

# TRACE METALS IN COMBUSTIBLE MUNICIPAL SOLID WASTE

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## ABSTRACT

During a four-season waste characterization program, 59 representative samples of a solid waste stream were sorted into components (e.g., paper, plastics) and the combustible portion of each was analyzed for ten trace metals. The average component compositions were relatively consistent over the year; however, relatively large standard deviations indicated extensive spread in the data. The range of concentrations of metals in the waste sampled was also broad. A comparison of the trace metal results with data from the 1970s indicated little change in ranges of composition.

## INTRODUCTION

Virtually all solid waste management systems, including recycling processes, solid waste composting, landfilling and incineration have the potential to release trace metals into the soil, groundwater, or atmosphere. This is due to the widespread use of such metals as lead, mercury, nickel and cadmium in consumer products, as well as their natural occurrences in the environment.

During the mid 1970s, while refuse-derived fuel (RDF) was being explored as a supplement to, or partial replacement for coal in power plants, researchers were concerned about atmospheric release of metals

condensing onto particulate matter. At that time, only a limited characterization of the trace metal content in combustible municipal solid waste was performed and as a result, little data is available in the literature.

Since the 1970s, the refinement of the health risk assessment and the development and use of high efficiency particulate matter control devices have lessened the concern over airborne metals from solid waste combustion facilities. However, as a result of the use of more efficient electrostatic precipitators and fabric-filter baghouses, the trace metals are largely concentrated in the ash residue streams from incinerators. The primary public and scientific attention over the ultimate fate of trace metals in the waste stream has now shifted to potential impacts from landfilling and from other uses of incinerator ash.

During 1987 and 1988, an extensive four-season waste characterization program was conducted in Monmouth County, New Jersey to determine component make-up and chemical composition of the County's municipal solid waste. One objective of the study was to gather data on the trace metals content of the combustible fraction of solid waste. To accomplish this, samples of the combustible materials were analyzed for ten trace metals. The metals included: arsenic, beryllium, cadmium, chromium, copper, mercury, manganese, nickel, lead, and zinc. Selected samples were also analyzed for hexavalent chromium. The

study methodology and analytical results are presented herein.

## METHODOLOGY

Five solid waste field surveys for sample collection were conducted over a one-year period; each survey was two weeks in duration occurring according to the following schedule:

- Survey #1—Early Fall 1987
- Survey #2—Mid Fall 1987
- Survey #3—Winter 1988
- Survey #4—Spring 1988
- Survey #5—Summer 1988

Obtaining representative samples of waste was a key objective of the field programs. Compaction trucks containing waste from commercial and residential origins were randomly selected after being weighed at the Monmouth County Reclamation Center. The selected trucks were driven to an enclosed shredder building housing a tipping floor.

After information was recorded identifying hauler, waste type and vehicle weight and volume, the driver was instructed to dump the entire load onto the floor. A front-end loader thoroughly mixed the waste and a grab sample of about 300 lb (136 kg) was collected by the front-end loader for sorting purposes. The grab sample was deposited onto a tarp and the sorting process commenced. Each sample was sorted into the following categories:

### Combustibles:

- Newspaper
- Corrugated paper
- Other paper
- Plastics
- Yard waste
- Food waste
- Wood
- Textiles, leather, rubber and other combustibles

### Noncombustibles:

- Aluminum cans
- All other aluminum
- Ferrous (bimetal) cans
- All other ferrous
- Nonferrous metals
- Amber glass
- Clear glass
- Green glass
- Ceramic and fines

When the entire sample was sorted, the weight of material in each category was recorded. The total weight of the combustible fraction of the sample was calcu-

lated based on the sum of the weights of all combustible items. The weight percentage of each of the combustible components was then determined and a representative 10 lb (4.5 kg) sample was reconstituted using these weight percentages. Subsequently, this sample was shredded, mixed, and coned and quartered to obtain a smaller representative sample. The shredded samples were sealed in plastic bags and shipped to a laboratory for chemical analysis. The samples were further ground at the laboratory and analyzed by chemical digestion and atomic absorption (AA) spectrophotometry.

## RESULTS AND DISCUSSION

Table 1 presents percentages of the combustible components composing those samples which also underwent analysis for metals. The data show that for the broad categories of waste types, the average composition of the combustible fraction remained fairly consistent over the course of the year-long program. However, with the exception of the paper category, the sample standard deviations suggest a large spread in data occurred within each component. This large range in the data for individual samples was expected due to the nonuniform nature of solid waste, although collectively, the composition is rather consistent.

Table 2 provides the analytical results of the trace metals for each field survey period. The data are represented as ranges, with the number of samples of less than detectable concentrations noted where applicable. The data is presented in this manner to ensure that the study results are not misleading.

