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Project Summary

Environmental Assessment of a Waste-to-Energy Process: Braintree Municipal Incinerator

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Field tests were conducted at the Braintree Municipal Incinerator in Braintree, Massachusetts for the purpose of providing data on multi-media emissions to help define potential environmental impacts and pollution control technology needs. The waterwall incinerator tested was fired with unprocessed refuse at a rate of about 5 tons/hr. Air pollution control was provided by an ESP. Primary emphasis was placed on evaluating air emissions, including criteria pollutants, as well as hazardous trace metals and organic compounds. Trace elements were found to be particularly concentrated in the incinerator bottom ash. Levels of major quality parameters in effluent from the bottom ash quench did not appear to be of concern. Analysis of fly ash collected by the ESP showed the presence of chlorides, sulfates, and certain trace elements. Stack emissions of NO_x (54 ppm), SO_2 (48 ppm), hydrocarbons (11 ppm), and chlorides (<120 mg/Nm³) were low. Particulate emissions average 0.24 gr/dscf, corrected to 12% CO_2 which was higher than expected. However, the high emissions were subsequently found to be related to deficiencies in plant operation. Multi-media emissions were evaluated using EPA's SAM-1A protocol.

Introduction

The EPA's Industrial Environmental Research Laboratory in Cincinnati is presently supporting a large-scale research program to conduct an environmental assessment of various waste-to-energy conversion systems. As part of this program, field tests were carried out by Midwest Research Institute (MRI) at the Braintree Municipal Incinerator in Braintree, Massachusetts in January, 1978. The sampling study was primarily designed to provide information on uncontrolled and controlled air emisssions so that control technology needs could be identified. A secondary objective was to conduct multi-media sampling to obtain data for an overall environmental assessment of the incineration process, including air, water, and solid waste effluent streams.

This paper presents a description of the incinerator facility, a summary of the sampling and analytical methods used, a discussion of the test results and conclusions of the study.

Description of the Facility

The Braintree Municipal Incinerator is a mass-burn facility, firing municipal refuse which is collected from the town of Braintree and surrounding communities. The plant, which was constructed in

1971, consists of twin waterwall combustion units, each with a design capacity of 120 tons of refuse per 24-hr period. A portion of the steam produced (20% to 35%) is supplied to neighboring small manufacturers and the remainder is condensed. Each furnace is equipped with an electrostatic precipitator for emission control and both ESP's exhaust to a common stack.

The "as received" refuse is fed to a charging chute for each furnace by an overhead crane. The material is first dried on an inclined stoker grate before being depositied on the horizontal, travelling grate. Underfire air is supplied to the combustion bed. Unburned and noncombustible materials at the discharge end of the grate are quenched with water before removal to a landfill.

The Riley Stoker boilers are of a single pass design and have about 895 ft^2 of waterwall heating surface prior to the boiler tub section. Total heating surface area is 3,305 ft^2. Rated capacity of each furnace is 30,000 lb of steam per hour at 400°F and 250 psig.

The electrostatic precipitator is a single field, 12 passage unit, with a specific collection area of 125 ft^2/1000 acfm. It was designed for a collection efficiency of 93%. A bypass duct connects the inlet ducts to the two precipitators so that the exhaust gases from one boiler can be diverted through both collectors in a parallel arrangement or through the opposite precipitator.

Sampling and Analysis Methodology

The environmental assessment program carried out at the Braintree incinerator consisted primarily of the determination of flue gas constituents. The sampling efforts also included measurements of the refuse feed and the solid and liquid effluent streams.

All tests were conducted while the incinerator was operated at its design refuse feed rate at 4.5 mg/hr (5 tons/hr). Actual feed rates during the 3 days of testing ranged form 4.1 to 4.7 mg/hr. Testing was carried out on Boiler No. 1 with the flue gases diverted through the bypass arrangement to the No. 2 ESP. This was done to provide more suitable sampling conditions (smoother velocity profile) at the inlet to the collector.

The multi-media sampling matrix for this program is illustrated in Figure 1. The general sampling and analysis schemes for each feed/effluent stream are briefly described next.

Refuse Feed—Once each test day, a 90 Kg(200 lb) sample of raw refuse was taken and manually sorted into its metal, glass, and combustible components. After each fraction was weighed, a 1 ft^3 sample of combustible material was retained for analysis. Each refuse sample was analyzed for moisture content and higher heating value. Also, proximate and ultimate analyses were carried out. Elemental concentrations in the samples were determined using Spark Source Mass Spectrometry (SSMS).

