THE CHLORINE CONTENT OF MUNICIPAL SOLID WASTE FROM BALTIMORE COUNTY, MARYLAND AND BROOKLYN, NEW YORK

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ABSTRACT

The total chlorine and water soluble chlorine contents of the components of municipal solid waste (MSW) have been determined from sampling studies carried out at two sites, Baltimore County, Maryland and Brooklyn, New York for a 5 day period. The total chlorine contents of the MSW samples from Baltimore County, Maryland and Brooklyn, New York are 0.45 and 0.89 mass %, respectively.

The component which contributed the largest fraction to the chlorine content in Baltimore County, Maryland was the paper fraction (0.25 mass % or 56% of the total chlorine) while in Brooklyn, New York the plastics fraction provided the major contribution (0.46 mass % or 52% of the total chlorine). Additional information is provided in both text and tables.

INTRODUCTION

During the late 1970's and early 1980's, polychlorinated dibenzo-*p*-dioxins (PCDD's) and polychlorinated dibenzofurans (PCDF's) have been found in the precipitator fly ash and flue gas of a number of incinerator facilities in the U.S. and Europe in the parts per billion to parts per trillion range [1-9]. The resulting public alarm has seriously slowed or even stopped the construction or operation of waste-to-energy plants. In order to understand the reason for the presence of chlorinated organic pollutants in the precipitator fly ash and flue gas if incinerator facilities, an analysis for the chlorine content of each component of the input waste stream is needed. Examination of the literature showed that a study of the distribution of chlorine content among the components of municipal solid waste (MSW) had been carried out in Central Wayne County, Michigan in August of 1979 [10]. The data in that study consisted of the chlorine content of the textile/garment and plastic fractions of MSW for a 5 day period as well as data on the chlorine content of all waste components from one day's sampling. Examination of their results suggested that a more comprehensive study of the chlorine content of MSW was warranted. Hence, during the past year, a total chlorine and water soluble chlorine content study was carried out by the National Bureau of Standards (NBS) over a 5 day period on MSW from each of two sources: Baltimore County, Maryland and Brooklyn, New York. The results of the two studies are presented in this paper.

SAMPLING MUNICIPAL SOLID WASTE

Collection, Sorting, and Sample Preparation, Baltimore County, Maryland

Thirteen to 23 kg (29 to 51 lb) of RDF-2[1] were

[1]Refuse-derived fuel-2, RDF-2, is MSW that has been processed to reduce the particle size so that 95 mass-percent passes through a 15 cm square mesh.

[2]The commercial sources cited in this paper are included to adequately describe the experimental procedures. Such identification does not imply recommendation or endorsement by the National Bureau of Standards.

obtained on each of 5 working days (January 10, 11, 12, 19, 21, 1983) from the Baltimore County Resource Recovery Facility in Cockeysville, Maryland. Each sample was removed from the conveyor belt immediately after the primary shredder, but before any further processing occurred. Only one sample was taken from the conveyor belt each day. The material was brought to NBS on the same day, dried for 12 hr at 105°C (221°F) to determine its total moisture content, and then stored at 5°C (41°F). We assumed that no moisture was lost in transit because samples were triple bagged. Each day's material was hand sorted into eight categories. The categories were: paper, soft (film) plastics, hard (rigid) plastics, wood/vegetable matter, textiles, "fines" (sweepings), glass/ceramics, and metals.

The daily and average compositions of MSW obtained from Baltimore County, Maryland are provided in Table 1 for each of the separated components in mass % on an as-received basis at the facility or dry basis. The first row gives the total moisture content on an as-received basis at the facility and rows 2–8 show the mass percent of each waste component on a dry basis. Rows 9–10 give the composition according to combustible content (the sums of paper, soft plastics, hard plastics, wood/vegetable matter and textiles), and noncombustible content (metals, glass/ceramics, and "fines"), also on a dry basis.

