CHARACTERISTICS OF RDF ASH

GEORGE M. SAVAGE AND LUIS F. DIAZ
Cal Recovery Systems, Inc.
Richmond, California

ABSTRACT

A laboratory-scale procedure was developed for the purpose of estimating the properties of combined bottom ash and fly ash from a boiler firing 100% low ash refuse-derived fuel (RDF) and equipped with a dry scrubber and fabric filter collection system. The properties of concern in the study are those defined in the hazardous waste regulations for the State of California. Samples of RDF and scrubber reagent were combusted in order to provide ash samples for testing under certain hazardous waste criteria for the State of California. The results of the study show that the ash samples were nonhazardous with respect to pH, the total concentrations of the regulated heavy metals, and the fish bioassay. In the case of the leaching test, the extracted concentrations of all the regulated heavy metals were below the regulatory limit for two of the three ash samples that were prepared and tested. In the third ash sample, the leached lead concentration exceeded the regulatory limit by about 20%.

INTRODUCTION

In order to evaluate the hazardous/nonhazardous nature of a combined fly and bottom ash generated by a dedicated RDF waste-to-energy system equipped with a dry scrubber and fabric filter train, samples of ash produced in a laboratory setting were analyzed in accordance with the hazardous waste regulations promulgated by the State of California Department of Health Services. The study was designed to produce and evaluate the characteristics of the ash that would be produced by a boiler firing a high quality refuse-derived fuel. The intent of this study was to develop a reliable indication of the characteristics of the ash prior to construction of the facility.

The evaluation of the characteristics of the ash consisted of the performance of the following sequential set of tasks:

(a) Prepare a sample that would be representative of a high quality RDF produced from the new generation of refuse processing facilities.

(b) Combust a moist mixture of the sample of RDF and calcium oxide (i.e., scrubber reagent) in a muffle furnace to simulate the burning of RDF, the dry scrubbing of the combustion gases, and the simultaneous production of a mixture of fly ash and bottom ash.

(c) Conduct laboratory tests on the ash produced in (6) according to the protocol established in the California Administrative Code [1].

The following battery of tests on incinerator ash is required by the State of California to designate ash from refuse combustion as hazardous or nonhazardous:

(a) pH
(b) Metals concentration
  Total
  Soluble

(c) Static acute bioassay

Three separate samples of ash were prepared and subjected to the aforementioned tests.

PROCEDURES

Preparation of Ash

Three samples of RDF were prepared using the combustible and noncombustible components of MSW. The components are listed in Table 1. The noncombustible components were collected and used for the purpose of introducing noncombustible contamination into the RDF samples.

In order to prepare the RDF samples, the combustible and noncombustible fractions were first size-reduced. The combustibles were sized reduced following ASTM Method E829. The noncombustibles were size reduced to less than 0.2 in. Subsequently, each RDF sample was assembled using proportions of combustible and noncombustible components that would yield an RDF composition similar to that to be expected from the newest generation of refuse processing systems. The RDF samples had a heating value of about 6000 Btu/lb on a wet weight basis and an ash content of about 16% on a dry weight basis. The approximate composition of the RDF used in the study is shown in Table 1.

Finally, a moist mixture (approximately 30% moisture) of RDF and commercial grade lime (i.e., calcium oxide) was combusted (i.e., ashed) in a laboratory muffle furnace following ASTM Method 830. The proportion of lime was based on the typical chemical stoichiometry for dry scrubber operation that would be employed at dedicated RDF waste-to-energy facilities. The reagent stoichiometry used for the study corresponded to 45 lb of calcium oxide per ton of RDF on a dry weight basis. The resulting ash was composed of: *(a)* inerts derived from the mixture of combustible and noncombustible components; *(b)* unreacted reagent; and *(c)* certain of the solid products of reaction.

Laboratory Analyses

All laboratory analyses were performed pursuant to Article 11, Title 22 of the California Administrative Code (CAC). Table 2 lists the relevant sections of Article 11 that specify procedures used in the laboratory analyses.

