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Project Summary

Characterization of Stack Emissions from Municipal Refuse-to-Energy Systems

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Stack emissions from three municipal refuse-to-energy systems were characterized: refuse-derived fuel (RDF), mass burning (MASS) and modular (MOD). A comprehensive set of measurements was performed at each site to determine the physical and chemical properties of the particulate and gaseous stack emissions.

The physical characterization included measurement of the mass concentration, and size distribution of the stack particulate matter. Inorganic chemical characterization of the stack emissions included determination of gaseous HCl and HF emissions, and determination of volatile trace element levels. The characterization of organic materials in the stack emissions included specific measurements for polynuclear aromatic hydrocarbons (PAH), tetrachlorinated benzo-p-dioxins (TCDD) and dibenzofurans (TCDF), and aldehydes. Screening analyses were performed to provide tentative identification of organic compounds in the stack emissions.

This Project Summary was developed by EPA's Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 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

Vast quantities of municipal refuse are generated daily throughout the United States. Although incineration has been used for reduction of refuse volume in the past, the most common and economical method of disposal has been the use of landfills or open dumps. However, the availability and cost of convenient landfill sites and public acceptance makes this option less economically attractive as a future disposal method. A second important factor which will impact on future waste disposal practice is the increased emphasis on energy conservation. Municipal refuse represents an energy source which when burned can supply steam for heat and electricity production. Because of these land and energy conservation considerations, it is anticipated that there may be a significant increase in refuse-to-energy incineration of municipal refuse in the future.

An important issue which must be addressed in view of the expected proliferation of energy-to-refuse incineration systems is the potential release of hazardous pollutants into the environment from these facilities. The information base is limited and additional work is needed to develop emission data to answer the environmental questions, particularly in the case of newer refuse-to-energy incinerator systems.

The purpose of the research program described in this report was to characterize the physical and chemical composition of airborne emissions from municipal refuse-to-energy units. The study included a comprehensive set of physical and chemical measurements which identify and quantify the emissions of three refuse-to-energy units; a refuse-derived fuel, mass burning, and modular design. Thus, the emission data provides an important contribution to the data base available to assess the environmental impact of refuse-to-energy systems, to identify specific pollutants which may have adverse health and/or environmental effects, and to determine the need for process and/or control technology modifications to reduce pollutant emissions.

Procedures

The study involved a comprehensive set of measurements to characterize the physical and chemical composition of stack emissions from three refuse-to-energy units. A summary of the measurements that were performed and the sampling and analytical methods that were employed in the study is given in Table 1.

Stack emission measurements were performed on three refuse-to-energy incineration units. A summary of the characteristics of the units is provided in Table 2. The sites included recently constructed units of three different designs; refuse-derived fuel (RDF), mass burning (MASS) and modular (MOD). All three units were fueled with solid municipal refuse, however, approximately 30 percent of the modular unit feed came from industrial sources. Refuse feed for the RDF unit was shredded and pneumatically and magnetically classified while the MASS and MOD units burned unclassified bulk refuse. The feed rate data given in the table are estimates for the period during which tests were conducted and do not necessarily represent the design capacity of the units.

At all sites, the emission measurements were performed by sampling from a duct or stack downstream of the control devices, if present. Operating conditions considered "normal" for each unit prevailed during the respective test periods.

Table 1. *Sampling and Analytical Methods Used for Characterization of Refuse-to-Energy System Stack Emissions*

Measurement	*Sampling Method*	*Analytical Method*
Particulate Mass	*EPA Method 5*	*Gravimetric*
Particle Size Distribution	*Andersen In-Stack Impactor*	*Gravimetric*
Elemental Composition of Flyash	*Source Assessment Sampling System (SASS) (Cyclones/filter catch)*	*(1) Spark-source mass spectrometry (2) X-ray fluorescence (3) Combustion*
Volatile Trace Elements	*SASS (impingers loaded with ammonium persulfate/silver nitrate solution*	*Atomic absorption*
HCl/HF	*Impinger train with 1N NaOH solution*	*Ion chromatography*
Anions in flyash	*SASS (Cyclones/filter catch)*	*Ion chromatography*
Polyaromatic hydrocarbons (PAH)	*SASS (Cyclones/filter/XAD-2 catch)*	*Combined high resolution gas chromatography/ mass spectrometry (HRGC/MS)*
Tetrachlorodibenzo-p-dioxins/tetrachlorodibenzo furans (TCDD/TCDF)	*SASS (Cyclones/filter/XAD-2 catch)*	*Combined high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS)*
Aldehydes	*Impinger train with dinitrophenyl hydrazine solution*	*High performance liquid chromatography (HPLC/ fluorescence*
Organic compound screening	*SASS (Cyclones/filter/ XAD-2)*	*HRGC/MS—computer search/spectra matching*
Volatile organic compounds	*Stainless steel cannister grab samples*	*Capillary column gas chromatography with FID and EC detection*