Each category except for metals and glass/ceramics for each day's material was processed to 2 mm particle size or less and blended as described in Table 2. As indicated in the second column, all components except paper required some initial processing. Dry ice was used in the final particle size reduction of plastics, wood/vegetable, and textiles to prevent jamming of the milling equipment. Four milling machines were used to carry out the size reduction of the waste components; a Williams Hammer Mill[2] (Model GP-1512, Williams Patent Crusher and Pulverizer Co.), a Wiley Mill (No. 4, model S-60982, Sargent-Welch Co.), and two Brinkmann Instrument Co. Mills (Models SR-3 and ZM-1).. The Williams Hammer Mill was used in the initial processing of the hard plastics and in the final reduction of the paper. The cutting action of the Wiley Mill was found to be most suitable for the final reduction of the wood/vegetable and textiles components. A rotor-beater mill (Brinkmann Instrument Co., Model SR-3) was used in the final reduction of the soft and hard plastic components. A centrifugal grinding mill (Brinkmann Instrument Co., Model ZM-1) was used in the final reduction of the "fines" component. The SR-3 mill is similar to the ZM-1 mill in its principle of operation but is better suited for processing large quantities of softer materials than the ZM-1 mill.

The processed components were stored at 5°C in glass or polyethylene bottles except for the paper which was stored in large double polyethylene bags. After blending each of the components, samples were removed from each of the components for total chlorine analysis (three samples, each about 2 g), water soluble chlorine analysis (three samples, each between 3.5 to 5 g), residual moisture determinations (two samples, each about 0.2 g), and a reserve for use in later tests.

The processing of MSW components to 2 mm particle size increases the surface area of the sample making it more susceptible to the adsorption of moisture from the air. Consequently, a second moisture determination is necessary and called residual moisture. The residual moisture is smaller in magnitude (3–5 mass %) than the original total moisture (20–26 mass %). The residual moisture determinations are usually performed concurrently with other analyses, such as chlorine, so that calculation to a dry basis is possible.

A composite sample having a mass of about 42 g was prepared from each day's components. The composite sample had almost the same composition as the original waste exclusive of the glass/ceramics and metal fractions. If was prepared from the reserve fractions in appropriate proportions assuming that each separate component was totally dry. Thereafter, duplicate residual moisture determinations were performed on each of the components and the moisture data were used to correct the composition of the composite sample to a dry basis. Also, the residual moisture was determined for the composite sample itself so that the corresponding analyses for total chlorine and water soluble chlorine could be adjusted to a dry basis.

The composite sample was blended by end-over-end tumbling in a polyethylene bottle for 24 hr. It was then subdivided into test samples using a Brinkmann Instrument Co. Sample Divider PTZ to obtain samples for total chlorine, water soluble chlorine, and residual moisture analyses. A previous study carried out at NBS on assessing the credibility of the calorific value of MSW [11] showed that sample subdivision by this method gives aliquots that are representative even though the sample is heterogeneous.

The samples of individual components as well as the composite sample for each type of analysis were analyzed in random order; the entire contents of each sample (e.g., 2 g for an individual chlorine analysis) was used in a single measurement. Chlorine and residual moisture analyses were carried out according to ASTM standard methods: E775-81. "Forms of Chlorine in Refuse-Derived Fuel;" and E790-81, "Residual Moisture in a Refuse-Derived Fuel Analysis Sample," respectively. The determinations for chlorine and re-

TABLE 1 COMPOSITION OF MUNICIPAL SOLID WASTE OBTAINED ON JANUARY 10, 11, 12, 19, AND 21 1983 FROM THE BALTIMORE COUNTY RESOURCE RECOVERY FACILITY, COCKEYSVILLE, MARYLAND

Day	1	2	3	4	5	Average
	(Mass%, As-Received at the Facility)					
1) Total Moisture	25.9	22.4	34.5	23.5	20.9	25.8
	(Mass %, Dry Basis)					
2) Paper	50.9	56.9	61.5	56.6	67.6	58.7
Plastics, soft	4.0	2.2	3.0	9.2	5.0	4.7
Plastics, hard	3.0	3.0	1.9	3.6	2.1	2.7
3) Plastics, total	7.0	5.2	4.9	12.8	7.1	7.4
4) Wood/ vegetable	2.9	2.1	1.0	0.4	1.9	1.7
5) Textiles	3.6	0.8	0.5	11.7	5.1	4.3
6) Metal	10.9	10.0	7.9	1.1	5.4	7.1
7) Glass/ Ceramics	5.8	10.9	5.8	2.7	3.8	5.8
8) "Fines"	18.9	14.1	18.4	14.7	9.1	15.0
9) Combustible content	64.4	65.0	67.9	81.5	81.7	72.1
10) Noncombustible content	35.6	35.0	32.1	18.5	18.3	27.9