TABLE 1 AVERAGE COMPOSITION OF RDF USED IN THE STUDY

Component	As-Received Weight Percent	
Paper	52.11	
Plastic	9.59	
Yard waste	3.90	
Food waste	11.38	
Wood	6.36	
Other organics	5.91	
Total Combustibles		89.25
Ferrous	0.33	
Aluminum cans	0.55	
Glass	6.55	
Other inorganic	3.32	
Total Noncombustibles		10.75
TOTAL		100.00

TABLE 2 TEST METHOD SPECIFICATION—CALIFORNIA ADMINISTRATIVE CODE, TITLE 22, ARTICLE 11

Test	Section Specifying Method
pH	Section 66708 (1)
TTLC, STLC (heavy metals)	Section 66700
Static acute bioassay	Section 66696 (4)

RESULTS

The results of the laboratory program are presented in Table 3 along with the threshold criteria of a hazardous substance according to the CAC. As shown in the table, in all cases the average values of the characteristics of the three ash samples are below the values that would render the ash hazardous under regulations set forth by the State of California.

Corrosivity of the ash (as denoted by pH) measured 11.2, 11.3, and 10.1 for the three samples of ash. All of the pH measurements were below the hazardous alkaline limit of 12.5.

As shown in Table 3, total heavy metal concentrations were, in general, measured at levels amounting to a small fraction of the hazardous total threshold

TABLE 3 RESULTS OF LABORATORY TEST PROGRAM

				Lab Test Results				California	
				Sample No.					
Hazard	Test	Units	Metal	1st	2nd	3rd	Average	Title 22 Article 11 Hazardous Criterion[a]	One or More Measurements Exceeding Criterion
Corrosivity	pH	pH	NA	11.2	11.3	10.1	10.9	2> pH >12.5	No
Resistant + Bioaccumulative Toxicity	TTLC[b]	mg/kg	Antimony	<8	<7	<5	<7	500	No
		mg/kg	Arsenic	<5	<5	<4	<5	500	No
		mg/kg	Asbestos	<1	<1	<1	<1	1.0	No
		mg/kg	Barium	250	180	280	237	10,000[c]	No
		mg/kg	Beryllium	<0.3	0.34	<2	<0.9	75	No
		mg/kg	Cadmium	4.7	6.4	7.7	6.3	100	No
		mg/kg	Chromium, Hexavalent	11	5.4	42	19	500	No
		mg/kg	Chromium, Total	83	64	250	132	2,500	No
		mg/kg	Cobalt	95	120	82	99	8,000	No
		mg/kg	Copper	350	4.3	660	338	2,500	No
		mg/kg	Fluoride	100	210	68	126	18,000	No
		mg/kg	Lead	590	180	570	447	1,000	No
		mg/kg	Mercury	<2	<0.04	<0.03	<1	20	No
		mg/kg	Molybdenum	1.8	2.3	7.2	3.8	3,500	No
		mg/kg	Nickel	100	83	120	101	2,000	No
		mg/kg	Selenium	<5	<5	<4	<5	100	No
		mg/kg	Silver	<0.8	<0.7	2.2	<1.2	500	No
		mg/kg	Thallium	<8	<7	<5	<7	700	No
		mg/kg	Vanadium	12	19	44	25	2,400	No
		mg/kg	Zinc	410	470	2,700	1,194	5,000	No
	STLC[d]	mg/l	Copper	5.5	0.14	<0.1	<1.9	25	No
		mg/l	Lead	6	1	4.4	3.8	5	Yes
		mg/l	Zinc	ND[e]	ND	89	NA[f]	250	No
Acute Aquatic Toxicity	Static Acute Bioassay	mg/l (LC_{50})	NA	>1,000	>1,000	>1,000	>1,000	<500	No

a) California Administrative Code.
b) TTLC = total threshold limit concentration.
c) Excludes barium sulfate.
d) STLC = soluble threshold limit concentration.
e) ND = not determined due to low total metal concentration.
f) NA = not applicable.

limit concentrations (TTLC) established by the CAC. Exceptions were the elements zinc and lead. In two of the samples total zinc concentrations were measured at 410 and 470 mg/kg. In the third sample a level of 2700 mg/kg was measured, approximately one-half the total threshold limit concentration listed in the CAC. Total lead concentrations for the three ash samples averaged 447 mg/kg with a peak value of 590 mg/kg. These values are nearly half the TTLC of 1000 mg/kg.