Bottom Ash—A grab sample of bottom ash was collected for each hour of testing. At the end of the day, the samples were composited and then segregated into metal, glass, and combustible fractions. A 1 ft^3 portion of the combustible material was retained for analysis. Bottom ash analysis consisted of moisture determination and elemental analysis by SSMS.

Quench Water—Grab samples of effluent from the bottom ash quench trough were obtained each day and analyzed for BOD, COD, TSS, pH, phenols, and oil and grease.

ESP: Inlet—Uncontrolled particulate emissions were measured using EPA Method 5. One sampling run was conducted each day. Sample analysis included determination of the filterable particulate catch and also the organic and inorganic components of the condensible particulate. Particulate collected on the filters was analyzed for general elemental composition by SSMS and for seven specific metals (Fe, As, Sb, Hg, Pb, Cu, and Cd) by atomic absorption spectrometry (AAS).

EPA Ash—Samples of fly ash were collected hourly from the ESP hoppers and composited at the end of each test day. A 1 ft^3 sample was then extracted from each composite for analysis, which included elemental composition by SSMS, analysis for specific anion (Ce^-, F^-, Br^-, $SO_4^=$, NO_3^-, and CN^-), and determinations for polychlorinated biphenyl (PCB) and polycyclic aromatic hydrocarbon (PAH compounds)

Stack Emissions—Air emissions of the ESP outlet were sampled and analyzed for a variety of particulate and gaseous constituents.

Particulate sampling at the ESP outlet was carried out simultaneously with the sampling runs at the precipitator inlet, again using EPA Method 5. The resulting filter samples were analyzed for elemental composition by SSMS and AAS.

An Andersen cascade impactor w used to measure particle size distributi in the outlet gases. Two sizing runs w conducted each test day.

Gaseous composition of the flue ga included Orsat analysis for O_2 and C and continuous monitoring for O_2, N SO_2, CO, and total hydrocarbons.

An absorption sampling train, based guidelines presented in the *Los Ange APCD Source Testing Manual*, was us to obtain two daily samples which we analyzed for carbonyl materials. Anotl absorption sampling train was used determine levels of Cl, F, Br, and C anions, as well as vaporous mercury.

Finally, the Source Assessment Sa pling System (SASS) developed by EF was used to provide one sample for tl EPA Level 1 analytical matrix.

Discussion of Test Results

This section presents the results of tl sampling and analysis efforts. An evalu tion of the emissions using the Sour Analysis Model (SAM) is also summ rized.

Refuse Feed

Data obtained from analysis of tl refuse samples are presented in the con plete project report. The refuse sampl had an average heat of combustion 16,780 kJ/kg (7,214 Btu/lb). Correctior for a moisture content and percentage glass, metal, and inerts showed that th "as received" solid waste had a heatin value of 10,200 kJ/kg. The combustibl fraction of the refuse contained 0.33% sulfur and 4.6% ash, based on results the proximate/ultimate analysis.

Bottom Ash

Spark Source Mass Spectrometr (SSMS) analysis showed an increase i the concentration of nearly every elemer in the bottom ash relative to the refus feed. Even some of the more volatil elements, which would be expected t vaporize and be carried off with the flu gases (e.g., As, Sb, Pb), were found i greater concentrations in the bottom ash For example, a ten-fold increase in Pb was noted after the mass ratio of bottom ash to input refuse was determined However, it should be noted that the hand sorting technique used to separate the combustible materials from the raw refuse could have allowed lead containing metals to be incompletely separated from the paper and plastics.

