Metal and Particulate Emissions from Incinerators Burning Sewage Sludge and Mixed Refuse

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ABSTRACT

The experience of many larger municipalities indicates that sludge disposal from sewage-treatment plants can be handled rather efficiently in incinerators especially designed for this purpose. In addition, a trend seems to be developing to dispose of mixed refuse and sewage sludge in the same unit, in various mixtures. Many of the metals that have caused problems in the past for sanitary engineers responsible for sludge digestion at sewage disposal plants are now adding to air-quality problems in certain communities. The metal and particulate content in the atmospheric emissions from a 300-ton-day incinerator burning mixed refuse and sewage sludge is documented.

This paper should be of interest to incinerator designers, air-pollution-control officials, and researchers interested in devising new methods for removing contaminants from stack emissions.

INTRODUCTION

In the past, municipal incinerators were of interest in air-pollution control mainly because of their emission of smoke, odor, and particulates. With the more sophisticated techniques now available, attention is being given to the less noticeable but more important constituents in the emissions from these sources and their effect on air quality.

The incinerator surveyed for this study is a part of the Waterbury, Connecticut, waste-treatment plant, a system that handles mixed refuse and sewage sludge and serves a population of 110,000 people. The system consists of two 150-ton/day, circular, batch-fed units. The mixed refuse is burned every day on a 24-h day basis; sewage sludge is burned in one of the units three days a week.

The sludge is from the Waterbury sewage-treatment plant, a part of the waste-treatment complex. It is a primary treatment plant, which was designed to treat a flow of 15.2 million gal/day but is now overloaded at 26 million gal/day. Approximately two to three million gal/day of this flow is storm water, and 1000 to 5000 gal/day is septic-tank pumpings disposed of at the plant by scavengers. The sludge from the sewage-treatment-plant clarifiers is vacuum filtered with an Eimco rotary vacuum filter, flashdried, and burned in suspension in the secondary-combustion chamber of one of the incinerator units. The sludge is flash-dried in a Raymond System (Fig. 1).

Waterbury is highly industrialized; many metal fabricators and electroplaters are located in the area. As a result, large quantities of metals are found in the sewage sludge. For these reasons, the site was selected as appropriate for the purposes of this survey and analysis.

TEST FACILITY

The Waterbury Plant has two separate 150-ton/day, circular-type, batch-fed furnaces with individual secondary-combustion chambers. Effluent from these two chambers feeds into a single expansion and water-spray chamber before entering the 196±-ft stack.
Fig. 1 Flash-Drying System with Mixed-Refuse Incinerator

Fig. 2 Flow Diagram of Waste-Disposal System
heat from one furnace is used to dry sewage sludge by the Raymond process; dried sludge is then returned to the same furnace and burned in suspension (see Fig. 2).

The incinerator was installed in 1957. At that time, there were no air-pollution-control devices on the stack. In 1967, the unit was shut down to permit modification by the addition of a wet scrubber to improve the air quality in the region. The installation of the scrubber was completed in 1967, and the system was returned to service in 1968. Visual observations and some cursory laboratory studies indicated that the burning of sewage sludge would alter the pollutant characteristics of emissions. This led to the detailed tests on performance and air-pollution emissions, which are conducted at the facility.

The spray chamber has refractory baffles that are continuously wetted and a drain system that leads to a clarifier for fly-ash settling and disposal. Water from the clarifier is returned to the sewage-treatment-plant influent line. Domestic tap water enters the spray chamber through three manifolds ahead of the refractory baffles. The water that is unevaporated goes to the base of the chamber and overflows to the clarifier. The chamber is drained and flushed every 8 h.

**TESTING PROCEDURE**

Emissions from the incinerator stack were sampled early in October by F. Rehm of the Wisconsin Chemical and Testing Company. Samples were collected at the 66.5-ft elevation (approximately five stack diameters above the breeching) of the 196±ft-high stack. Three isokinetic samples were collected while the system was burning refuse, and three samples were collected while mixed refuse and dried sludge were being burned. Samples were collected using a null-balance probe. (See Refs. [2] and [3] for a description of the procedures used.)

