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SUMMARY REPORT OF ANALYSES OF MERCURY FROM CONSUMER BATTERIES IN THE WASTE STREAM

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SUMMARY

In 2011 the National Electrical Manufacturers Association (NEMA) Dry Battery Section conducted the eleventh round of analyses of samples of post consumer round cell, alkaline manganese and zinc carbon batteries in the municipal waste stream. These analyses were conducted from Lee County Florida and San Mateo County California curbside collection programs. The purpose of these analyses was to determine the age, type, and mercury level of the batteries currently disposed of in the US. Prior sorts were also conducted in Camden County, New Jersey and Hennepin County, Minnesota.

Prior to the elimination of the use of mercury in these batteries, average mercury levels for alkaline batteries were 8,000-12,000 ppm. Between 1989 and 1991, the industry shifted to producing very low (< 250 ppm) mercury alkaline batteries. In 1992-1993, the industry stopped adding mercury to alkaline batteries altogether. The results of the analyses in 2011, which show a significant reduction of the average level of mercury in the waste stream from batteries, are as follows:

<u>Mercury Level in Parts Per Million (ppm)</u>

Location	Alkaline Manganese & Carbon Zinc	% Mercury Free Batteries
Lee County	7.2	99.2%
San Mateo County	87.6	97.4%
Weighted Average	27.3	98.6%

In calculating the mercury content, NEMA made certain assumptions documented in this report. The analysis used gives a "worst case" mercury concentration. The battery industry developed the method of analysis employed in this study over a five-year period during stockpile analyses in Germany, Sweden, Belgium and The Netherlands. The industry had employed it in the 1990's to predict the decline of residual mercury in collected batteries within The Netherlands. Independent chemical analyses conducted during mercury removal trials on typical mixes of batteries, which found similar levels of residual mercury, have validated the accuracy of this method.

Mercury levels from batteries continue to decline significantly from the first analyses in the 1990's and these results now represent nearly a complete elimination in mercury levels in the waste stream from batteries since the mid 1980s. NEMA has now undertaken 26 studies and the analyses of mercury levels are in broad agreement despite some regional differences. Because the number of mercury-containing batteries is so low, and decreasing every year, subtle differences in the number of mercury-containing batteries sampled in any particular sort can dramatically change the amount of mercury.

1. Determination of the Mercury Content of Round Alkaline Manganese and Zinc Carbon Batteries

1.1 Introduction

In 2011 NEMA conducted the latest analyses of post consumer round alkaline manganese and zinc carbon batteries collected in Lee County Florida and San Mateo County California. Past analyses were also conducted in Camden County, New Jersey and Hennepin County, Minnesota. The objective of the analyses was to determine the age and types of batteries present in the waste stream and to determine the extent by which the mercury content has decreased since the first set of analyses conducted in 1996 and 1997. The age and battery type information, together with compositional information supplied by battery manufacturers, was used to calculate the amount of mercury still present in these batteries in the waste stream.

In 2011, the Lee County analysis was based on a 383.5 lb. sample collected from the Lee County Florida curbside collection program over the period of approximately 11 weeks. In this program, single-family households use sealable plastic bags for disposal of used batteries as part of a household battery disposal system. Curbside collection vehicles operate under contract for the Lee County Department of Solid Waste Management and regularly collect these bags.

The San Mateo County analysis was based on a 129 lb. total sample collected during two days of San Mateo curbside collection. The San Mateo program also collects from single family homes using sealed plastic bags set on top of recycling containers.

1.2 Method

The battery industry developed the method of analysis employed in this study over a five-year period during stockpile analyses in Germany, Sweden, Belgium and The Netherlands. The industry has employed this method for the past two decades to predict the decline of residual mercury in batteries. Independent chemical analyses conducted during mercury removal trials on typical mixes of batteries, which found similar levels of residual mercury, has validated the accuracy of this method.

1.2.1 Aging of the Sample

Manufacturers generally either stamp date codes or best if used by dates on the base or side of the battery. The analysis determined the age of each battery and hence the mercury content by recording the manufacturers date code and converting this back to the year of manufacture.

1.2.2 Calculation of Mercury Content

The mercury content of the batteries for each year of manufacture was calculated from manufacturing information supplied by Duracell and Energizer. The study uses the mercury content of each battery type, for each year of manufacture, to calculate an average (mean) mercury-content for that battery type. These were then used to determine the mercury contents of the alkaline streams within the samples.

Some assumptions, however, were made:

1. When a manufacturer changed the mercury content of a battery, all batteries manufactured in that year were taken as having the higher mercury content.

2. Batteries manufactured before mercury concentration data was available were taken as having the same concentration as the year in which the first data became available.

3. As Duracell and Energizer batteries make up a super-majority of collected samples, the two brands were used to determine the mercury level in the waste stream.

   *Assumption #1 is likely to bias the mercury content higher than the actual level.

   *Assumption #2 is unlikely to cause major changes to the overall mercury content since battery companies manufactured these batteries before they introduced the mercury reduction programs. In general, this method of analysis will give a "worst case" mercury concentration.

Table 1 shows the calculated mercury content breakdown for alkaline and carbon zinc batteries in 2011.