TABLE 2 PROCESSING OF WASTE COMPONENTS

Component	Initial Processing	Final Particle Size Reduction	Blending
Paper	---	Hammer Mill, 3 mm sieve	Hand mix in storage bags
Plastic, soft	Remove metals, shear to 20-25 mm size	SR-3 Mill, 2 mm sieve dry ice	Vee blend with intensifier
Plastic, hard	Hammer Mill 12mm sieve	do	Vee blend without intensifier
Wood/Vegetable	Remove metals, shear to 20-25 mm size	Wiley Mill, 2 mm sieve dry ice	do
Textiles	do	do	Vee blend with intensifier
"Fines"	Remove magnetic metals with magnet	ZM-1 Mill, 2 mm sieve	Vee blend without intensifier

sidual moisture were performed at Gascoyne Laboratories, Inc., Baltimore, Maryland for both Baltimore County, Maryland and Brooklyn, New York.

Collection, Sorting, and Sample Preparation, Brooklyn, NY

Sampling of MSW at the Greenpoint Incinerator Facility was carried out on five consecutive days from January 30 through February 3, 1984. The total number of increments withdrawn and mass per increment were selected on the basis of ASTM Committee E-38 provisional document EDS-18, which is based on ASTM method D 2234, "Collection of a Gross Sample of Coal." The mass per increment was chosen to correspond to the "unit" size of the MSW as-received in a nominal trash bag. The total number of increments was set by the mass per increment and the maximum mass allowed by our working and storage space at NBS, 227 kg (500 lb).

After examining the ASTM's provisional document EDS-18, we decided to withdraw 35 increments for the week, 7 increments each day with each increment of about 7 kg (15 lb) mass.

In practice a total of 29 increments were withdrawn for the week rather than the planned 35; the number of increments per day ranging from five to seven. Each of the increments was withdrawn at as nearly the same time each day as circumstances permitted.

The day shift started at 8:00 A.M. Sampling was limited to between 9:00 A.M. and 3:00 P.M. Truck deliveries ceased after 3:00 P.M., or so, for the day shift and resumed after 7:30 P.M. for the next shift. Increments were prepared by sampling the contents of two or more delivery trucks. As each truck dumped its load into the receiving pit, the storage bags which contained most of the MSW broke open, and part of

the load spilled over on the actual traffic area in front of the receiving pit. This spillover was collected, provided it did not appear to be grossly different from the bulk of the truck's contents (e.g., by visual comparison with the bulk dropped into the bottom of the pit). Otherwise the material was discarded and the next truck was sampled and so on. Hospital refuse was not included in the collection because of the potential health hazard. Some types of MSW (e.g., tapes and files of legal evidence) could not be included because this is prohibited by the New York City Police. Construction materials and ash (i.e., from tenement buildings), which are sometimes dumped into the pit, were not included since this material is normally dumped into barges and then transported to a landfill.

Sample increments were triple bagged, dried at NBS for 12 hr at 105°C to determine their total moisture content, and then stored at 5°C. Thereafter, each increment was hand-sorted into nine categories: unbleached paper, bleached paper, soft (film) plastics, hard (rigid) plastics, wood/vegetables, textiles, metals, glass/ceramics, and "fines" (sweepings). The corresponding components of the increments of the same day were then combined.

The daily and average compositions for each day's components at Brooklyn's Greenpoint Incinerator are given in Table 3. Each category except for metals and glass/ceramics for each day's material was processed to 2 mm particle size or less and blended as described in Table 2. Thereafter, the processing procedures for the Brooklyn samples were identical to those used for the Baltimore County samples with respect to the choice of milling machines, blending, preparation of a composite sample, sub-sampling, bottling, and storage. Similarly, analyses for total chlorine, water soluble chlorine, and residual moisture were carried out using the corresponding ASTM methods mentioned earlier.