As an example, mercury was detected in only one of twelve samples of program #1 at a concentration of 0.152 ppm. In eleven of twelve samples, concentrations were less than 0.002 ppm, the minimum detection limit.

Table 2 also provides the ranges of metal concentrations over the entire study period. Large ranges in data resulted from the analyses, although the high and low concentrations for each metal were about the same magnitudes across the five surveys. Because the data for metals were so variable, and the mean weight percents of waste categories were relatively consistent across the five surveys, no specific correlation between the two data sets (Tables 1 and 2) was attempted. Nevertheless, it is apparent that the variability of trace metal content in solid waste is quite broad.

Table 3 depicts a compilation of results of studies conducted during the 1970s on concentration of trace metals in combustible municipal solid waste [1]. A comparison with data in Table 2 indicates that the

**TABLE 1 COMPONENT COMPOSITION FOR COMBUSTIBLE FRACTION**

Component	Component Composition (Mean weight percent, as received/standard deviation)				
	Field Program				
	1	2	3	4	5
Paper	49.7/11.3	52.9/7.4	53.1/12.0	46.2/13.0	52.0/10.6
Plastics	11.7/5.0	16.0/4.7	14.8/5.0	14.1/3.5	16.2/7.8
Organics (Yard & Food Waste)	28.5/12.3	20.1/8.0	21.0/9.2	28.6/15.0	19.6/10.6
Wood	2.9/2.7	2.6/1.7	1.9/1.9	2.5/2.4	3.5/3.8
Textiles, Leather & Other Combustibles	7.0/4.9	8.4/2.6	9.2/10.5	8.6/4.5	8.0/8.0
Number of Samples	12	9	12	12	14

**TABLE 3 LITERATURE DATA ON METALS IN COMBUSTIBLE MSW  
(Courtesy of the American Chemical Society)**

Metal	Average Concentration (mg/kg)	Range (mg/kg)
Cd	9	2-22
Cr	55	20-100
Cu	350	80-900
Pb	330	110-1500
Hg	1.2	0.66-1.9
Mn	130	5.0-240
Ni	22	9-90
Zn	780	200-2500

Source: Law, S.L. and Gordon, G.E., Environmental Science & Technology, 13:432, April 1979.

**TABLE 2 METAL CONCENTRATION IN COMBUSTIBLE FRACTION**

Metal	Field Program (mg/kg, dry basis (*))					Range of all Samples
	1	2	3	4	5	
As	2.76-25.5	10.9-38.0	4.04-61.7	1.33-46.2	<0.001 <sup>(2)</sup> -2.46	ND <sup>(2)</sup> -61.7
Be	<0.015	<0.015	<0.015	<0.02	<0.02	ND <sup>(59)</sup>
Cd	<0.025	<0.025 <sup>(6)</sup> -9.56	<0.025 <sup>(9)</sup> -13.6	<0.05 <sup>(10)</sup> -10.6	<0.05 <sup>(10)</sup> -16.7	ND <sup>(47)</sup> -16.7
Cr	0.05 <sup>(2)</sup> -61.1	<0.05 <sup>(1)</sup> -28.4	8.33-159.0	<0.25 <sup>(4)</sup> -157.0	<0.25 <sup>(6)</sup> -160.7	ND <sup>(13)</sup> -160.7
Cr <sup>+6</sup>	NA	<0.05 <sup>(+)</sup>	<0.25 <sup>(+)</sup>	NA	NA	ND <sup>(8)</sup>
Cu	<0.10 <sup>(1)</sup> -824.0	8.27-42.6	14.9-57.2	13.6-149.0	5.2-126.0	ND <sup>(1)</sup> -824.0
Pb	20.0-397.0	<0.05 <sup>(1)</sup> -61.9	11.1-384.0	9.75-251.0	<0.10 <sup>(2)</sup> -836.1	ND <sup>(3)</sup> -836.1
Hg	<0.002 <sup>(11)</sup> -0.152	<0.002 <sup>(3)</sup> -13.2	<0.002 <sup>(9)</sup> -0.74	<0.001	<0.001 <sup>(8)</sup> -0.81	ND <sup>(43)</sup> -13.2
Mn	37.5-159.0	27.0-67.6 <sup>(++)</sup>	62.7-102.0 <sup>(++)</sup>	25.1-299.0	25.5-95.3	25.1-299.0
Ni	<0.10 <sup>(11)</sup> -51.4	<0.10 <sup>(8)</sup> -56.9	0.125 <sup>(5)</sup> -154.0	0.10 <sup>(2)</sup> -202.0	0.10 <sup>(2)</sup> -250.4	ND <sup>(28)</sup> -250.4
Zn	59.1-2628.0	61.8-488.0	60.1-604.0	49.7-319.0	43.6-208.0	43.6-2628.0
No. of Samples	12	9	12	12	14	59

Notes: (\*) Number in parenthesis indicates number of samples less than detectable.  
 (+) Total number of samples for program #2 was 3; number for program #3 was 5.  
 (++) Total number of samples for program #2 was 6; number for program #3 was 7.  
 ND = Not Detected  
 NA = Not Analyzed

trace metals content of combustible waste has probably changed little in 10 years, although during that period some changes in uses of metals in specific products may have occurred.