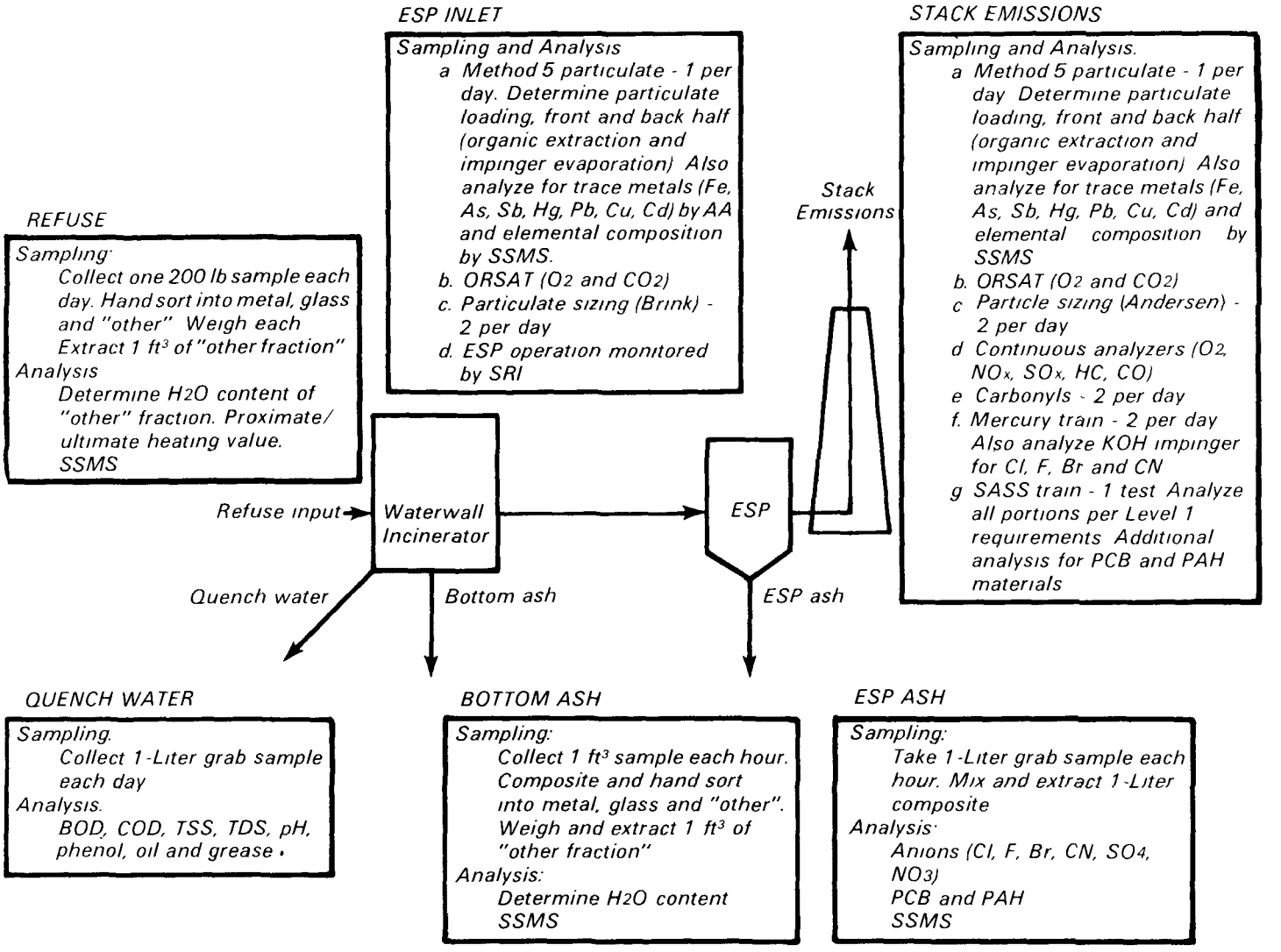

Figure 1. *Sampling and analysis matrix for the Braintree Municipal Incinerator.*

Quench Water

In general, the water quality analysis results revealed moderately low concentrations of BOD, COD, oil and grease, and TSS. TDS averaged 710 mg/liter at the outlet. Levels of phenol were all <0.1 mg/liter.

ESP Inlet

Uncontrolled particulate emissions averaged 0.82 g/dscm (0.36 gr/dscf), or 0.60 g/MJ heat input (1.4 lb/10^6 Btu). In terms of an uncontrolled emission factor, about 11.3 lb of particulate were discharged for every ton of refuse charged to the incinerator.

Analysis of the particulate catch for metals by atomic absorption (AA) showed relatively high levels of Pb in the uncontrolled particulate. Pb concentrations averaged 11.9 mg/dscm. Concentrations of Hg and As were low, (10 and 50 μg/dscm, respectively), while levels of Sb, Cd, Cu, and Fe were in the range of 100 to 1,000 μg/dscm.

In addition to these values, elemental analysis of the particulate samples by SSMS indicated average concentrations of Bi, Sn, Br, Zn, Ca, Ti, K, P, Si, Al, Na, and Mg which were greater that 1,000 μg/g (about 500 μg/dscm). The data also showed levels of Cl, F, and Br in this same range.

The concentrations of O_2 and CO_2 in the flue gas at the ESP inlet were 16.8% and 4.8% respectively.