EXPERIMENTAL RESULTS

Baltimore County, Maryland Results

The results of the analyses for the Baltimore County, Maryland study are given in Tables 4 and 5. Table 4 provides data on the composition and chlorine content of the prepared composite sample and also gives the corresponding values derived from the original composition of the waste and the chlorine content data. The purpose of the "measured" and "calculated" columns for each day in Table 4 is to show that the earlier assumption of the "dryness" of the components was acceptable in the preparation of the composite samples. The smallness of the differences between the measured and calculated values suggested that good control prevailed during the preparation and chlorine analyses of the composite samples assuring their representativeness.

The calculated contribution of the various components of the waste to the overall total chlorine, water soluble chlorine, and water insoluble chlorine content of each day's material are listed in Table 5. The water insoluble chlorine content is the total chlorine content minus the water soluble chlorine content. The water insoluble chlorine content has been called "organic" chlorine content but this can be misleading. Some organic chlorides are water soluble and some inorganic chlorides are water insoluble. It is assumed that the chlorine contents of the glass and metal fractions are negligible. Each day's value for total and water soluble chlorine content was calculated by multiplying the average percent chlorine content on a dry basis of each component by the mass percent of that component. The water-insoluble chlorine content was calculated by difference. One finds that the total chlorine content of the original waste is predominantly (76%) water insoluble chlorine.

Brooklyn, New York Results

The results of the analyses for the Brooklyn, NY study are given in Tables 6 and 7. Table 6 provides data on the "measured" composition and chlorine content of the prepared composite sample. Also, the corresponding "calculated" values are shown and were derived from the original composition of the waste and the chlorine content data.

The calculated values of the total, water soluble, and water insoluble contents of the Brooklyn MSW based on its initial (dry) composition are given in Table 7. Here again, it is assumed that the chlorine contents of the glass and metal fractions are negligible, although their presence must be accounted for in calculating the final values for the mass percent of chlorine. Each day's value for total or water soluble chlorine content was calculated by multiplying the percent chlorine content of each component by the mass percent of that component. The water insoluble chlorine content value was calculated by difference. One can see that the total chlorine content of the original waste stream is predominantly (76%) water insoluble chlorine.

Comparison of Experimental Results

The mass percent of the paper in the Baltimore County waste (59%) and Brooklyn waste (47%) are grossly comparable (compare Tables 1 and 3); fewer

TABLE 3 COMPOSITION OF MUNICIPAL SOLID WASTE OBTAINED JANUARY 30, 1984—FEBRUARY 3, 1984 FROM THE GREENPOINT INCINERATOR, BROOKLYN, NEW YORK

Day	1	2	3	4	5	Average
	(Mass %, As-Received at the Facility)					
1) Total Moisture	16.6	18.4	15.3	15.8	13.9	16.0
	(Mass %, Dry Basis)					
Paper, unbleached	46.0	43.7	44.3	40.7	37.7	42.5
Paper, bleached	4.7	3.0	6.2	5.0	4.3	4.6
2) Paper, total	50.7	46.7	50.5	45.7	42.0	47.1
Plastics, soft	2.3	4.6	3.4	5.1	1.5	3.4
Plastics, hard	6.9	7.2	5.9	8.9	10.6	7.9
3) Plastics, total	9.2	11.8	9.3	14.0	12.1	11.3
4) Wood/Vegetable	5.9	7.0	8.1	8.1	6.9	7.2
5) Textiles	3.0	1.7	2.1	3.1	1.8	2.3
6) Metals	7.4	11.3	11.9	6.9	10.9	9.7
7) Glass/Ceramics	15.3	18.7	15.9	17.3	25.4	18.5
8) "Fines"	8.5	2.8	2.2	4.9	0.9	3.9
9) Combustible content	68.8	67.2	70.0	70.9	62.8	67.9
10) Noncombustible content	31.2	32.8	30.0	29.1	37.2	32.1

TABLE 4 COMPOSITION AND CHLORINE CONTENT OF COMPOSITE SAMPLES, BALTIMORE COUNTY, MARYLAND

(Mass %, Dry Basis)