Lead and cadmium have gained attention lately because of the tendency for solid waste combustion ash to yield concentrations greater than EP toxicity limits for these two metals upon testing. Sources of lead and cadmium in solid waste have been well documented in recent publications [2, 4].

According to these documents, the vast majority of lead in the waste stream originates from noncombustible materials; the major sources are lead-acid batteries and lead solders in consumer electronic products. Combustible materials accounted for only 2.3% (by weight) of lead in the waste stream in 1986 [4]. Lead in this fraction originates predominately from its use as a heat stabilizer in plastics and as a component of pigment in resins, paints, printing inks and textile dyes. The use of lead in these products appears to be declining, for example, because of the conversion to lead-chromate-free inks, due to concerns about its toxicity.

In contrast to lead, an estimated 36% of the cadmium in the waste stream was derived from combustible products in 1986. The major cadmium sources in burnable materials are similar to those for lead, such as stabilizers in plastics and pigments in plastics, printing inks, textile dyes and paints. Predicted trends in discards of cadmium in combustible consumer products indicate its relatively stable use in plastic products and pigments to the year 2000. Noncombustible consumer products containing the majority of cadmium in the waste stream include household batteries (rechargeable nickel-cadmium), electronics (cadmium-plated chassis), and appliances (cadmium plating and plastics) [4].

Mercury is another metal on the EP toxicity list, and an element of great concern in flue gas emissions. Its primary sources in the waste stream are fluorescent lights, mercuric oxide batteries, and gauges and meters [5]. The use of mercury as a mildew prohibitor in paints may cause its appearance in combustible materials.

A simple mass balance around an incinerator demonstrates that removal of a specific metal from the waste stream will reduce the quantity of that metal emitted from the facility in the air emissions and the ash residue. Quantitative data was recently published presenting such a mass balance [3]. The researchers tested incoming waste, air emissions, and combustion ash for metals at three mass burn facilities to investigate the effects of presorting aluminum, ferrous metals, glass/grit and batteries on the metals content of the flue gas and ash.

Removing materials containing trace metals to reduce their appearance in flue gas and incinerator ash may create an additional problem related to preventing introduction of these metals into the environment through alternate waste management strategies. Landfilling the removed materials may contribute to the appearance of the metals in landfill leachate. Recycling processes may also produce effluents, emissions, or other byproducts through which the metals of concern can be emitted into the environment. For example, sludge from recycled paper deinking processes will contain lead if the paper ink initially contained lead. The sludge must then be disposed of. All options for disposal of the sludge risk release of lead into the environment. Specific processes for recovery of metals through recycling is only feasible when the metals are present in large quantities in the particular product. Typically this occurs only in noncombustible materials such as lead, cadmium, and mercury from lead-acid, nickel-cadmium, and mercuric oxide batteries. Recycling of trace metals from the combustible waste fraction is more difficult due to the low concentrations [5].

The most appropriate strategy to ensure the long-term protection of the environment and human health from potentially toxic trace metal release may necessitate the institution of product composition changes that replace the metals used in consumer products with other less or nontoxic compounds. Without such a strategy currently in place, methods to mitigate the potential for release of metals into the environment from incinerator ash are being researched. Because the physical and chemical properties of ash are similar to natural aggregates, ash residue can be used as a fill material in asphalt and cement for highway pavement and road bed construction. Research is underway to determine the structural integrity and environmental stability of blocks composed of Portland cement and incinerator ash. Studies at the State University of New York at Stony Brook and at the Florida Institute of Technology are examining the use of such blocks in artificial ocean reef construction. Stabilization of incinerator ash, involving the addition of sorbent materials to bind metals prior to landfilling, is another means for reducing the potential for leaching to occur. Vitrification, a fusion process producing a glass-like product, may also prove to be an option for mitigating release of metals from ash.

Technical problems associated with trace metals in the waste stream must be addressed if environmental and health risks associated with waste disposal are to be reduced. Efforts toward this end also require public awareness of the problem and public acceptance of waste treatment and disposal technologies.

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