Results and Discussion

Particulate Mass and Size Distribution

The particulate mass concentrations were measured in the emissions from the RDF, MASS, and MOD units with EPA Method 5. Additional mass concentration data were obtained from the SASS tests. Based on the Method 5 data, the mass concentration of particulate material in the RDF emissions ranged from 272 to 441 mg/dscm and the emission rate ranged from 22.4 to 36.1 kg/hr. For the MASS unit, the extremes in particulate mass concentration were approximately 261 and 599 mg/dscm and the particulate emissions of the MOD unit based on two valid tests ranged from approximately 153 to 261 mg/dscm in mass concentration and from 2 to 3.6 k/g in mass emission rate.

Particulate size distribution data were obtained for the three incinerator units. From the curves obtained, it is evident that the emissions from none of the units follow a log-normal distribution. The approximate mass median diameter of particulate emissions determined by measurements made with an Andersen impactor were: 6 μm for the RDF unit, 12 μm for the MASS unit, and 0.8 μm or less for MOD unit. The RDF and MASS units were equipped with electrostatic precipitators.

Inorganic Emissions

Elements detected in the particulate emissions of the three units at levels of 10 percent by weight or higher were C and Cℓ. Those generally present at or above 1 percent by weight were Ca, Zn, Fe, S, Si, K, Al, Na, and Pb. The principal anions common to samples from all three units were sulfate, chloride, and bromide. The soluble fraction of the fly ash from the three units varied from approximately 13 to 77 percent by weight with the MOD sample exhibiting the least solubility.

Of the volatile elements measured in the stack emissions of the three incinerator units, the most abundant element was Hg, which was found at widely varying levels; 16 to 6250 μg/dscm. Concentrations of As, Se, Sb, and Pb were generally less than 10 μg/dscm, although Sb was detected at a concentration of 42 μg/dscm in one of the MASS samples. Levels of HCl ranging from 352 to 516 mg/dscm (263 to 340

Table 2. *Summary of Study Site Characteristics*

	Refuse-Derived Fuel Unit	*Mass Burning Unit*	*Modular Unit*
Site Code	*RDF*	*MASS*	*MOD*
Process characteristics	• *shredding* • *air classification* • *magnetic separation* • *semi-suspension stoker-grate boiler*	• *mass burning* • *bulk refuse*	• *Consumat unit* • *bulk refuse*
Feed	*Municipal refuse*	*Municipal refuse*	*Municipal and commercial refuse*
Estimated feed rate during study	*600 TPD*	*125 TPD*	*50 TPD*
Emission control	*Electrostatic precipitator*	*Electrostatic precipitator*	*None*
Stack gas temperature	*230°C*	*270°C*	*255°C*

ppm) were measured in the RDF and MASS units. Lower levels of HCl, 53 to 231 mg/dscm (35 to 153 ppm), were detected in the MOD emissions. The concentration of HF in the emissions of the three units was fairly uniform, ranging from 0.3 to 1.4 mg/dscm (0.4 to 1.7 ppm).

The results of the infrared analysis of emission samples from the refuse-to-energy units are summarized and the infrared spectra of the various samples are presented in the report. Identification of compounds in the particulate emission samples from the three units are given as positive, probable or possible. In all cases, those identifications which are only tentative (marked possible) are of minor or trace components; because the component is present in such low concentration, a positive identification is not possible.