Day	1		2		3		4		5	
	Meas.[a]	Calc.[b]	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.
Composition of Composite Samples										
Paper	61.5	61.1	70.1	71.9	67.6	71.3	57.8	58.8	69.0	74.4
Plastics, soft	4.8	4.8	4.0	2.8	3.4	3.5	9.1	9.6	5.3	5.5
Plastics, hard	3.7	3.6	4.0	3.8	3.8	2.2	4.8	3.7	2.7	2.3
Wood/ vegetable	3.6	3.5	2.6	2.7	1.5	1.2	0.4	0.4	3.3	2.1
Textiles	4.6	4.3	1.1	1.0	0.9	0.6	11.5	12.2	5.9	5.6
"Fines"	21.8	22.7	18.2	17.8	22.8	21.2	16.4	15.3	13.8	10.1
Chlorine Content of Composite Samples										
Total Chlorine	0.61	0.62	0.64	0.66	0.43	0.44	0.51	0.48	0.41	0.46
Water Soluble Chlorine	0.18	0.14	0.12	0.10	0.13	0.12	0.10	0.15	0.10	0.12

a Composition and chlorine content of the composite sample determined from separate components which were processed to 2 mm particle size. Total mass of each day's composite sample was about 42 grams.

b Composition of composite sample calculated from data in table 1 and chlorine content calculated from table 5.

TABLE 5 AMOUNT OF CHLORINE CONTRIBUTED BY MSW COMPONENTS, BALTIMORE COUNTY, MARYLAND

(Mass %, Dry Basis)

Day	1	2	3	4	5	Average	Std. Dev. Average
			Total Chlorine				
Paper	0.265	0.228	0.258	0.255	0.250	0.251	0.0063
Plastics, soft	0.055	0.030	0.038	0.070	0.084	0.055	0.0100
Plastics, hard	0.092	0.206	0.028	0.040	0.048	0.083	0.0326
Wood/Vegetable	0.006	0.007	0.001	0.002	0.011	0.005	0.0018
Textiles	0.044	0.002	0.002	0.037	0.010	0.019	0.0090
Metal	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
Glass/Ceramics	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
"Fines"	0.051	0.028	0.046	0.053	0.030	0.042	0.0053
Total	0.513	0.501	0.373	0.457	0.433	0.455	0.0363[a]
			Water Soluble Chlorine				
Paper	0.092	0.063	0.098	0.108	0.081	0.088	0.0077
Plastics, soft	0.004	0.002	0.002	0.009	0.005	0.004	0.0013
Plastics, hard	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
Wood/Vegetable	0.003	0.005	0.002	0.002	0.005	0.003	0.0007
Textiles	0.006	0.001	0.001	0.018	0.005	0.006	0.0031
Metal	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
Glass/Ceramics	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
"Fines"	0.013	0.007	0.007	0.009	0.009	0.009	0.0011
Total	0.118	0.078	0.110	0.146	0.105	0.110	0.0085[a]

TABLE 5 (Cont'd) AMOUNT OF CHLORINE CONTRIBUTED BY MSW COMPONENTS, BALTIMORE COUNTY, MARYLAND

Day	(Mass %, Dry Basis) 1	2	3	4	5	Average	Std. Dev. Average
			Water Insoluble Chlorine				
Paper	0.173	0.165	0.160	0.147	0.169	0.163	0.0099
Plastics, soft	0.051	0.028	0.036	0.061	0.079	0.051	0.0101
Plastics, hard	0.092	0.206	0.028	0.040	0.048	0.083	0.0326
Wood/Vegetable	0.003	0.002	-0.001	0.000	0.006	0.002	0.0009
Textiles	0.038	0.001	0.001	0.019	0.005	0.013	0.0095
Metal	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
Glass/Ceramics	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
"Fines"	0.038	0.021	0.039	0.044	0.021	0.033	0.0054
Total	0.395	0.423	0.263	0.311	0.328	0.344	0.0373[b]

[a]The square root of the sum of squares of the standard deviations of the averages for each component of MSW listed in the column above.

[b]Values for water insoluble chlorine contents are the square root of the sum of the squares of the standard deviations of the averages for the total chlorine and water soluble chlorine values for individual components.

Note: Conversion from a dry basis to an as-received basis at the facility can be made multiplying the mass %, dry basis in table 5 by (100 - % total moisture (table 1))/100 for daily or average values. For example, the average total chlorine content is 0.455 mass %, dry basis; (0.455) (100-25.8)/100 = 0.338 or 0.34 mass %, as-received at the facility.