The stack samples were analyzed for particulates by Wisconsin Chemical and Testing Company (Table 1) and then shipped to the Research Triangle Park, North Carolina to be analyzed for metals by staff members of the Office of Manpower Development, National Air Pollution Control Administration (NAPCA).
Table 1
Dust Loadings

<table>
<thead>
<tr>
<th>Test Run</th>
<th>Grain/ft³ (70°F, 1 atm, dry 50% excess air)</th>
<th>lb dust/1000 lb flue gas (50% excess air)</th>
<th>Emission</th>
<th>Emission factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refuse 1</td>
<td>0.320</td>
<td>0.632</td>
<td>74.4</td>
<td>7.44</td>
</tr>
<tr>
<td>2</td>
<td>0.268</td>
<td>0.415</td>
<td>60.12</td>
<td>6.45</td>
</tr>
<tr>
<td>3</td>
<td>0.268</td>
<td>0.538</td>
<td>73.80</td>
<td>9.43</td>
</tr>
<tr>
<td>Mixed refuse and sludge</td>
<td>0.241</td>
<td>0.499</td>
<td>83.20</td>
<td>7.01</td>
</tr>
<tr>
<td>6</td>
<td>0.194</td>
<td>0.397</td>
<td>61.40</td>
<td>4.48</td>
</tr>
</tbody>
</table>

*Not to exceed 0.4 lb dust/1000 lb flue gas corrected to 50 percent excess air (State of Connecticut regulation).

At the same time that the stack tests were being conducted, water and sludge samples were being collected for metals analysis by the Connecticut State Department of Health. Identical samples were forwarded also to NAPCA in North Carolina for this purpose.

LABORATORY PROCEDURES

The stack samples were in two forms: (1) samples in jars from the cyclone collector in the sampling train and (2) glass-fabric filter samples.

To put the metals into solution, all samples were leached with an acid solution and digested for 24 h. The acid solution was a mixture of nitric (HN03) and hydrochloric (HCl) acids in a 2:1 ratio. The samples were filtered, washed, concentrated, and then made up to a known volume for analysis. All samples were analyzed for metals using atomic-absorption equipment. Most of the analyses were determined on an Instrumentation Laboratory Model 153 instrument (Pb, Cu, Fe, Cr, Zn, and Ni). Cadmium was determined on a Perkin-Elmer Model 403 instrument. Analyses were reported in terms of total weight of metals and then converted to stack concentrations (mg/m³) and emissions (lb/h). Analyses of the water samples were reported in mg/l (Table 2).

DISCUSSION

As expected, due to the heavy industrialization of the area, analyses showed that there were more metals in the samples collected during the burning of dust loadings...
both sludge and refuse than during the burning of refuse alone. This was verified in all of the tests for metals except for lead and cadmium. There was almost no difference in the cadmium emissions when burning either fuel (Table 3).

Air-pollutant emissions from both refuse and sludge during burning were 1.7 times greater than those from burning refuse alone. Emissions of metals while burning refuse ranged from 0.007 lb/h (Cd) to 1.5 lb/h (Pb); when both refuse and sludge were burning, the range was from 0.007 lb/h (Cd) to 2.13 lb/h (Zn).

It is interesting to note that during the stack-sampling tests appreciably more particulates were reported in the bag filters than in the combined cyclone collector and sampling train washdown water. In our analysis, zinc, lead, and cadmium followed this trend, but the quantities of copper, nickel, iron, and chromium were greater in the cyclone samples. This finding would indicate a definite difference in specific gravity, size distribution, and chemical composition of the particles.

Since the incinerator charging rate was determined during the tests, emission factors could be calculated in terms of pounds of metals discharged from the stack per ton of fuel charged into the incinerator (see Table 4). These factors should be useful to air-pollution-control agency personnel and others conducting emission inventories of municipal incinerators. They provide indicators for metals emissions from a batch-fed incinerator with a wet-baffle scrubber when either mixed refuse alone or refuse and sludge together were burning.