Under California hazardous waste regulations, the solubility (i.e., leachability) of metals in a waste is determined using the waste extraction test (WET) [2]. The WET was run on each ash sample for those metals for which the measured total metal concentration indicated a potential for exceeding the soluble threshold limit concentration (STLC) if 100% of the metal was soluble. Those metals were copper, lead, and zinc, as shown in Table 3. Each of the three samples would not be designated hazardous with respect to the STLC for the other metals.

Soluble lead concentrations were measured at an average of 3.8 mg/L compared to the STLC of 5 mg/L. The soluble lead concentration for one of the samples (No. 1) was measured at 6 mg/L, slightly exceeding the STLC. This was the only soluble metal measurement in the test program that exceeded the STLC limits set forth by the CAC.

Acute aquatic toxicity was determined using the procedures for fish bioassay as specified in the CAC. Flathead minnows were used in the conduct of the bioassay. For all three ash samples LC_{50} was shown to be greater than 1000 mg/L, thus classifying the ash as nonhazardous with respect to the bioassay criteria. (The LC_{50} is the concentration of a pollutant that results in a death rate of 50% after a 96 hr exposure.)

The solubility of copper, lead, and zinc in the ash can be calculated from the results of the total metal analyses and of the WET. The results of the calculations show the solubility of copper in the ash to be in the range of about 0.2 to 32%. The range of solubility of lead was calculated to be 5.6 to 10.1% The one sample for which total and extracted zinc were performed yielded a solubility of zinc of 33%. These results are summarized in Table 4.

TABLE 4 SOLUBILITY (Percent) OF CERTAIN METALS IN ASH FROM RDF COMBUSTION REACTED WITH LIME AND SUBJECTED TO THE CALIFORNIA WASTE EXTRACTION TEST (Wet)

Metal	Ash Sample No. 1	2	3
Copper	15.7	31.8	<0.2
Lead	10.1	5.6	7.7
Zinc	NA[a)]	NA	33

a) NA = not applicable; metal extractions were not performed for the samples indicated.

DISCUSSION

The authors caution the reader that neither the methodology used for the study nor the averaging of the results have been accepted by the State of California as suitable for designating the characteristics of refuse-derived ash. The methodology and results are reported for the purpose of suggesting a means of evaluating the characteristics of ash produced by waste-to-energy facilities before construction. A reliable laboratory methodology would certainly be of substantial utility for a number of reasons. The reasons include: *(a)* the ability to predict ash characteristics early in the design of the waste-to-energy project; *(b)* generation of a database for estimating ash disposal costs based on projected ash characteristics; and *(c)* a low cost for producing quality information. A distinct advantage of the methodology followed for this study is the ability to economically produce ash from solid waste that is characteristic of the project location under consideration.

An obvious drawback to the methodology is the lack of correlation with ash samples of larger size collected at operating facilities. Such correlation would be needed prior to judging the precision of the method and prior to acceptance of the test results by regulatory agencies in lieu of those from the operating facility. Unfortunately, operating data concerning RDF ash from systems using a combination of dry scrubber/particulate control were not available to the authors for comparison with the laboratory methods. The reason is that at the time that the present study was conducted there were not any commercially operating RDF combustion systems with dry scrubber/particulate control systems in operation.

The EP toxicity of bottom ash, fly ash, and combined ash is available for incinerator ash (i.e., ash from unprocessed MSW). Unfortunately, comparisons are not possible between the results of the present study and past studies because the present study was conducted using the WET procedure while the vast majority of results of incinerator ash analyses reported in the open literature were conducted using the EPA extraction procedure. The two extraction procedures are substantially different and consequently their results cannot be compared.

The results of the study presented herein are encouraging from the standpoint of establishing a laboratory procedure for evaluating the potentially hazardous characteristics of refuse-derived ash. From the standpoint of utility, cost, and convenience additional work on this topic is warranted.

REFERENCES

[1] State of California. *California Administrative Code,* Title 22. Social Security, Division 4, Environmental Health; Chapter 30. "Minimum Standards for Management of Hazardous and Extremely Hazardous Wastes."

[2] State of California. *California Administrative Code,* Title 22. Social Security, Division 4, Environmental Health, Chapter 30. "Minimum Standards for Management of Hazardous and Extremely Hazardous Wastes," Section 66700.