TABLE 6 COMPOSITION AND CHLORINE CONTENT OF COMPOSITE SAMPLES, BROOKLYN, NEW YORK

(Mass %, Dry Basis)

Day	1		2		3		4		5	
	Meas.[a]	Calc.[b]	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.
Composition of Composite Samples										
Paper unbleached	59.0	59.5	61.9	62.4	59.1	61.4	55.6	53.7	58.1	59.2
Paper, bleached	6.5	6.1	4.3	4.3	8.1	8.6	7.3	6.6	6.7	6.8
Plastics, soft	3.0	3.0	6.6	6.6	3.8	4.7	5.9	6.8	2.5	2.4
Plastics, hard	9.0	8.9	10.6	10.3	8.3	8.2	12.7	11.7	17.5	16.6
Wood/ vegetable	7.5	7.6	9.7	10.0	10.7	11.2	7.0	10.7	10.6	10.8
Textiles	3.8	3.9	2.7	2.4	2.7	2.9	4.4	4.1	3.0	2.8
"Fines"	11.2	11.0	4.2	4.0	7.2	3.0	7.1	6.5	1.7	1.4
Chlorine Content of Composite Samples										
Total Chlorine	2.06	2.31	0.65	0.65	0.82	0.96	0.63	0.68	1.37	1.54
Water Soluble Chlorine	0.94	0.68	0.17	0.18	0.14	0.12	0.17	0.16	0.42	0.34

[a] Composition of composite sample determined from separated components which were processed to 2mm particle size. Total mass of each day's composite sample was about 42 grams.

[b] Composition of composite sample calculated from data in table 3, and chlorine content calculated from table 7.

TABLE 7 AMOUNT OF CHLORINE CONTRIBUTED BY MSW COMPONENTS, BROOKLYN, NEW YORK

Day	(Mass %, Dry Basis) 1	2	3	4	5	Average	Std. Dev. Average
Total Chlorine							
Paper, unbleached	0.469	0.135	0.075	0.130	0.245	0.211	0.0702
Paper, bleached	0.010	0.012	0.015	0.011	0.018	0.013	0.0015
Plastics, soft	0.073	0.142	0.277	0.098	0.027	0.123	0.0427
Plastics, hard	0.540	0.112	0.249	0.142	0.616	0.332	0.1038
Wood/Vegetable	0.073	0.028	0.104	0.049	0.028	0.056	0.0145
Textiles	0.023	0.011	0.005	0.059	0.004	0.020	0.0102
Metal	0.000	0.000	00.000	0.000	0.000	0.000	0.0000
Glass/Ceramics	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
"Fines"	0.587	0.014	0.009	0.029	0.015	0.131	0.1141
Total	1.775	0.454	0.734	0.518	0.953	0.886	0.1757[a]
Water Soluble Chlorine							
Paper, unbleached	0.373	0.074	0.035	0.061	0.158	0.140	0.0618
Paper, bleached	0.003	0.007	0.005	0.005	0.013	0.007	0.0017
Plastics, soft	0.009	0.009	0.004	0.009	0.003	0.007	0.0014
Plastics, hard	0.028	0.006	0.001	0.004	0.005	0.009	0.0049
Wood/Vegetable	0.031	0.017	0.019	0.020	0.026	0.023	0.0026
Textiles	0.017	0.006	0.003	0.008	0.001	0.007	0.0028
Metal	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
Glass/Ceramics	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
"Fines"	0.067	0.011	0.007	0.018	0.008	0.022	0.0114
Total	0.528	0.130	0.074	0.125	0.214	0.215	0.0632[a]

TABLE 7 (Cont'd) AMOUNT OF CHLORINE CONTRIBUTED BY MSW COMPONENTS, BROOKLYN, NEW YORK

(Mass %, Dry Basis)