ESP Ash

Grab samples of the fly ash collected in the ESP hoppers were taken during each test period and analyzed for anions, polychlorinated biphenyl (PCB) and polycyclic aromatic hydrocarbon (PAH) compounds, and elemental composition.

Concentrations of chlorides and sulfates averaged 41 and 10.4 mg/g, respectively. Levels of cyanides and nitrates were below the limit of detection while F^- and Br^-, concentrations were about 0.5 mg/g.

No PCBs were detected in the ESP ash. Concentrations were all below the detection limit of 0.4 mg/g. Four PAH compounds were identified in the ash samples, but their levels were below the

range of reliable quantitative analysis (0.3 to 0.7 μg/g).

Several elements in the SSMS elemental composition data had concentrations in excess of 1%. They included Ca, K, Cl, P, Si, Al, Mg, and Na. The concentrations of many elements increased in the collected fly ash relative to the uncontrolled particulate. This would seem to indicate that these elements were predominantly associated with larger sized particles. Conversely, there were also elements whose concentrations showed a definite decrease in the collected ash, namely Bi, Sb, Sn, Cd, Ag, Br, Se, As, Ga, Cu, and F. It is likely that these elements may be associated with smaller particles.

Stack Emissions

Gaseous analysis data of the stack effluent is shown in the complete report on this project. This data shows low concentrations of hydrocarbons (11.3 ppm), NO_x (54 ppm), and SO_2 (48 ppm), but high levels of carbon monoxide. CO levels ranged as high as 750 ppm and averaged 475 ppm. Emission factors for the criteria pollutants were calculated in terms of pounds per ton of refuse charged. These were as follows: particulate — 3.1 lb/ton, NO_x — 1.6 lb/ton, SO_2 — 2.0 lb/ton, CO — 8 5 lb/ton; and hydrocarbons — 0.12 lb/ton. Two other pollutants of interest, chlorides and lead, had emission factors of 1.92 lb/ton and 0.086 lb/ton, respectively

Filterable particulate emissions, which are tabulated in the complete project report, averaged 0.55 g/dscm corrected to 12% CO_2, which exceeded the applicable state and federal emission regulations of 0.23 and 0.18 g/dscm, respectively. The total uncorrected concentration was 0.22 g/dscm (0.094 gr/scf) of which 11% was condensible particulate. The high particulate loadings can be traced to an apparent low collection efficiency of the ESP. ESP efficiency during MRI testing was determined to be only 74%, while its design efficiency was reported to be 93%. Monitoring of the ESP during sampling did not indicate any abnormalities in it operation. However, plant personnel claimed subsequently that the high particulate levels were most likely the result of mechanical problems in the operation of the incinerator. A new series of compliance tests have been conducted since the MRI tests and the emission levels are reported to be within the compliance regulations.

Andersen impactor particle size analysis showed an average particle size of about 3μm at the ESP outlet. Approximately 22% of the particles were smaller than 0.6μm and about 23% were 10 μm or larger, indicating a fairly uniform distribution of particle sizes in the stack emissions.

Trace metal concentrations in the outlet particulate showed basically the same relative distribution as was seen in the inlet particulate but at generally reduced levels. Pb, at 5,400 μm/dscm, had the highest concentration while As and Hg had the lowest (16 and 14 μm/dscm, respectively). In terms of ppm (μg/g), the concentrations of Pb, As, and Hg were 47,600, 145, and 124, respectively.

The concentration of mercury in the particulate at the outlet was higher than the concentrations of the inlet. At the outlet, mercury concentration averaged 0.014 mg/dscm.

SSMS results showed that the concentrations of most elements decreased slightly or remained essentially the same in the stack emissions when compared to the uncontrolled emissions. Some elements increased in concentration and the most prevalent elements were Pb, Zn, Si, and Al.

Results of the sampling for carbonyl compounds showed very low concentrations, averaging 1.3 ppm.

Another absorbant train was used to sample for vaporous mercury and selected anions (Cl^-, F^-, Br^-, and CN^-). Vaporous Hg concentrations varied widely from 30 to 1,800 μg/m³. The average was 560 μg/m³. The wide variation in Hg levels could have been the result of fluctuations in mercury-bearing materials in the refuse. Results of the anion analysis showed all concentrations at or near the limits of detection. The highest chloride concentration was 190 μg/m³ (130 ppm).

