at the stack.

The full reports were submitted in fulfillment of Contract No. 68-02-4288 by Radian Corporation under the sponsorship of the U.S. Environmental Protection Agency. A paper containing data summaries has also been published in *Process Safety and Environmental Protection, Transactions of the Institution of Chemical Engineers* (England), Part B, Volume 69, Number B1, pp 20-28, February 1991.

Table 1. *Particulate and Metals Stack Emission Factors for Steady State and Normal Operation*

	Emission factors (g metal emitted/g metal fed)							
	Site 1		Site 2		Site 3	Site 4 (all steady state)		
Pollutant	Steady state	Normal	Steady state	Normal	Steady state	Cool AB off[a]	Hot AB on[a]	Hot AB off[a]
PM (g/kg dry sludge feed)	3.18	2.63	0.41	0.38	0.396	1.2	0.55	1.3
Arsenic	<0.015[b]	<0.029[b]	0.031	0.075	0.0011	0.0026	0.0017	0.0013
Beryllium	ND[c]	ND	ND	0.002	ND	ND	ND	ND
Cadmium	0.10	0.15	0.21	0.22	0.041	0.20	0.23	0.18
Chromium	0.002	0.001	0.0065	0.0038	0.0025	NA	NA	NA
Lead	0.12	0.21	0.030	0.047	0.0013	0.10	0.19	0.14
Nickel	0.010	0.006	0.013	0.0097	0.0049	0.0013	0.0007	0.0013

[a] Cool, AB off = Cool furnace, afterburner off. Hot, AB on = Hot furnace, afterburner on. Hot, AB off = Hot furnace, afterburner off.

[b] Arsenic not detected in sludge. Detection limit used to calculate emission factor.

[c] ND = Not detected.

Table 2. *Metals and Particulate Removal Efficiency across Scrubber (%)*

Element	Site 2		Site 4 (Steady state Cool AB off)
	Steady state	Normal	
Arsenic	77.2	77.7	97.2
Beryllium	>74.6[a]	87.9	NA[b]
Cadmium	62.8	68.1	47.1
Chromium	79.1	90.6	98.0
Lead	76.5	78.1	36.6
Nickel	53.1	80.3	95.4
PM	95.1	95.4	97.1

[a] Not detected at outlet. Detection limit used to calculate removal efficiency.
[b] NA = Not available. Beryllium not detected at inlet but detected at outlet.

Table 3. *VOC Stack Emission Rates under Steady State (gram/hr)*

Compound	Site 1	Site 2	Site 3	Site 4	
				Steady state	Hot furnace, afterburner on
Acrylonitrile	6.23	12.6	ND[a]	21.6	0.317
Benzene	7.87	5.29	0.401	4.40	0.107
Carbon tetrachloride	0.0474	0.0026	0.014	9.20	0.0055
Chlorobenzene	0.490	0.356	0.0051	0.536	0.176
Chloroform	2.27	0.609	3.89	0.251	0.318
1,2-Dichloroethane	0.012	ND	ND	ND	0.0196
trans-1,2-Dichloroethane	0.0952	0.009	ND	0.0297	ND
Ethylbenzene	0.795	0.445	0.024	1.06	0.0125
Methylene chloride	1.04	0.577	0.070	1.47	0.270
Tetrachloroethene	5.74	0.882	0.151	0.892	0.596
Toluene	2.36	11.9	0.067	4.15	0.429
111-Trichloroethane	0.134	0.020	0.043	1.10	0.896
Trichloroethene	0.643	0.157	0.011	1.51	0.990
Vinyl chloride	2.49	7.97	ND	1.10	ND
Butene	1.14	0.152	ND	1.63	ND
Methylhexene	0.342	ND	ND	0.204	ND
Xylene	2.08	1.00	0.405	0.287	0.038
Trimethylbenzene	0.092	1.59	0.051	0.020	0.200
Thiophene	0.262	1.84	ND	0.346	ND
Pentene	0.625	0.123	ND	1.54	ND

[a] ND = Not detected.

Table 4. *Emission Rates for Semivolatiles (gram/hr)*

Compound	Site 1 (controlled)	Site 2		Site 3 (controlled)	Site 4 (uncontrolled)
		(uncontrolled)	(controlled)		
Phenol	ND	49	2.3	ND	30.1
Naphthalene	ND	18	2.4	ND	13.1
Bis(2-ethylhexyl)phthalate	0.89	1.1	0.85	0.3	ND
1,2-Dichlorobenzene	1.0	0.44	0.51	ND	ND
1,3-Dichlorobenzene	0.83	ND	0.05	ND	ND
1,4-Dichlorobenzene	2.2	0.48	0.62	ND	
2-Nitrophenol	ND	5.5	1.6	ND	ND

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Table 5. Summary of VOCs Formed as Products of Incomplete Combustion

Site 1	*Site 4*
Acrylonitrile	*Cool furnace, afterburner off*
Benzene	*Acrylonitrile*
Methylene chloride	*Benzene*
Tetrachloroethene	*Chlorobenzene*
Toluene	*Ethylbenzene*
Vinyl chloride	*Toluene*
	Vinyl chloride
Site 2	*Hot furnace, afterburner on*
Acrylonitrile	*Acrylonitrile*
Benzene	
Vinyl chloride	
Site 3	
Chloroform	

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The complete report, entitled "Emissions of Metals and Organics from Municipal Wastewater Sludge Incinerators," consisting of eight volumes, will be sold as a set (Order No. PB91-151472; Cost $160.00, subject to change) or singly.
"Volume I: Summary Report," (Order No. PB91-151480; Cost: $15.00, subject to change) presents a summary of all the emission test data.
"Volume II: Site 1 Final Emission Test Report," (Order No. PB91-151498; Cost: $31.00, subject to change),
"Volume III: Site 2 Final Emission Test Report" (Order No. PB91-151506; Cost: $31.00, subject to change),
"Volume IV: Site 2 Final Emission Test Report—Appendices," (Order No. PB91-151514; Cost: $11.00, subject to change),
"Volume V: Site 3 Final Emission Test Report," (Order No. PB91-151522; Cost: $23.00, subject to change),
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"Volume VII: Site 4 Final Emission Test Report—Appendices," (Order No. PB91-151548; Cost: $23.00, subject to change), present the detailed test results from each individual incinerator test program.
"Volume VIII: GC/MS Tapes Review Report," (Order No. PB91-151555; Cost: $23.00, subject to change) presents the findings from the review of the original GC/MS organics data. The GC/MS chromatograms were reviewed and additional volatile and semivolatile organics data were retrieved.
All volumes of this report will be available from:
National Technical Information Service
5285 Port Royal Road
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