Day	1	2	3	4	5	Average	Std. Dev. Average
				Water Insoluble Chlorine			
Paper, unbleached	0.096	0.061	0.040	0.069	0.087	0.071	0.0935
Paper, bleached	0.007	0.005	0.010	0.006	0.005	0.007	0.0023
Plastics, soft	0.064	0.133	0.273	0.089	0.024	0.117	0.0427
Plastics, hard	0.512	0.106	0.248	0.138	0.611	0.323	0.1039
Wood/Vegetable	0.042	0.011	0.085	0.029	0.002	0.034	0.0147
Textile	0.006	0.005	0.002	0.051	0.003	0.013	0.0106
Metal	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
Glass/Ceramics	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
"Fines"	0.520	0.003	0.002	0.011	0.007	0.109	0.1147
Total	1.247	0.324	0.660	0.393	0.739	0.674	0.1867[b]

[a]The square root of the sum of squares of the standard deviations of the averages for each component of MSW listed in the column above.

[b]Values for water insoluble chlorine contents are the square root of the sum of the squares of the standard deviations of the averages for the total chlorine and water soluble chlorine values for individual components.

Note: Conversion from a dry basis to an as-received basis at the facility can be made by multiplying the mass % dry basis in table 7 by (100 - % total moisture (table 3))/100 for daily or average values. For example, the average total chlorine content is 0.886 mass %, dry basis; (0.886) (100-16.0)/100 = 0.744 or 0.74 mass %, as received at the facility.

newspapers and more commercial paper (e.g., office, computer, and bank papers) were observed in the Brooklyn paper fraction. The mass percent of the plastic fraction of the Baltimore County waste (7%) was two-thirds as large as that of the Brooklyn waste (11%). The mass percent of the hard plastic fraction of the Brooklyn waste (8%) was some two and one-half times greater than that from Baltimore County (3%). The sum of the mass percent of the glass/ceramic and "fines" fractions for Baltimore County (21%) and Brooklyn (23%) were comparable. The larger mass percent of the "fines" fraction for the Baltimore County waste (15%) versus that for Brooklyn (4%) is possibly due to the passage of the Baltimore County waste through the primary shredder prior to our sampling.

Tables 5 and 7 indicate that the total chlorine, water soluble, and water insoluble chlorine are all roughly a factor of two larger for Brooklyn as compared to Baltimore County. From these tables, one sees that the total chlorine content of the Brooklyn waste is larger because of the larger contributions by the Brooklyn plastic fraction, 0.46% versus 0.14% for Baltimore County and the Brooklyn, "fines" fraction, 0.13% versus 0.04% for Baltimore County. The larger contribution of the Brooklyn wood/vegetable fraction, 0.06% versus 0.01% for Baltimore County, is about offset by the smaller contribution of the Brooklyn paper fraction. 0.22% versus 0.25% for Baltimore County. The larger contribution to the total chlorine content by the Brooklyn "fines" and wood/vegetable fractions, as well as the larger overall water insoluble chlorine content of the Brooklyn waste, are in part due to the larger food wastes observed in the Brooklyn waste. This could be due to the prohibition of "disposals" in Brooklyn residential areas and also to the fact that the Greenpoint Incinerator receives restaurant waste from Kennedy airport.

SUMMARY AND CONCLUSIONS

(a) Chlorine in MSW is present in all combustible components.

(b) The major amounts of the chlorine in MSW are contained in the paper and plastic fractions.

(c) The paper fraction contains about one-third to one-half of its chlorine as the water soluble form while the plastic fraction contains most (greater than 90 mass %) of its chlorine as the water insoluble form.

(d) The weekly average of the total chlorine content of the MSW Samples from Baltimore County, Maryland is 0.45 mass %; about one-half of this amount comes from the paper, one-quarter from the plastics, and the other quarter from the remaining components.

(e) The weekly average of the total chlorine content of MSW Samples from Brooklyn NY is 0.89 mass %; about one-half of this amount comes from the plastics, one-quarter comes from the paper, and the other quarter from the remaining components.

We acknowledge that the above summary and conclusions are based on a limited amount of sampling. A more definitive assessment of the chlorine content at any particular site would require additional sampling to be carried out in order to determine its variability in the waste stream as a function of time. This work provides only a small window to the amount present and some indication of variability of the chlorine content in MSW.

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Key Words: Chlorine Analysis; Municipal Solid Waste; Sample Size Reduction; Sampling; Sorting; Total Chlorine Content; Water Insoluble Chlorine; Water Soluble Chlorine