Table 1: Mercury Content by Battery Size - Alkaline Batteries

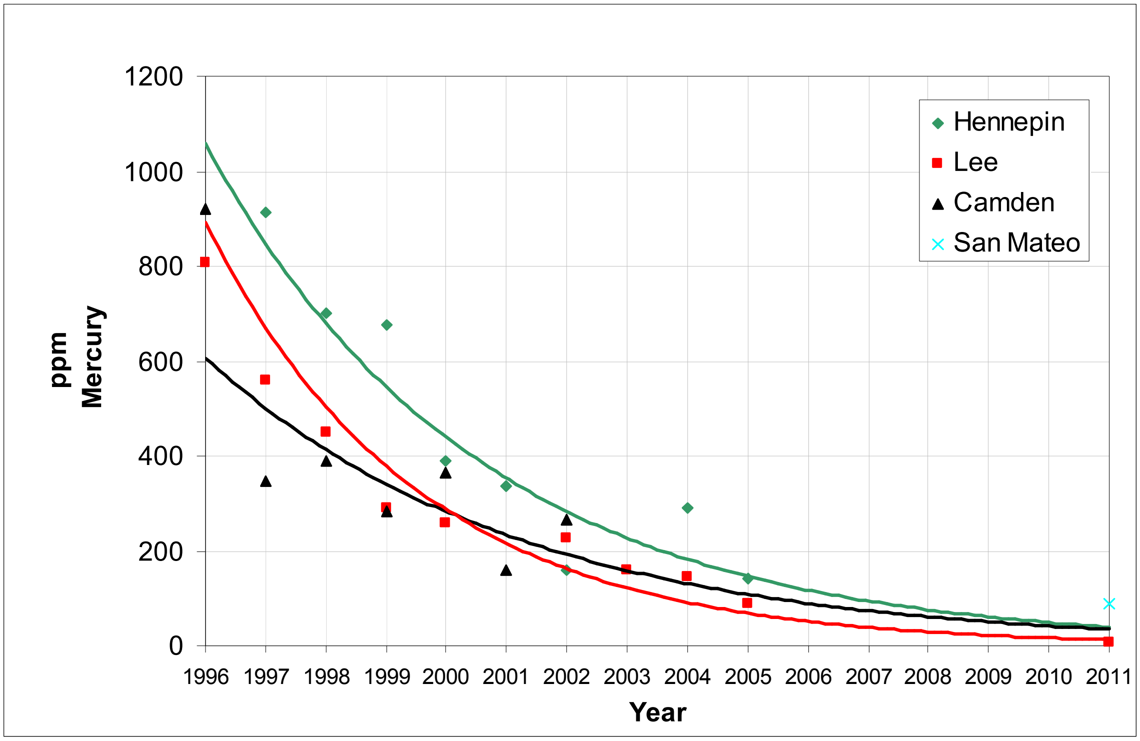
Battery Type	Mean Hg Percentage (ppm)	
	Lee (2011)	San Mateo (2011)
AA	1.7	28.7
AAA	7.7	30.9
C	5.8	344
D	9.8	87.7
9V	0	24.3

1.3 Discussion

As seen in previous years, there continues to be a decreasing trend in mercury content within the stockpiles. With a marked increase in the percentage of mercury free batteries in the samples, and the subsequent overall reduction in mercury content, it is not atypical to find differences between the samples as a few old, high mercury batteries will have a greater influence on the result as was seen in the San Mateo analysis. Clearly when comparing these results with previous years, we are able to see the exponential nature of the mercury reduction, typified by the slowing down of the decay rate.

1.4 Age Distribution and Projection of Mercury Decline in Alkaline Batteries

Figure 1. Prediction of the decline of mercury in the Alkaline Batteries



Using the data from each sort, NEMA used a Microsoft Excel curve fit to predict the decline of mercury in the waste stream from alkaline manganese and carbon zinc batteries. The projections show the mercury level to be in the less than 50 ppm by 2010, which was partially verified by the Lee sort in 2011 (7.2 ppm). Because the number of mercury-containing batteries is so low, and decreasing every year, subtle differences in the number of mercury-containing batteries sampled in any particular sort can dramatically change the amount of mercury seen as shown in the San Mateo, California sort in 2011 which showed a mercury level of 87.6 ppm. The weighted average for 2011 was 27.3 ppm.

2. Summary of Waste Sorts 1996-2011

Mercury Level in Parts Per Million

County	Year	All Round Cells	Alkaline Manganese	Zinc Carbon	Percentage Mercury Free
Camden 1	1996	728	920	11	67
Camden 2	1997	138	348	5	84
Camden 3	1998	--	389	8	85
Camden 4	1999	--	284	8	88
Camden 5	2000	--	365	--	88
Camden 6	2001	--	158	--	94
Camden 7	2002	--	266	--	98.7
Lee 1	1996	622	806	4	62
Lee 2	1997	354	559	7	79
Lee 3	1998	--	451	5	80
Lee 4	1999	--	289	7	86
Lee 5	2000	--	259	--	88
Lee 6	2002	--	228	--	90
Lee 7	2003	--	158	--	97
Lee 8	2004	--	145	--	98
Lee 9	2005	--	88.5	--	96.3
Lee 10	2011	--	7.2	--	99.2
Hennepin 1	1997	741	915	11	66
Hennepin 2	1998	569	701	6	72
Hennepin 3	1999	--	677	12	80
Hennepin 4	2000	--	388	--	87
Hennepin 5	2001	--	336	--	91
Hennepin 6	2002	--	158	--	94
Hennepin 7	2004	--	289	--	93
Hennepin 8	2005	--	142.5	--	94.6
San Mateo 1	2011	--	87.6	--	97.4

3. Discussion of Results

These analyses indicate that extremely low levels of mercury are still present in post consumer batteries, and these levels continue to decline with time.

3.1 Limitations and future work

The results of this study should be interpreted with some caution. The analysis is based on a small number of producers and relatively small samples sizes compared to national waste amounts, but the results are assumed to be valid for all manufacturers.