The ratio of refuse to sludge in the charges during these tests was approximately equal to 3.5:1.

Table 3
Summary of Metals in Stock Emissions

<table>
<thead>
<tr>
<th>Burning Conditions Run No.</th>
<th>Copper mg/m³ #/h</th>
<th>Nickel mg/m³ #/h</th>
<th>Zinc mg/m³ #/h</th>
<th>Iron mg/m³ #/h</th>
<th>Lead mg/m³ #/h</th>
<th>Chromium mg/m³ #/h</th>
<th>Cadmium mg/m³ #/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refuse only</td>
<td>1</td>
<td>5.7</td>
<td>0.31</td>
<td>0.49</td>
<td>0.03</td>
<td>27.1</td>
<td>1.54</td>
</tr>
<tr>
<td>Refuse + Sludge</td>
<td>2</td>
<td>9.1</td>
<td>0.49</td>
<td>0.71</td>
<td>0.04</td>
<td>15.2</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Average                  6.8              0.38           0.53           0.03           30.8            0.19             13.1            0.77           26.3           1.50            1.16             0.07            0.13            0.007

Refuse only              4               10.3            0.75           0.98           0.07           62.7              4.58             15.4            1.13           25.5            1.86            1.93             0.14            0.13            0.009

Average                  10.2            0.69           0.87           0.06           30.4            1.23             13.2            0.91           16.8           1.17            1.63             0.11            0.11            0.007

*mg/m³ 1 atm, dry, 70°F, 50 percent excess air.

Table 4
Compilation of Emission Factors

<table>
<thead>
<tr>
<th>Incinerator Leading Conditions</th>
<th>Total Mass Emission Rate (lb/ton of charge)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Particulates Copper Nickel Zinc Iron Lead Chromium Cadmium</td>
</tr>
<tr>
<td>Refuse only</td>
<td>7.7            4.2 × 10⁻²  3.3 × 10⁻³  1.3 × 10⁻¹  8.1 × 10⁻²  1.5 × 10⁻¹  7.7 × 10⁻³  7.7 × 10⁻⁴</td>
</tr>
<tr>
<td>Refuse and sludge</td>
<td>7.23           5.7 × 10⁻²  4.9 × 10⁻³  1.8 × 10⁻¹  7.5 × 10⁻²  9.6 × 10⁻²  9.1 × 10⁻³  5.7 × 10⁻⁴</td>
</tr>
</tbody>
</table>
burning rate during these tests averaged 85 percent of the rated capacity of the incinerator.

The test situation was unusual due to the industrialization of the area and the burning of primary, treated-sewage sludge together with mixed refuse. It is anticipated that additional tests of this nature will be conducted at the Ansonia, Connecticut, municipal incinerator, a system that also burns both mixed refuse and digested sewage sludge.

CONCLUSIONS

It is increasingly apparent that smoke, odor, and fly ash are not the only important constituents in air-pollutant emissions from municipal incinerators. In an industrial area in which sludge is burned together with mixed refuse, stack concentrations of metals from 0.13 to 20.8 mg/m³ may be expected when refuse is burning in a batch-fed operation with a wet-baffled-type scrubber and from 0.11 to 30.4 mg/m³ when refuse and sludge together are burning at a 3.5:1 ratio in the same system. Stack emissions of metals range from 0.007 to 1.22 lb/h when refuse and sewage sludge are burning.

Emission factors have been established in terms of pounds of metals emitted per ton of fuel burned and range from $7.7 \times 10^{-4}$ to $1.5 \times 10^{-1}$ lb/ton while burning mixed refuse and from $5.7 \times 10^{-4}$ to $1.8 \times 10^{-1}$ lb/ton while refuse and sludge are burning.

In the future, the design engineer may develop methods to remove and recover metals from incinerator stack gases, and the ecologist may clarify the deleterious effects of these airborne metals on our environment.

ACKNOWLEDGMENTS

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REFERENCES