Stack emissions sampling conducted using SASS equipment indicated that 43% of the particulate was 1 μm or smaller in size. PCB analysis of the SASS organic module revealed observable levels only in the XAD-2 resin absorbent. About 100 μg of PCB (reported as DCB) were detected, which corresponds to a concentration of 4 μg/m³. The PCB concentration in the particulate was below the detectability of the GC/MS analysis technique used. Four PAH compounds were quantitatively identified in the XAD-2 resin and aqueous condensate. All levels, however, were quite low. Highest observed concentrations was 4 μg/m³.

Level 1 analysis for the vaporous metals As, Sb, and Hg, showed the highest concentrations in the particulate sample fractions, indicating possible adsorption of these metals on the particulate. Sb showed the greatest increase in concentration in the finer particle size.

Organic analysis of the SASS train components was carried out in accordance with EPA Level 1 protocol. These data were interpreted using EPA's Source Analysis Model (SAM-1A) which is discussed below.

SAM-1A

Because of the difficulty involved in interpretating the Level 1 analysis results the environmental assessment work was extended to include application of the methodology known as SAM-1A, recently developed by EPA.

This methodology was applied to the Braintree data for the four effluent streams: bottom ash, quench water, ESP ash, and stack emissions. Results, shown in Table 1, indicated that the stack emissions had the highest degree of hazard (H value), but this was primarily due to groups of organic compounds which could not be individually identified and therefore were assigned a conservatively low Minimum Acute Toxicity Effluent (MATE) value in accordance with the SAM-1A methodology. The bottom ash stream had the highest Toxic Unit Discharge Rate (TUDR), due to several metals present in high concentrations. This finding would seem to indicate that the bottom ash stream should receive the highest priority for control or removal of specific metallic constituents. However, considering the physical nature of the bottom ash and the methods for its disposal, further work should be done to better assess its environmental hazard potential.

Conclusions

Based upon the data obtained from this study, the following conclusions summarize the environmental assessment of the Braintree Municipal Incinerator. They are presented in general order of the plant operation for each effluent stream.

- Elemental analysis of the glass- and metal-free bottom ash revealed an overall increase in the elemental concentrations when compared to the refuse feed.
- Levels of BOD, COD, oil and grease, TSS, and TDS in the bottom ash quench water do not appear to be of concern. The phenolic content was found to be <0.1 mg/liter in all samples.

Table 1. Summary of Results from SAM-1A Methodology

	Health based	*Ecological based*
Degree of hazard		
Bottom ash	*3,800*	*1,740,000*
Quench water	*<20*	*<0.2*
ESP ash	*1,300*	*200,000*
Flue gas	*14,000*	*110*
Toxic unit discharge rate		
Bottom (g/sec)	*1,700,000*	*780,000,000*
Quench water (liter/sec)	*<76*	*<0.76*
ESP ash (g/sec)	*6,900*	*1,100,000*
Flue gas (m^3/sec)	*137,000*	*1,100*

- The collected fly ash contained levels of chlorides, sulfates, and several trace elements which may be of concern. However, the leachability of the ash should be investigated to determine a more realistic hazard potential.
- PCBs were not detected in the ash recovered by the ESP and only very minimal levels of four PAH compounds were identified.
- Stack emissions of hydrocarbons, NO_x, and SO_2 were low. However, CO levels were high. This could not be explained considering the large quantities of excess air used in the Braintree incinerator.
- Particulate concentrations exceeded both federal and State of Massachusetts regulations governing municipal incinerators. Average particulate concentration was 0.55 g/dscm (0.24 gr/dscf), corrected to 12% CO_2. The ESP removed only about 74% of the incoming particulate, while its design efficiency was reported to be 93%. Subsequent tests conducted for compliance purposes reported an outlet loading of only 0.074 g/dscf.
- Levels of gaseous chlorides and other halides were low.
- The presence of PCBs was confirmed only in the SASS train XAD-2 resin, which yielded a concentration of 3.6 $\mu g/m^3$.
- Results of the SAM-1A environmental assessment procedure show the incinerator stack emission to have the highest apparent degree of health hazard. Further analysis, however, is needed to determine the exact composition of the organic components of the stack emissions to ascertain its true hazard potential.
- SAM-1A also showed that the bottom ash effluent had the largest toxic unit discharge rate due primarily to the abundance of phosphorus and metals contained in this stream.

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The complete report, entitled "Environmental Assessment of a Waste-to-Energy Process, Braintree Municipal Incinerator," (Order No. PB 80-219421, Cost: $14.00, subject to change) will be available from:
National Technical Information Service
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