The three samples are similar in composition in that they are mixtures of sulfates, silicates and quartz. Perhaps more striking is the number of possible compound types *not* present, in particular, metal oxides. Most fly ashes from combustion sources contain significant quantities of metal oxides. These samples contain neither these nor any other oxide with the possible exception of the oxides which adsorb only in the far infrared region. In addition, though less surprising, these samples show no indication of nitrates, phosphates or ammonium compounds which are also frequently found in fly ash.

Organic Emissions

Concentrations of polynuclear aromatic hydrocarbons (PAH) compounds found in the stack emissions of the refuse-to-energy systems varied widely for the same unit as well as among the three units. The lowest values were observed in the MOD emissions and the highest in the MASS emissions. Compounds present in emissions of all three units included: naphthalene, phenanthrene/anthracene, pyrene, acenapthylene. The higher molecular weight PAH compounds, e.g., benzopyrenes were detected only in the MASS emissions. Data for the RDF and MASS units shows that the PAH distribution in the emissions heavily favors the gas phase at the temperature maintained during sample collection (205°C). Separate analysis of the particulate and gas phase samples was not performed on the MOD samples.

The TCDD and TCDF data show considerable variation in levels among tests on the same unit and between units, however, the variations are not as great as observed for the PAH compounds. The average total TCDD concentrations measured in the RDF, MASS, and MOD stack emissions were 174, 245, and 11 ng/dscm, respectively. The 2,3,7,8-TCDD isomer constituted a significantly larger fraction of the total TCDD emission from MASS unit than from the other two incinerators. The average total TCDF emissions from the RDF, MASS, and MOD units were 458, 385, and 73 ng/dscm, respectively. The distribution of TCDD generally appears to favor the particulate phase although RDF Test No. 2 shows the major fraction in the gas phase. The TCDF data does not show a clear trend in distribution between the particulate and gaseous phases of the emissions.

The concentrations of aldehydes found in the incinerator emissions show large variations in aldehyde levels both within and between sites. Generally higher concentrations were observed in the MASS emissions. The Mass Test No. 2 data show that the aldehydes were efficiently collected by the impinger train.

Conclusions and Recommendations

This study provides physical and chemical characterization data to support assessment of the impact of municipal refuse-to-energy system emissions on public health and the environment and to guide future similar studies. The data show wide variations in the composition and levels of various species in the stack emissions both among the various units studied and among repetitive measurements at the same unit. These variations may be due to influences from one or a combination of the following factors: unit type, unit design, refuse composition, or operating conditions. The scope of this study did not encompass the collection of data and measurement of the parameters required to evaluate the factors that influence refuse-to-energy system emissions. It is assumed that "normal" operating conditions prevailed during the emission measurements, however, the possibility that abnormal operating events occurred during test period and that these events influenced the emission characteristics, cannot be discounted. This possibility should be kept in mind in considering the following conclusions.

The high concentration and the relatively large size particulate emissions indicate either inefficient operation of the electrostatic precipitators (ESP) on the RDF and MASS units or combustion conditions for which the ESP's were not designed.

The particulate emissions from the three types of refuse-to-energy units are similar in inorganic chemical composition. Inorganic compounds in the emissions are present primarily as chlorides and sulfates.

The emissions from the municipal refuse-to-energy units varied greatly in organic chemical composition. This result is presumably due to design differences and variations in refuse feed composition and operating parameters of the units.

The study has yielded a comprehensive data base to support environmental assessment of municipal refuse-to-energy systems and to identify areas that may require additional research. The most urgent need of future studies is to acquire the supporting data required to establish the incinerator operating conditions during emission measurement periods. This information would identify abnormal conditions and, in general, would permit the elucidation of the relationship between design and operating parameters and emission characteristics.

Based on data obtained in this study, it appears that improvements in design or operation of municipal refuse-to-energy systems could be made to reduce stack emissions. In general, modifications e.g., in refuse preparation, combustion air feed, etc., that increase combustion efficiency should significantly reduce emission levels. Control devices should also be selected and operated to provide more efficient capture of particles from the emission stream. Future studies should adopt a parametric experimental design to clearly identify the design and operational variables that influence emission levels and to optimize conditions for emission reduction.

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The complete report, entitled "Characterization of Stack Emissions from Municipal Refuse-to-Energy Systems," (Order No. PB 87-110 482/AS; Cost: $18.95, subject to change) will be available only from:

National Technical Information Service
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